

50+

Circuits &
Projects

132 Pages!

Circuit Special 2023

Design Ideas,
Tips, and Tricks



- > Active rectifier
- > A Low-Cost Frequency Standard
- > Simple Dynamic Compressor
- > Speed Controller for Fan or Ventilator
- > Tiny Solar Supply
- > THD Generator
- > Programmable Video DAC
- > Large RGB Digit
- > ChatGPT and Arduino
- > Solar-Powered Christmas FM Radio Ball
- > Tiny DCF77 Simulator

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Today
0800 Morning swim
0830 Start active rectifier
1200 Picnic lunch
1330 Notes @ Elektor Labs
1430 Beach walk collect shells
1600 Fix circuit
1800 Relax

Tomorrow
Morning swim
Yoga on beach
New circuit project



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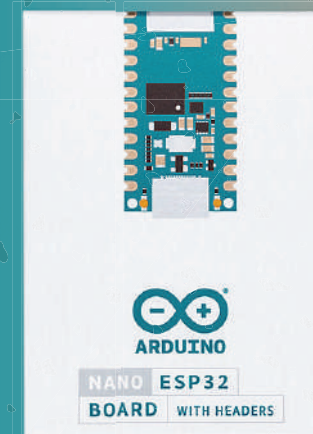
Our next guest



In December 2022, Elektor was proud to announce Arduino as the second ever Guest Editor of its magazine, following the 2021 partnership with SparkFun. We can confidently state that this collaboration resulted in an outstanding synergy, generating tens of thousands of sales and downloads. You can still get your copy today!



Arduino hands over the guest editor position to **Espressif**



The new Arduino Nano ESP32

Almost as if providing additional testament to the perfect synergy of our guest editor partnerships, Arduino recently announced a board that encapsulates it all: the brand new **Arduino Nano ESP32**.

The Arduino Nano ESP32 combines the accessibility and support of the Arduino brand with the robust capabilities of the ESP32-S3, packaged in the compact and practical form factor of the Nano family.

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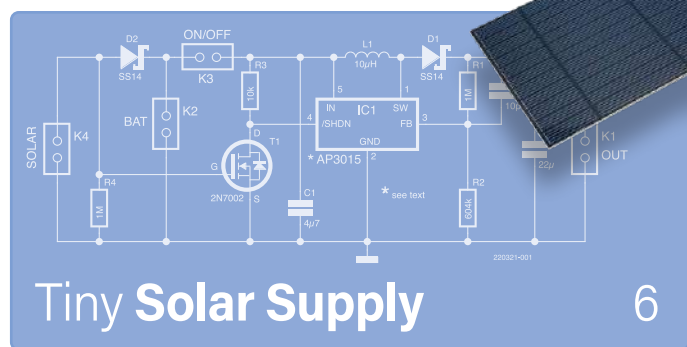


is ...



Today, we're thrilled to announce another leading name in our industry as our next guest for the 2023 Guest Edited edition our magazine: **Espressif**. We are already hard at work to curate an enticing blend of hands-on applications, tutorials, and in-depth articles showcasing Espressif technologies. Available in December 2023.





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COLOPHON

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Jens Nickel
International Editor-in-Chief,
Elektor Magazine

For the second time, you're holding the new approach to our Circuit Special, which is part of Elektor's decades-long tradition of "semiconductor specials." This year, we decided to omit the "Summer" in the title because the more than 50 projects in this issue are meant to inspire you to build throughout the entire year. As always, we've made sure to include many simple circuits that even beginners can understand, explicitly including those that don't require microcontrollers.

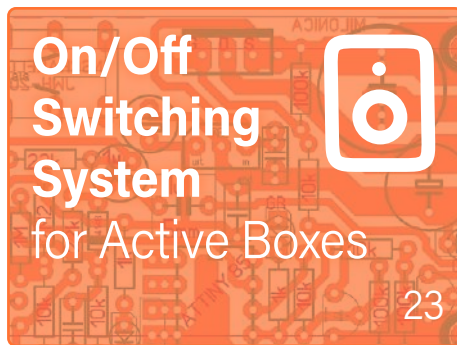
Our goal is not only recreational, but also to ensure that foundational knowledge of how components interact with each other is not lost. In times when ready-to-use modules are available for just a few euros and various AI tools generate finished software, it's a challenge to preserve the wealth of knowledge that you, dear readers, still possess, for future generations.

We're not ignoring modern developments, though. Rapid prototyping and the timely proof-of-concept of a wild idea have their place, as early successes motivate further project development. You will find more about how clever — often free — tools (with and without AI) can assist in this process in the upcoming issues. Even in this issue, my colleague, Brian Tristram Williams, begins his journey into the world of AI (page 28). I invite you not only to accompany him on his journey, but also to provide him with suggestions (editor@elektor.com)!



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Next Edition

**Elektor Magazine Edition 9-10/2023
(September & October 2023)**

Our next regular edition deals with all things about Wireless and Communication, and you can expect the usual mix of projects, circuits, fundamentals, and all the resources a pro engineer, maker, or student needs.

From the Contents:

- Cloud-Based Energy Meter
- Raspberry Pi Pico as a Spectrum Analyzer
- LoRa: The Swiss Army Knife of Wireless
- Low-Cost GNSS RTK Positioning Systems
- SDR Hardware for Time Signal Receiver
- Adjustable Current Sink

And much more from Elektor, as always! Elektor Magazine edition 9-10/2023 (September & October 2023) will be published around September 6th, 2023. The arrival of printed copies for Elektor Gold Members is subject to transport. Contents and article titles are subject to change.



elektormagazine.com/circuit-special-2023

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01 Tiny Solar Supply

Sunlight In, 3.3 V Out

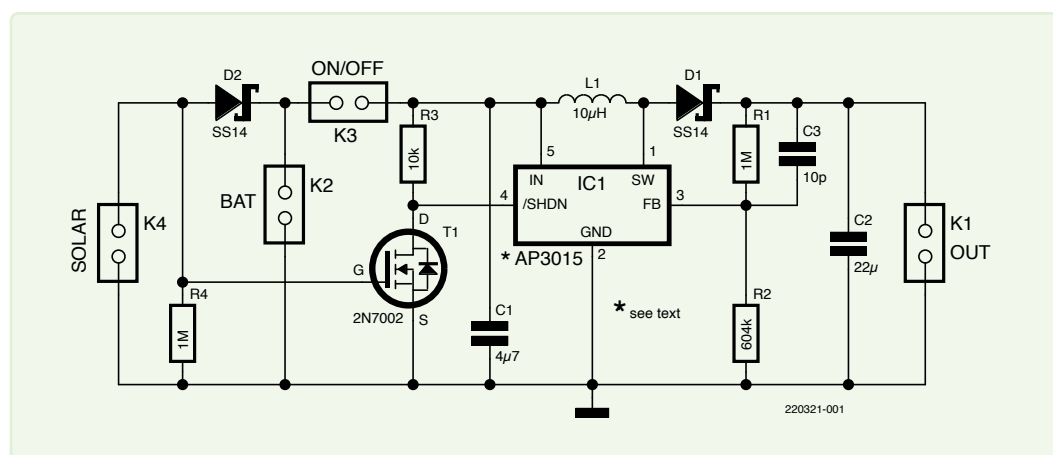


Figure 1: The A-version of step-up converter IC1 works with input voltages from 1 V up to 12 V and can deliver 100 mA.

By Clemens Valens (Elektor)

Need a regulated voltage out of an AA(A) solar-charged battery? Then, this tiny boost converter might just be what you're looking for.

We used to have two solar-powered garden light strings from Ikea lighting up our garden at night. They worked very well, but over the years, the colorful lights slowly disintegrated until only the solar panels were left over. As these solar panels are well-built, waterproof and all that, I decided to keep them and see if I couldn't do something else with them.

During the day, the solar panel charges a single 1.2 V Ni-MH AA rechargeable battery. When it gets dark, charging stops, and a tiny boost converter switches on to pump up the battery voltage to something

suitable for powering a string of white LEDs. Nice, but unregulated, as the output voltage depends on the load.

Circuit Diagram

That's why I designed this little circuit. It turns the 1.2 V at its input into a regulated 3.3 V suitable for e.g. a microcontroller-based something. The schematic is shown in **Figure 1**. The heart of the circuit is IC1, an AP3015 micropower step-up DC/DC converter from Diodes, Inc. Its A-version works with input voltages as low as 1 V (and up to 12 V) and can deliver 100 mA. The non-A version starts at 1.2 V, but can supply up to 350 mA.

The output voltage is determined by the ratio of R1 to R2:

$$V_{OUT} = 1.23 \times (1 + R1/R2)$$

With the given values, the output voltage is (almost) 3.3 V.

L1, D1, and C1 to C3 are the recommended components needed to

make the boost converter work. L1 can be one of those inductors that look like a resistor, as long as it can pass the maximum load current.

While the solar panel (on K4) is getting light, it charges the battery (connected to K2) through diode D2. At the same time, it pulls the gate of T1 up. This makes T1 conduct, pulling the shutdown pin of IC1 low, turning it off. When the output voltage of the solar panel drops too low, battery charging stops, T1 switches off and IC1 switches on. If you don't want this automatic switching, then leave T1 out. An On/Off switch or jumper connected to K3 gives you a bit more control over the circuit.

I designed a little PCB for the circuit that fits nicely inside the old Ikea solar panel. Today, this model is obsolete, but I am sure it will fit in other types too. The design files can be found at [1].

220321-01

Questions or Comments?

Do you have questions or comments about this article? Email the author at clemens.valens@elektor.com, or contact Elektor at editor@elektor.com.

About the Author

Clemens Valens is an engineer who manages the Elektor Labs online platform. He holds a BSc in Electronics and an MSc in Electronics and Information Technology. Clemens started working for Elektor in 2008 as Editor in Chief of Elektor France, and he has also worked as an editor for Elektor UK/US and ElektorMagazine.com. Later, Clemens was head of Elektor's design labs in the Netherlands, Germany, and India. Today, he is Elektor's Creative Technologist responsible for the Elektor Labs community website where electronics enthusiasts can publish their work and interact with peers from all over the world. Besides contributing his own projects and other articles to the magazine, he also produces regular videos for Elektor TV and moderates webinars. His main interests are sound generation and signal processing.

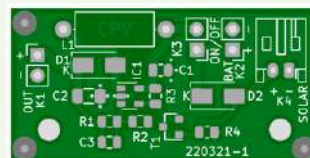


Related Products

- > **Sseed Studio Solar Panel for Outdoor Environments (3 W)**
<https://elektor.com/19131>
- > **Qoitech Otii Arc – Power Supply, Power Meter, and Data Acquisition**
<https://elektor.com/19270>



Component List



Resistors (0805, 0.125 W)

R1, R4 = 1 MΩ
R2 = 604 kΩ, 1%
R3 = 10 kΩ

Capacitors

C1 = 4.7 μF, 50 V, X7R (0805)
C2 = 22 μF, 10 V, X7R (1206)
C3 = 10 pF, 50 V, X7R (0805)

Inductors

L1 = 10 μH, 680 mA

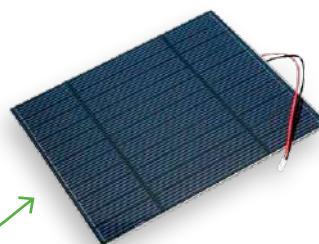
Semiconductors

D1, D2 = SS14 (DO-214AC)
IC1* = AP3015 or AP3015A
T1 = 2N7002 (SOT-23)

Miscellaneous

K1, K2, K3 = pin header, 1 row, 2 contacts, 2.54 mm pitch
K4 = pin header, 1 row, 2 contacts, right-angle, 2 mm pitch

* = see text



WEB LINKS

[1] Project files at Elektor Labs: <https://elektormagazine.com/labs/tiny-solar-supply>

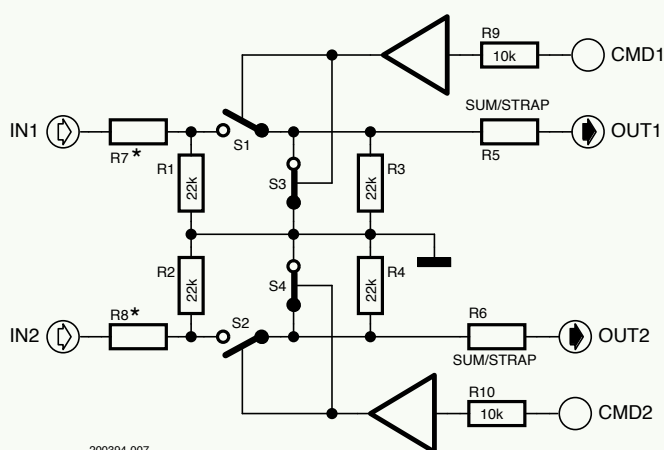


Solid-State Stereo Audio Switch

Free of Clicks and Moving Parts

By Thierry Clinquart (Belgium)

Switching audio signals remotely can be done with relays, but these are clunky and power-hungry. Here is a solution that uses solid-state switches instead.



200394-007

Figure 1: All that is needed to use the DG403 are a few resistors.

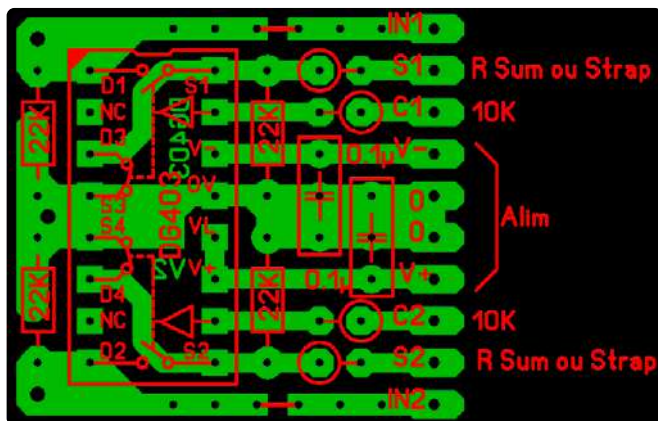


Figure 2: A PCB is practical when you need several modules; otherwise, a perfboard assembly is just fine.

We have all used classic mechanical switches to switch audio signals. As long as they are used locally, they can be sufficient; but when you need to switch sound remotely via logic or microcontrollers, you have to use either relays or analog switches. There used to be the SSM2402 dual audio analog switches from Analog Devices, but they are obsolete nowadays. Therefore, I looked for an alternative and tried out the DG403 improved dual high-speed analog switches, also from Analog Devices, with success.

The DG403 is powered from $\pm 15\text{ V}$ like a standard op-amp and contains two independent switches, each having its own independent control input. These inputs can be driven by either TTL or CMOS logic. Actually, each control signal drives two switches at the same time, a normally-open (NO) and a normally closed (NC) switch. Compared to older devices like the 4066, the $R_{DS(ON)}$ value of the DG403 and its brothers and sisters is much lower.

The schematic is shown in **Figure 1**. The input signal is connected to R7 (and R8). On my prototype, these were simply wire bridges, but they can be used to create an input attenuator. R1 to R4 are pull-down resistors that avoid annoying audible clicks during switching.

At rest, switches S1 and S2 are open, S3 and S4 are closed, and so no signal can pass through. Applying a logic high level to CMD1

and CMD2 will make S1 and S2 close while S3 and S4 open.

The output series resistors R5 and R6 allow for signal summing. If you only want to switch signals, you can replace R5 to R8 with straps.

The small PCB I designed for the circuit [1] is quite ergonomic as it gathers all the connections on a single pin header. This allows it to be placed vertically, saving space. If several of these boards are used in one system, they can be powered from a bus. For the more skillful readers, an SMD version should be possible too, reducing the size of the PCB even more.

The applications of the circuit are multiple: signal source switching, muting, switch matrix, etc. If you are a microcontroller or other programming enthusiast, you can control your switches without limits while keeping them close to the input connectors.

Also, check out other members of the DG series from Analog Devices (originally Maxim). The DG419 is a single-channel version of the DG403, it can switch between two signals with one control channel. ◀

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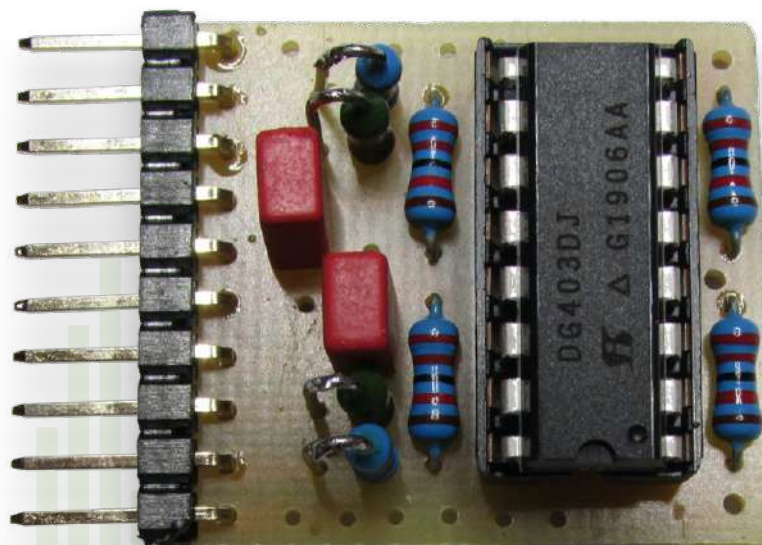


Figure 3: The module can be much smaller than this one if you use SMT parts.

About the Author

A trained electronics technician, Thierry Clinquart has directed his passion towards audio. All his projects revolve around analog audio – preamplification, dynamic processing, corrections, signal distribution, etc. Since in this field one can't hope to obtain conclusive results with prototyping boards, he makes his own PCBs the old-fashioned way with Sprint-Layout from Abacom and sPlan for the diagrams.



Related Products

- > **Pimoroni Raspberry Pi Pico Audio Pack**
<https://elektor.com/19765>
- > **Elektor Audio Collection (USB Stick)**
<https://elektor.com/19892>



WEB LINKS

[1] Project files at Elektor Labs: <https://elektormagazine.com/labs/audio-switching-with-dg-403>



Large RGB Digit

With Through-Hole WS2812 LEDs

By Clemens Valens (Elektor)

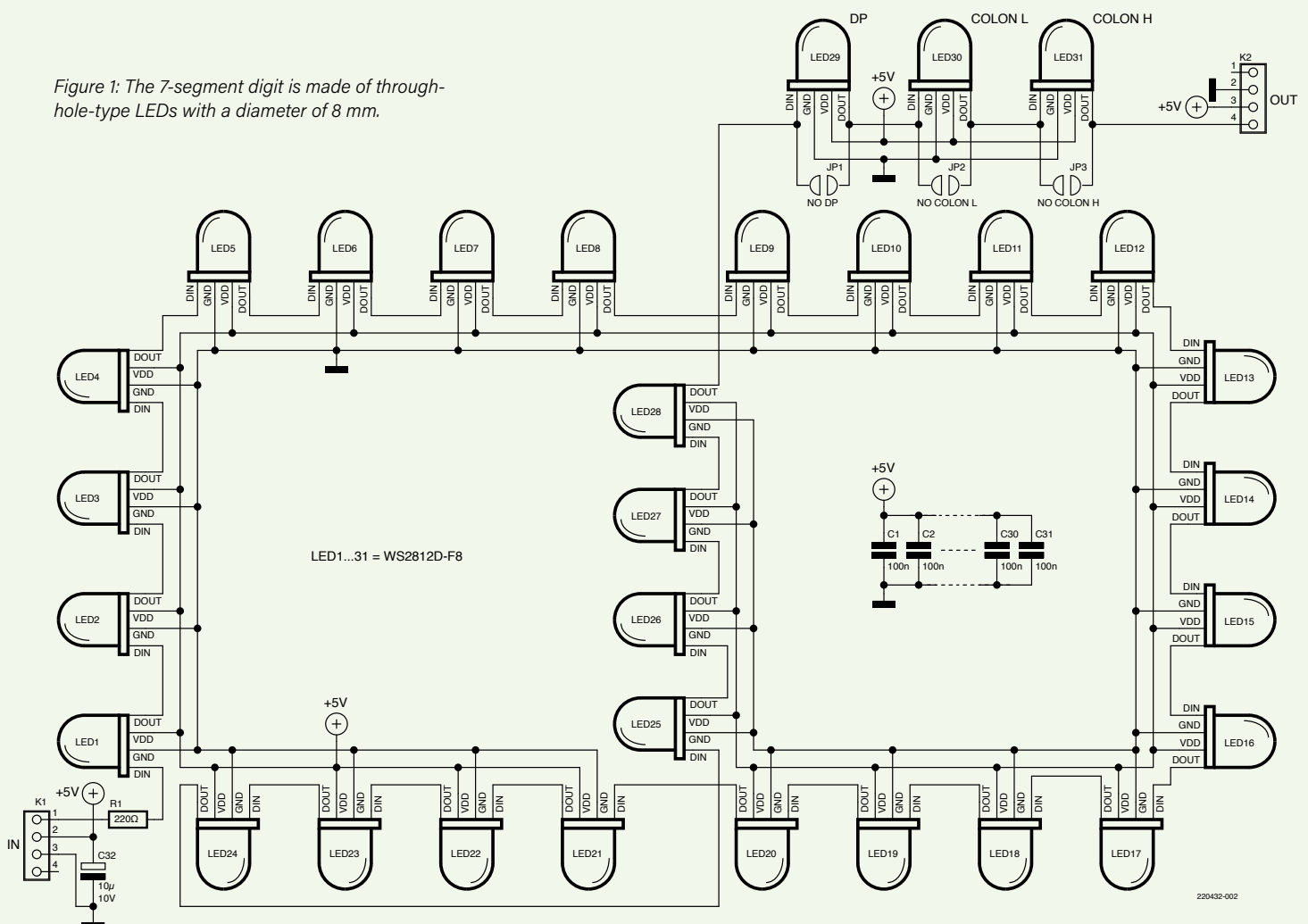
Addressable RGB LEDs are practical components that can be strung together easily. Here, we shaped the string as a 7-segment digit and put it on a stylish black PCB.

A few years ago, when they weren't as popular and widely available as they are today and software support was limited, I bought a bag containing 100 pieces of 8 mm WS2812D-F8 addressable RGB LEDs. These are through-

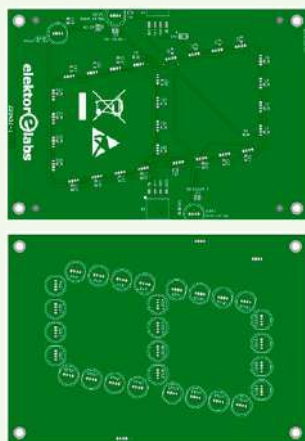
hole types, not SMT. After receiving them, I checked if they worked and put the bag in a drawer as I didn't really know what to use them for. A Hundred pieces may sound like a lot, but it is only enough for a 10 by 10 matrix

— not enormous. Therefore, they remained in the drawer until a few months ago when the need for a large seven segment display came up. That sounded like a good application for my LEDs.

Figure 1: The 7-segment digit is made of through-hole-type LEDs with a diameter of 8 mm.



Component List



R1 = 220 Ω (0805)
 C1...31 = 100 nF (0805)
 C32 = 10 μ F, 10 V (1206)
 LED1...31 = WS2812D-F8
 K1 = 4-way pin socket, horizontal, SMD
 K2 = 4-way pin header, horizontal, SMD

Deciding on the number of LEDs to use per segment meant finding a compromise between digit size and unused LEDs. I finally settled for four LEDs per segment plus a decimal point and a colon. This meant 31 LEDs per digit, i.e., three digits, while leaving seven LEDs unused.

Circuit and PCB

The circuit design was easy, as shown in **Figure 1**. The main effort went into drawing the PCB.

The LED's datasheet recommends putting a small resistor in series with every LED's DIN pin, but I didn't do that. I inserted only one (R1) at the input of the board. Furthermore, I placed a decoupling capacitor close to every LED, and a large capacitor (C32) at the power input.

Solder jumpers are provided for shorting optional LEDs. The DIN and DOUT pins for unmounted LEDs must be shorted; otherwise the data signal can't pass through.

For positioning the LEDs, I consulted a few datasheets of seven segment displays. Some have detailed mechanical drawings. The LEDs

should not be spaced too far apart, but not too close together, either. Also, the slant angle of the vertical segments must be just right. For a modular approach, the spacing between the digits should be nice, too. It is a bit of a Goldilocks thing.

After lots of moving LEDs around, I came to the design shown here. The colon is broken in two, with the upper LED on the left of the digit and the lower LED on the right. This allowed for a symmetric digit with good inter-digit spacing. The digit has a height of 10 cm and a width of almost 7 cm (not counting the decimal point). The board measures 13 cm by 9 cm.

A final design constraint that I imposed was to have a front side void of everything but LEDs. No visible traces or vias, no print, and no other parts. I managed to achieve this by using SMT devices for the resistors, capacitors, and connectors. Any vias and top-side traces are hidden underneath the LEDs. The component print of the optional LEDs (decimal point and colon) was moved to the bottom side.

At this point, the PCB pooling service chosen to produce the board (if you use one) can destroy the effort as they tend to put a production number somewhere on the board in a random spot, the most probable place being exactly where you really didn't want it. Luckily, some pooling services let you specify a position for this number (I used JLCPCB), so choose carefully. The result is a stylish black board with diffused-light-type LEDs on it.




Figure 2: Three cascaded digits fading between different numbers.

Arduino Code

I wrote an Arduino sketch to control the three digits as one display (**Figure 2**). The *Adafruit_NeoPixel* library drives the LEDs. As my LEDs are rather old, the data rate must be set to 400 kHz. Modern versions of these LEDs usually run at 800 kHz.

All the design files are available from [1].

As a last remark: Use a good 5 V power supply, as these LEDs can consume 60 mA or more a piece. A digit with 31 LEDs (white light, full brightness) can consume up to about 2 A! 

220432-01

Questions or Comments?

Do you have questions or comments about this article? Email the author at clemens.valens@elektor.com, or contact Elektor at editor@elektor.com.



Related Products

> **Adafruit Circuit Playground Bluefruit BLE**
<https://elektor.com/20105>

> **Velleman 3D LED Cube 5x5x5 (Blue LED)**
<https://elektor.com/19929>

WEB LINK

[1] Project files at Elektor Labs: <https://elektormagazine.com/labs/ws2812b-7-segment-digit>



Microphone Preamplifier with 48-V Phantom Power Distribution

Great for Podcasting and Pro Audio



By Thierry Clinquart (Belgium)

A microphone is a sensitive device producing a weak output signal that must be processed with care. This preamplifier does just that. It even lets you connect a 48-V phantom power supply for those mics that need it.

My adventure with microphone preamps started in the early 1980s with transistors such as the BC547. One day, while reading National Semiconductor's Audio/Radio Handbook [1], I discovered the LM387, LM381, and LF357. One trick at the time was to pair these with a 150 Ω / 10 k Ω impedance transformer to reduce noise. The transformer provides gain, allowing for a reduction in the op-amp gain. Shure microphones, like the PE15 and 586, had the impedance transformer built-in, along with a screw jumper to choose between Hi-Z or Low-Z mode.

In the early 1990s, PMI launched the SSM2017, which offered excellent quality in terms of dynamics and signal-to-noise ratio. Analog Devices later acquired it. Meanwhile, Burr Brown (now owned by Texas Instruments) released a replacement, the INA217. Later, DBX THAT Corporation, which only made VCAs, got into the game with the famous THAT1510, which I tried and adopted.

My microphone preamp follows the same template I used in a previous project [2], see **Figure 1**. It has the same dimensions and PCB layout, allowing MIC and LINE to be juxtaposed for bus power distribution.

Consequently, a true microphone/line preamp is put together quickly.

The Circuit

I have used the THAT1510 many times, but this time, I added two power distribution resistors R1 and R2 to supply phantom power to a microphone. This is very useful for the modern condenser and electret podcasting microphones requiring 48 V. Another reason

to place the phantom power on the PCB is to reduce wiring. Also, external P48-type phantom power units are not always of great quality.

The schematic of the preamplifier is shown in **Figure 2**. The microphone is connected to a Neutrik NC3FAH2 XLR receptacle. Capacitors C1, C2, and C3 make up an input RFI filter.

As I mentioned before, R1 and R2 distribute the 48-V phantom power. Since many electret microphones have internal Zener diodes of 5.6 V or 6.2 V to stabilize the power supply, why provide them with 48 V? 12 V can suffice. This can be done by changing the value of R1 and R2 from 6.8 k Ω to 1.8 k Ω or 2.2 k Ω to maintain a current of about 7 mA (48 V / 6.8 k Ω). Most field mixers also use 12 V for audio and phantom power.

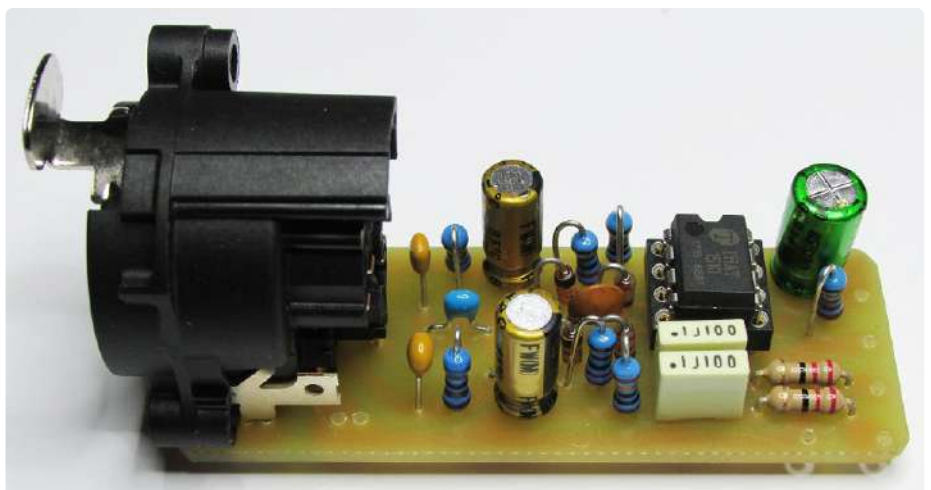


Figure 1: The microphone preamplifier fits on a small PCB. See [4] for details.

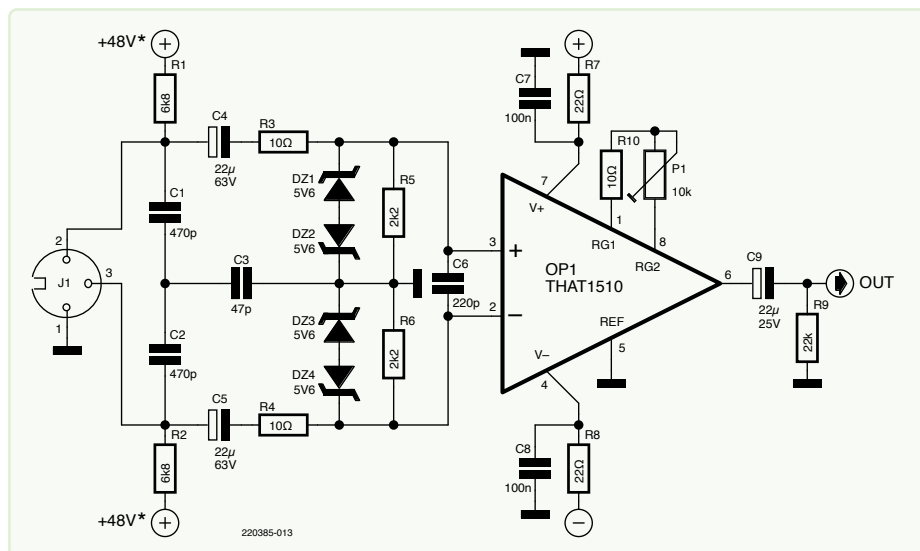


Figure 2: The circuit diagram for the microphone amplifier.

Of course, the Neuman U87, Schoeps, and other high-end microphones have internal Zener diodes close to 30 V, so for those 48 V is required.

C4 and C5 protect the THAT1510 against the phantom supply. I used the UFW1J220MDD from the Nichicon audio series. 63-V-types are preferable as 50 V is too close to 48 V. They take up little space.

R3 and R4 are recommended by the manufacturer to protect against power-on surges [3], while DZ1 to DZ4 protect the inputs of the THAT1510 against voltage spikes. Pull-down resistors R5 and R6 balance the input symmetry. They can be in the range from 1 kΩ to 10 kΩ. C6 eliminates any residual interference.

Power to the circuit is supplied through R7 and R8 and decoupled by C7 and C8. C9 is the output coupling capacitor. R9 is an output pull-down resistor.

The gain is calculated using $20 \log(1 + 10 \text{ k}\Omega / (R_{10} + P1))$. With P1 at its minimum value, the gain is 60 dB, and when it is at the maximum setting of 10 kΩ, the gain is 6 dB. **Figure 3** shows a way to create a gain control with 5 dB steps.

Various gain adjustment suggestions and design files can be found on the project page on Elektor Labs [4].

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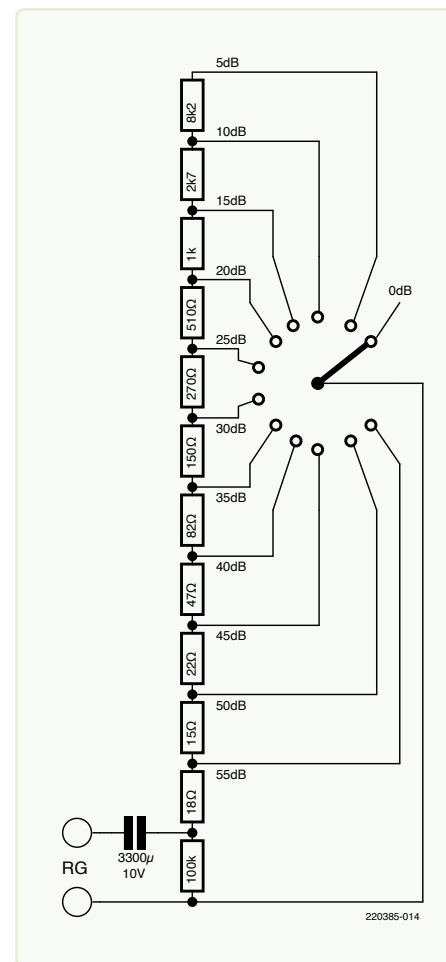


Figure 3: Using this gain selector switch in place of P1 allows adjusting the gain in steps of 5 dB.



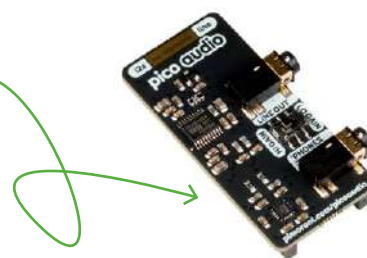
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<https://elektor.com/19892>



WEB LINKS

[1] National Semiconductor, Audio/Radio Handbook, 1980: <https://bit.ly/40VUQjA>

[2] Balanced-Unbalanced Converter: <https://www.elektormagazine.com/labs/line-receive-with-rfi-and-dc-protect>

[3] THAT Corp., "THAT 1510, 1512: Low-Noise, High Performance Audio Preamplifier IC," Document 60003, 2017: https://thatcorp.com/wp-content/uploads/2020/10/THAT_1510-1512_Datasheet.pdf

[4] Project files at Elektor Labs: <https://www.elektormagazine.com/labs/microphone-preamplifier-with-phantom-power>



Square Wave Generators with Duty Cycle and Frequency Controls

Simple Circuits with CMOS and TTL ICs

By Michael A. Shustov and Andrey M. Shustov

This article shows simple circuits of square wave generators with independent control of duty cycle and frequency. The duty cycle can be indicated by the brightness of single-color LEDs or the color of multicolor LEDs.

Most square wave generators with duty cycle and frequency control do not provide the ability to adjust the parameters independently. The circuits described below solve this problem.

Figure 1 shows a square wave oscillator built with standard CMOS Schmitt-Trigger inverters and NOR gates such as the CD4001. The circuit around IC1A generates pulses at Pin 2 with a duty cycle of about $\leq 1\%$. The frequency can be adjusted with potentiometer R2 in the range from about 100 Hz to 1 kHz. NOR gate IC2A generates the output signal of the generator. One input (Pin 1) is connected to this pulse signal and the other one (Pin 2) is controlled by the drain of small signal MOSFET T1. Its gate is fed with the signal from the slider of R4. The signal on C1 is the typical loading ramp of a capacitor and therefore similar to a sawtooth signal. This is why the pulse width can be continuously adjusted from almost 0 to 100 % by R4.

The second generator (**Figure 2**) is nearly identical but uses TTL ICs such as the SN7414N and the SN7428N. This time, for T1, small signal MOSFET 5LN015 is used, but its type is not critical.

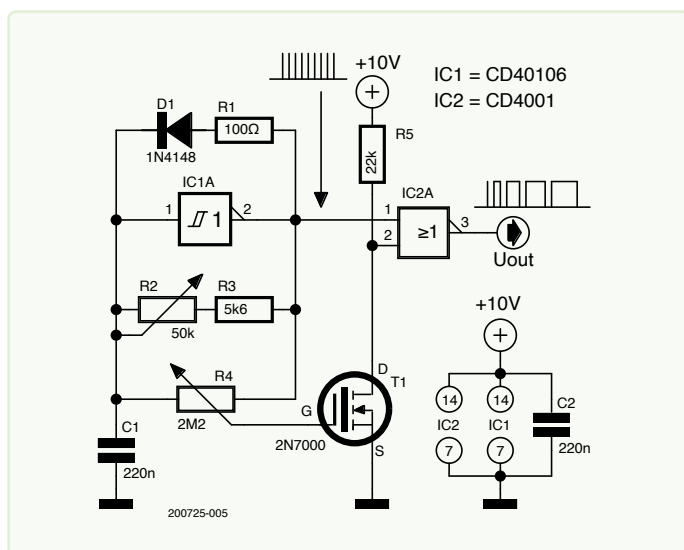


Figure 1: Pulse generator with independent control of pulse width and frequency, built using CMOS ICs.

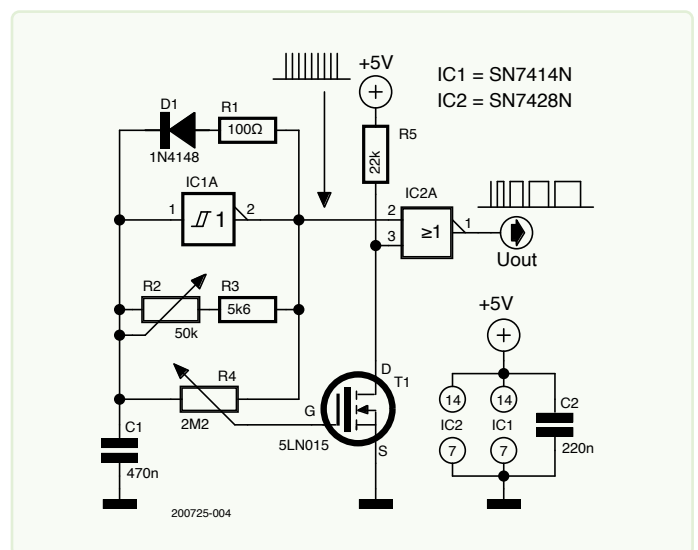


Figure 2: The same generator as in Figure 1, but now built with TTL ICs.

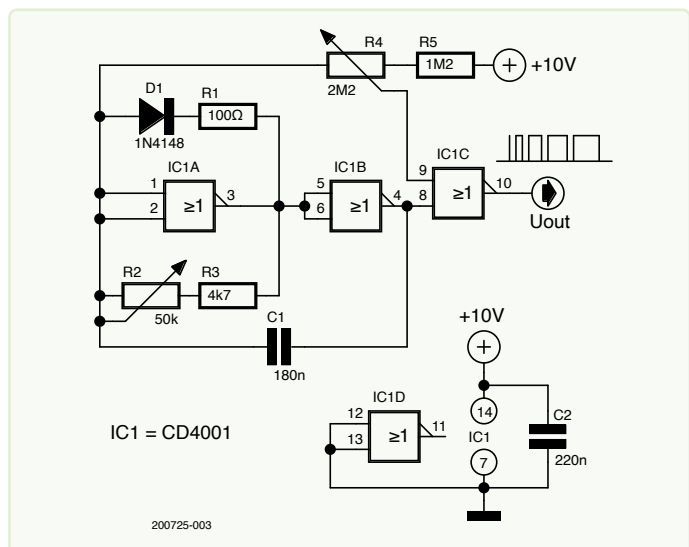


Figure 3: Variation of a pulse generator with independent control of pulse width and frequency.

Figure 3 shows a different variant of the basic oscillator. The advantage of this circuit is that no MOSFET is needed. This generator is built on three NOR gates from a CD4001. The inputs of IC1A and IC1B are connected to work as inverters. These two inverters form a pulse generator, whose frequency is controlled by R2 in the range of about 100 Hz to 1 kHz. The exponential sawtooth signal is taken from potentiometer R4 and fed to Pin 9 of IC1C. This potentiometer controls the pulse width in a range of about $\leq 1\%$ to about 65 %.

In **Figure 4** you can see two ways of indicating the pulse width by a LED. The left part shows a simple solution where the duty cycle corresponds to the brightness of a LED. The right solution uses a standard two-color LED whose green part seems continuously lit at first glance. Since the red part is controlled by the output signal of a generator, the color of the LED changes with the duty cycle from green (low duty cycle) to red (high duty cycle). This works because the voltage across the red LED chip is lower than that of the green chip. So, when the red LED is on, the green one is turned off. For a vintage aesthetic, you can replace the LED and its series resistor with a low-power incandescent lamp of appropriate voltage. ◀

200725-01

About the Authors

Michael A. Shustov holds the degree of Candidate of Chemical Sciences and Doctor of Technical Sciences, He is the author and co-author of more than 770 publications, including 21 monographs, 2 collections and 18 inventions, Andrey M. Shustov obtained a Master of Science at the Electrotechnical Institute of Tomsk Polytechnic University and from Karlsruhe Institute of Technology. He received his doctorate from the University of Kassel in 2009. He currently works for BASF in Ludwigshafen am Rhein (Germany), and is the author of more than 40 publications, including two books.

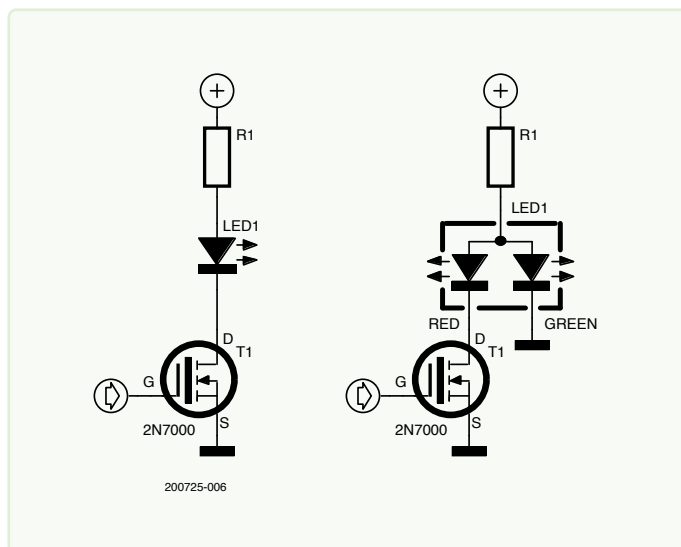
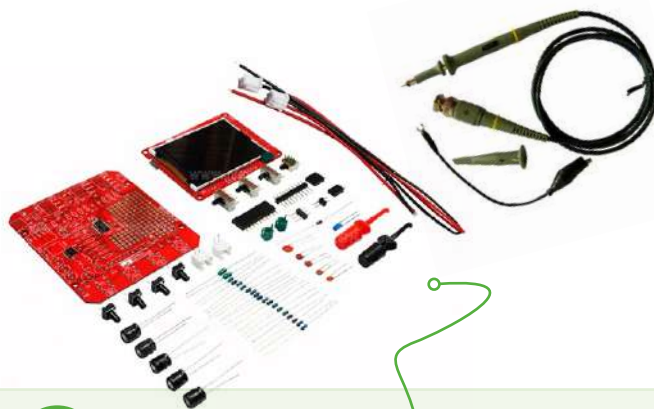


Figure 4: Options for output stages of pulse-width-controlled generators with LED, bicolor LED or other load.

Questions and Comments

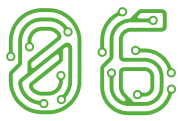
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Simple Dynamic Compressor

With Soft Control and Warm Sound

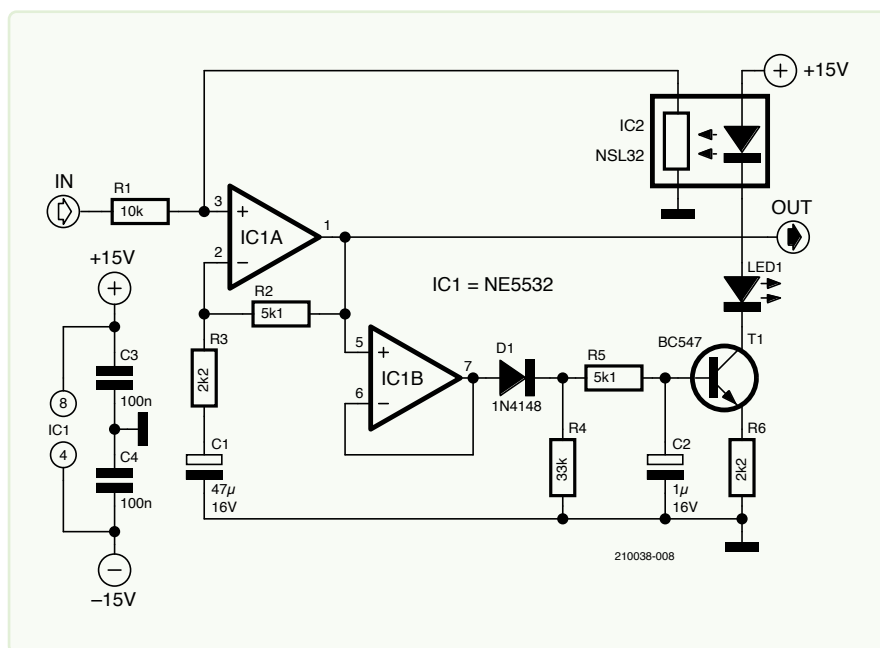


Figure 1: Vactrol IC2 is the magic part in this circuit that allows the dynamic compression of an audio signal.

By Thierry Clinquart (Belgium)

Dynamic compression of audio signals is essential for reducing signal peaks to avoid saturation of the output signal. This circuit uses a light-dependent resistor to achieve soft compression.

The heart of the compressor circuit, shown in **Figure 1**, is IC2, an NSL-32 resistive optocoupler. The value of the resistor inside the device depends on the amount of light produced by its built-in LED that shines on it. This way, the resistor value can be varied from about 500 kΩ (off) down to 500 Ω (on). This type of photoresistive element is also called a vactrol. They are widely used in audio applications, such as in compressors, filters, and envelope generators, where their slow response time and "soft" behavior are valued for their musical qualities.

IC2's resistor together with R1 form a light-dependent attenuator. When the signal becomes too strong, the LED inside IC2 will light up. This will lower the value of IC2's resistor, attenuating the input signal. The stronger the input signal, the higher the attenuation will be.

The dynamically attenuated signal is amplified by non-inverting amplifier IC1A, which provides the output signal of the compressor.

The output signal is also buffered by IC1B to drive a peak detector. When the thresholds of D1 and T1 are exceeded, T1 will start conducting and allow current to pass through the LEDs, activating the attenuator.

R4, R5, and C2 determine the control envelope. R5 and C2 set the attack time while the release time depends on R5 + R4 to discharge C2. R6 limits the LED current. LED1 provides visual feedback of the compressor operation.

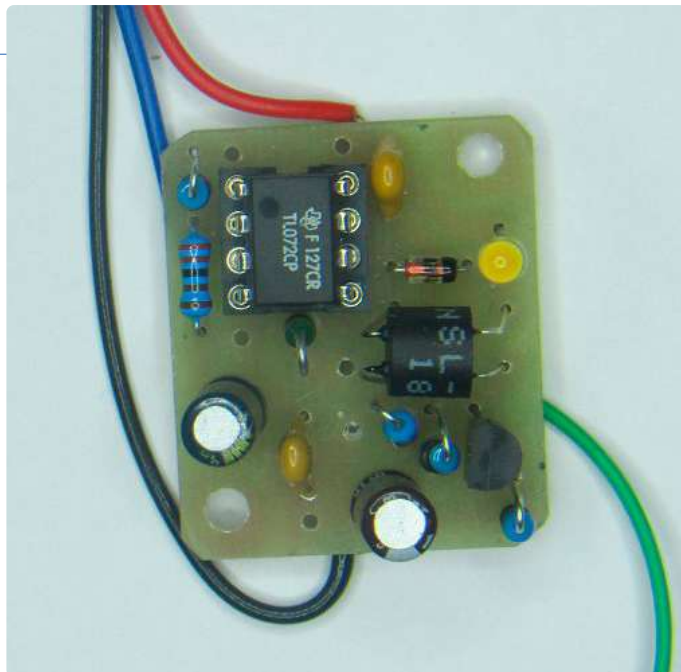


Figure 2: The compressor built on a small PCB. See [1] for the design files.

By interrupting the optocoupler connection, the compressor can be switched off.

Placed after a microphone, guitar, or instrument preamp, the compressor is a very useful device not only for signal quality protection but also for artistic qualities. ◀

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Questions or Comments?

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If you want to change the detection threshold of D1, you can put several Schottky diodes in series. This will give you threshold increments of about 0.2 V.

C1 blocks the amplifier feedback path R2/R3 for DC, while letting AC signals pass. Therefore, the DC gain is one. The input AC gain can be calculated by $20 \log(1+(R2/R3))$, which is about 10 dB for the given values. With an input signal of 250 mV, I measured an output signal of 775 mV.



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[1] Project files at Elektor Labs: <https://elektormagazine.com/labs/small-dynamic-compressor>

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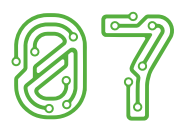
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Figure 1: This version of the lock uses numbers 1 to 10.



Simple Electronic Lock



By Rob van Hest (The Netherlands)

Locks come in many types — not just mechanical, but also electronic. Various mechanisms to open electronic locks have been devised, such as keypads, fingerprints, facial scans, and more. In the project described here, the lock is opened by turning a potentiometer.

This electronic lock does not require a key or a card to open it, but uses a code instead. To enter the code, you turn a potentiometer left and right in a way similar to a rotary combination lock. The operation is simple: Turn the

potentiometer to the first symbol of the secret code, then press the button to validate it and move on to the second symbol, and so on. When all symbols have been entered correctly, the relay is activated, and the lock opens.

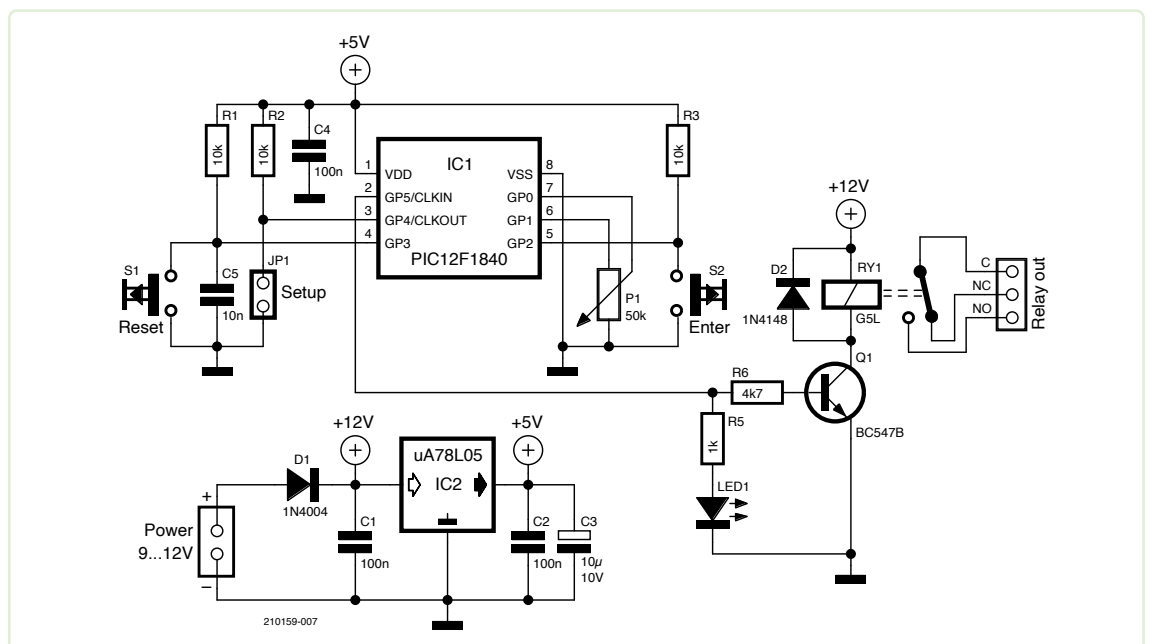
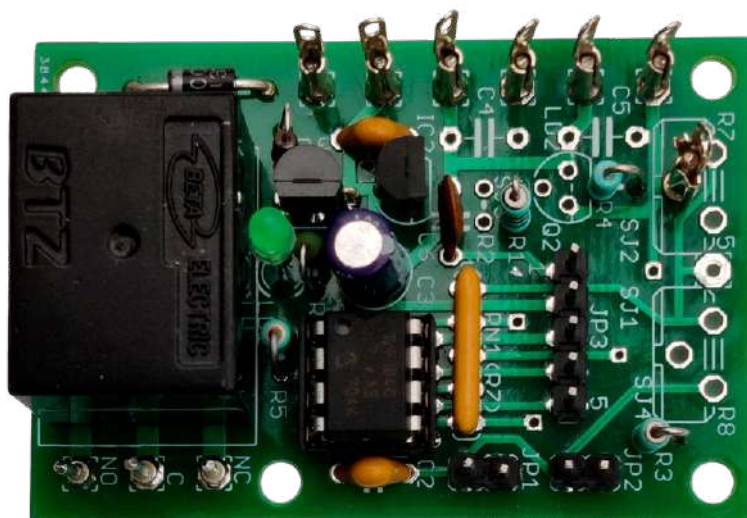


Figure 2: Almost half of this circuit can be ignored if you opt for battery power.

Figure 3: The lock built on the author's universal 8-pin PIC project board.



Because the input is analog, it is not necessary to use the ten digits from 0 to 9 for the symbols — icons, colors, or octal or hexadecimal characters may be used as well. If it fits on a potentiometer scale, then it can be used. My prototype uses the numbers from 1 to 10 (**Figure 1**).

Circuit Diagram

The circuit diagram of the lock is shown in **Figure 2**. It is built around a Microchip Technology 8-pin PIC12F1840 microcontroller (IC1) that controls a relay to switch a larger current. The PIC12F1840's little brother, the PIC12F1822, will also work in this circuit.

The code to open the lock is entered with P1 and S2. Potentiometer P1 receives power via pin 6 of the controller only when you press S2. This reduces the power consumption when the circuit is idle.

The circuit around IC2 is the power supply, and it accepts an input voltage of up to 12 V. However, battery power using three AA batteries, for example, is possible too. If you do so, use a 5-volt relay for RY1. Also, components IC2, C1, C2, and D1 can be omitted. The input and output of IC2 should be connected.

You can program a new code by placing a jumper on JP1. The procedure is the same as for opening the lock. After entering the new code, remove the jumper from JP1, and press reset (S1) to activate it.

Board and Software

The lock can be built on a universal board [1], which I use for all sorts of projects with various 8-pin PIC microcontrollers (**Figure 3**). This board has room for more parts than used here. Because the circuit is not very complex, you can also assemble it on a piece of perfboard.

Both the source code and the compiled HEX file are available from the project page at Elektor Labs [2].

A Microchip PICkit programming pod can be connected to JP3 to flash the HEX file into the MCU. If you program the chip when it is not fitted on the board, JP3 can be omitted.

If you want to make any changes to the program yourself, you will need the B. Knudsen CC5X compiler [3].

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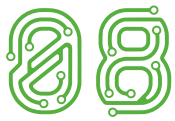
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- [1] Universal MCU printed circuit board:
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- [2] Project files at Elektor Labs: <https://elektormagazine.com/labs/simple-electronic-lock>
- [3] B. Knudsen Data, CC5X compiler: <https://bknd.com/cc5x>



Active Rectifier

A solution for 2...40 V at up to 3 A with Reverse Current

By Holger Nobach (Germany)

Active rectifiers are used when the loss voltage across the rectifier circuit needs to be smaller than the diode flux voltage. This keeps voltage losses low for small AC input voltages, and the power dissipation remains small enough to reduce cooling measures even at currents of several amperes.

The active rectifier circuit shown in **Figure 1** operates at input voltages of between 2 V and 40 V (peak) and at currents of up to 3 A (or 1.5 A without special cooling measures). The loss voltage across the entire circuit is as low as about 50 mV at low load (1 mA) and about 0.7 V at 3 A (**Figure 2**).

Bicycle Dynamo Rectified

The circuit is suitable, for example, for rectifying the voltage from a bicycle dynamo, which has a fairly high internal resistance. Under load, the voltage supplied by the dynamo therefore drops sharply, which means that a low loss is required for rectification and the circuitry should also be able to cope with a low operating voltage. A readily integrated solution for driving the MOSFETs (for example

an LT4320) is not optimal for use with a bicycle dynamo due to the specified input voltage range of 9...72 V.

To avoid an additional power supply for the circuit, active rectification by two P-channel and two N-channel MOSFETs each in a bridge circuit is the obvious choice here. The upper part of the circuit drives the corresponding MOSFETs through when the voltage at one of the inputs is sufficiently below the voltage at the positive output, which in turn is determined by the higher voltage of the two inputs. This circuit with cross-connected gates, used specifically for rectifying the voltage of a bicycle dynamo, is known from [1]. For a resistive load, this principle of rectification is suitable, but, when a support capacitance

Note!

The output of the LT1017 contains a pull-up current source which supplies only 15...70 μA from the positive supply voltage. In the proposed circuit, this is sufficient, but in other applications, this limitation should be considered.

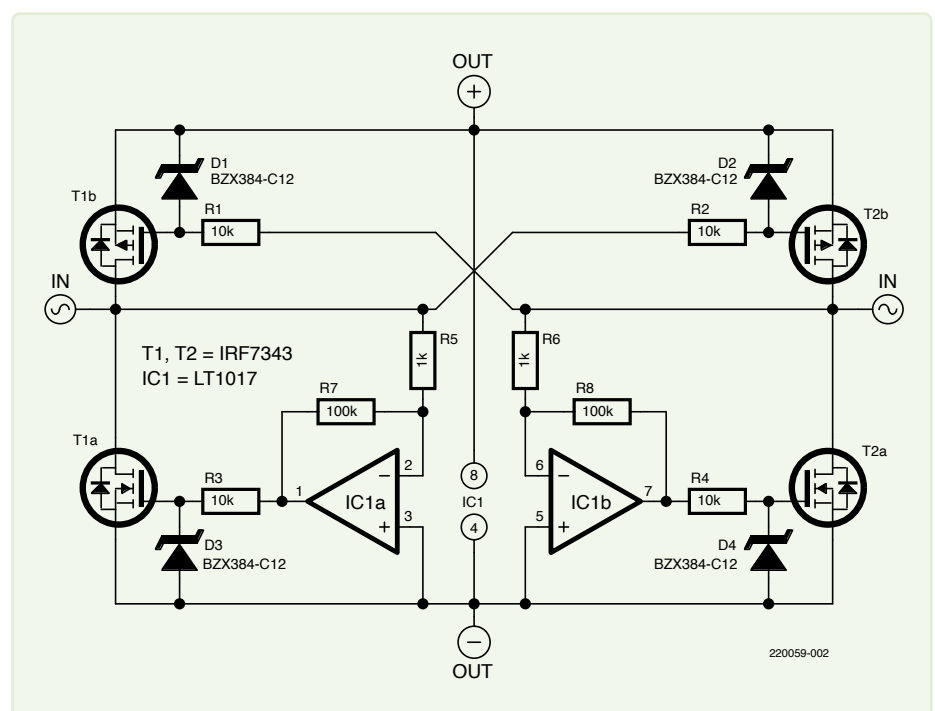


Figure 1: The active rectifier circuit.

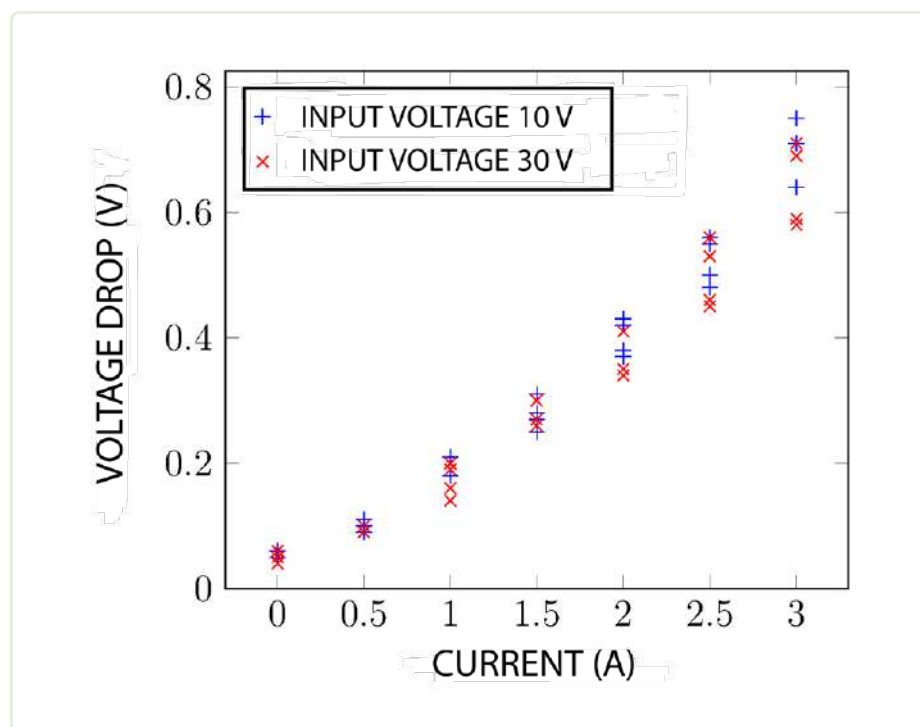


Figure 2: Loss voltage as a function of forward current for two different input voltages, for two modules each and two polarizations of the input voltage.

is used at the output of the rectifier circuit, reverse currents — and thus considerable reactive power — occur.

To prevent such reverse currents, it is not sufficient to compare only the input voltages. Rather, the input voltages must be compared with the two (target) potentials of the buffered output voltage and then the MOSFETs must be switched accordingly. A popular circuit [2] in different variants uses four operational amplifiers (for example LMV841, LMV842 or LMV844), which are wired as an inverting amplifier, each comparing one of the two input voltages with one of the output potentials. Since the operational amplifiers must be supplied from the output voltage, they must be able to process input voltages exceeding the two supply voltages. The LMV84x is suitable for this, but its supply voltage is limited to a maximum of 12 V. The LT1017 used here, on the other hand, has a supply voltage range of 1.1...40 V. However, the input voltage range only includes the lower supply voltage (up to 0.3 V below the negative supply voltage), while the input voltage must not exceed the

positive supply voltage. Therefore, only the lower part of the circuit, used to provide the negative output voltage, is controlled by the operational amplifiers, while the upper part is controlled only by the comparison of the input voltages, which is why it remains conductive until the voltage reverses, even when the input voltage decreases. The blocking of the MOSFETs in the lower part of the circuit must be correspondingly precise in order to reliably prevent current return flows.

Two MOSFETs Each in Conductive State

A pair of IRF7343 MOSFETs is used in the circuit; alternatively, an IRF7341 (dual N-channel MOSFET, for T1a and T2a) and an IRF7342 (dual P-channel MOSFET, for T1b and T2b) can be used. The two upper P-channel MOSFETs each start to gate through when the gate voltage becomes negative relative to the source voltage (threshold voltage -1 V). This is always the case when the voltage difference at the input exceeds 1.5 V. At a voltage difference of 3 V, the MOSFETs are fully conductive. The maximum drain-source voltage of

± 55 V is higher than the maximum input voltage of ± 40 V specified here. On the other hand, because of the maximum gate-source voltage of ± 20 V, the gates must be protected against overvoltages, for example, by a combination of a resistor (R1...R4) and a Z diode (D1...D4). With 10 k Ω resistors, a maximum of 4 mA flows through the Z diodes even at small Z voltages, so that small types with low power dissipation (300 mW) can be used. However, the exact type is not critical, within wide limits. The Z voltage can be selected in a wide range above 3 V, where the MOSFETs are fully conductive, up to the maximum allowed gate-source voltage of 20 V. Since the actual voltage across the Z diodes also depends on the current, one should keep far enough away from the range limits. With a Z-voltage of 12 V, you are certainly on the safe side. With a limitation of the input voltage range to ± 20 V as suggested in the **Caution, High Voltage!** box, the Z diodes D1...D4 can be omitted, and resistors R1...R4 can be bypassed.

The hidden body diodes within the MOSFETs (P-channel at the top and N-channel at the bottom) cause the entire circuit to operate like a diode bridge rectifier, even when the MOSFETs are blocked. As soon as the voltage difference at the input of the circuit exceeds about 2 V, the operational amplifier is sufficiently supplied and all MOSFETs are driven for active rectification.

The two lower N-channel MOSFETs are each supposed to open when one of the two input voltages has a greater amplitude than the negative output voltage. The two operational amplifiers are accordingly implemented as inverting amplifiers with a gain of 100. With a threshold voltage of 1 V, the two MOSFETs start to conduct at an input voltage of 10 mV below the negative output voltage. At a gate-source voltage of 3 V and an input voltage of 30 mV below the negative output voltage, the MOSFETs are fully conductive. For this purpose, the LT1017 allows voltages at the inputs up to 0.3 V below the negative supply voltage.

Conversely, when the voltages at the inputs and the outputs of the circuit are equal, the



Caution: High Voltage!

It is reported in forums that the output voltage of a bicycle dynamo can reach 80 V in idle mode. For such a case, the circuit should be protected at the input terminals (~ symbol) using two antiseriably switched Z diodes with a Zener voltage of, for example, 39 V. They do not contribute to rectification and are therefore not shown in the circuit diagram here. When using such an "external" limitation to the allowed MOSFET input voltage of ± 20 V, the Z diodes, D1...D4, may be omitted, and the resistors, R1...R4, may be bypassed.

MOSFETs should safely close to prevent reverse currents. When the voltage at its inputs is the same, the output of an inverting amplifier rises to the same voltage. Thus, in the ideal case, the gate voltage of the MOSFET is equal to the source voltage and the MOSFET turns off. With a maximum comparator offset voltage of 1 mV, this equilibrium state shifts to a maximum gate-source voltage of 100 mV, which is sufficiently below the threshold voltage for the MOSFETs to close safely.

Sometimes people ask about the necessity of the external circuit for operational amplifiers. In principle, the direct comparison of the input voltage with the output voltage would be sufficient. However, even with identical input voltages, an unwanted offset voltage from the op-amps could cause one of the MOSFETs to remain conductive and thus cause an unwanted reverse current to flow from the output back to the input. Only when the (reverse) current is sufficiently large, is the voltage drop across the MOSFET sure to be large enough to switch the output of the operational amplifier and thus disable the MOSFET. In order to guarantee that the MOSFETs reliably close at identical input voltages, the voltages at the input of the operational amplifier would have to be shifted

against each other by at least the possible offset voltage, for example by means of diodes in the flux direction and corresponding leakage resistors (either diodes with different flux voltages or identical diodes with different leakage resistances — and thus different forward currents). However, the circuit complexity would then increase somewhat compared to the solution presented here. ◀

Translated from German by Jörg Starkmuth — 220059-01

Questions or Comments?

Do you have questions or comments about this article? Email the author at holger.nobach@nambis.de, or contact Elektor at editor@elektor.com.

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Holger Nobach (Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany) studied and received his PhD in electrical engineering at the University of Rostock. He developed measurement techniques and signal processing methods in Copenhagen, Darmstadt, in the USA, and in Göttingen, where he heads electronics development at the Max Planck Institute for Dynamics and Self-Organization and gives lectures at the University of Göttingen. From time to time, the experimental work at the institute requires control and measurement technology beyond off-the-shelf products. The latest project involves fast and sensitive measurement probes for turbulent flows.



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- [1] Jürgen Heidbreder, Benno Kröck, "Mosfet-Gleichrichter für Fahrradbeleuchtung," *Fahrradzukunft* Ausgabe 14, 2012 [German]: <https://fahrradzukunft.de/14/mosfet-gleichrichter>
- [2] mikrocontroller.net, Forum Analoge Elektronik und Schaltungstechnik, MOSFET-Gleichrichter mit OPV [German]: <https://mikrocontroller.net/topic/375657#new>

On / Off Switching System for Active Boxes

By Jac Hettema (Netherlands)

Active speakers have their own power supplies and deliver high-quality sound. Their downside is that you need to turn them on to listen to them, and then off again when you're done. This project dispenses with that chore by turning the speakers on when there's a signal, and off when they're not in use for some time.

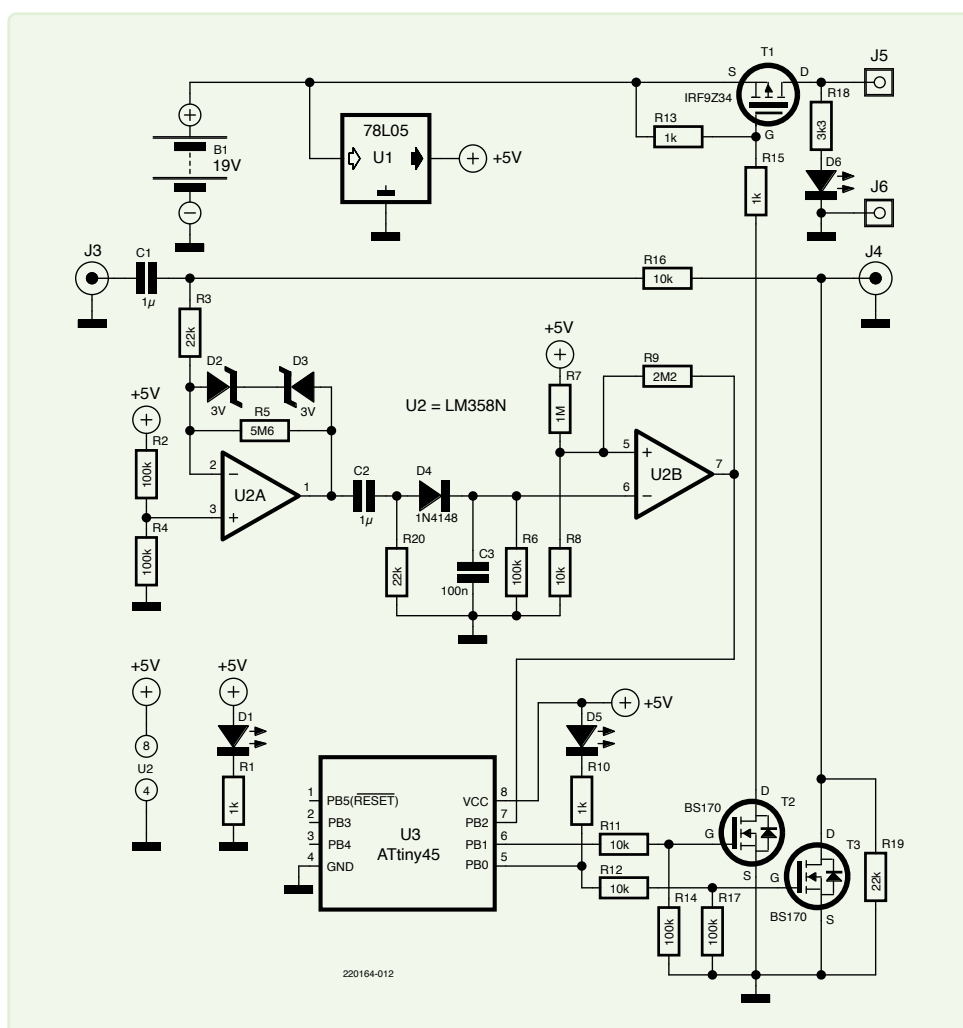


Figure 1: Active switching system schematic.

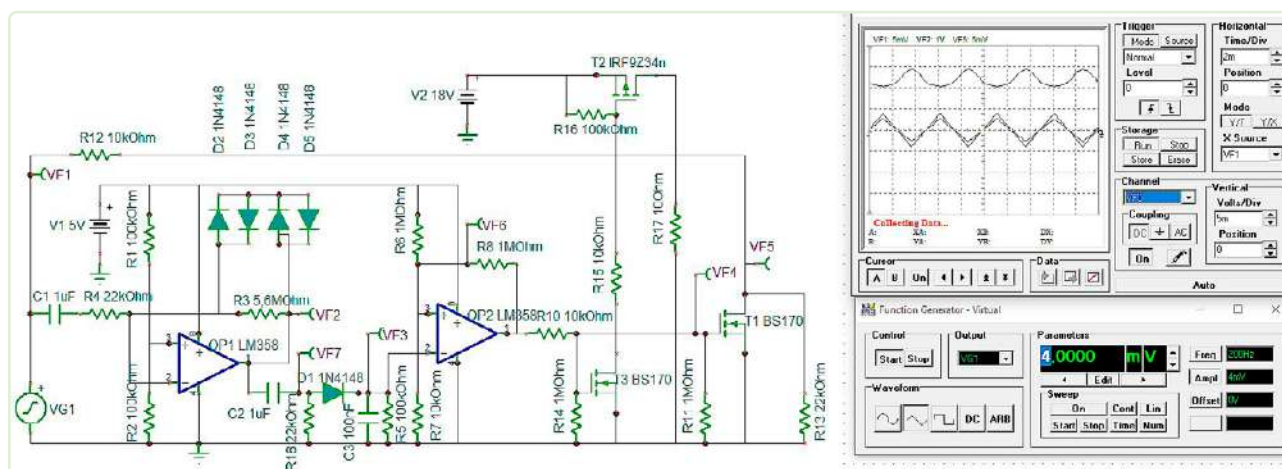


Figure 2: Simulation circuit using diodes.

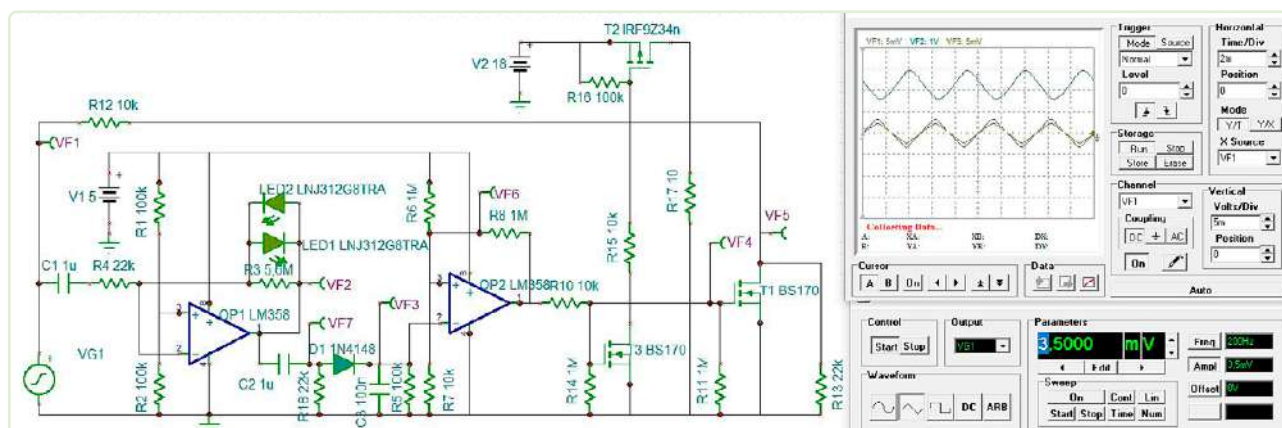


Figure 3: Simulation circuit using LEDs.

Speaker boxes come in all shapes and sizes. The “better” boxes are usually equipped with several speakers, each of which is then fed a part of the sound spectrum through a filter. Usually, these filters consist of capacitors and coils that separate the frequencies, as well as possibly resistor networks to adjust levels. Such systems are difficult to design and are only suitable for the combination for which they are designed.

It is also possible to use an active crossover filter and give each speaker its own amplifier. Such a system is easy to build into a loudspeaker box, which is then known as an active box. There are currently many amplifier modules for sale.

The design presented here is intended to take advantage of Class-D amplifiers, which are widely available. The intended types are based on Texas Instruments designs and are of good quality. These amplifiers can be powered with a single DC voltage that can vary from approximately 12 to 30 volts.

Because many laptop power supplies are available from discarded laptops these days, using them is an attractive proposition. Many of them can deliver about 19 V at 3 A — enough for a decent amplifier.

A tricky point with active boxes is switching them on and off. It is annoying if you first have to walk to the speakers to turn them on before you can enjoy the music. That has to be done in a different way.

Circuit

The circuit's complete schematic is shown in **Figure 1**. The box turns on as soon as there is a sound signal at J3. To this end, the audio signal is amplified and, as soon as there is a bit of level, a comparator switches over. This controls a timer that immediately switches on the power supply and switches the audio signal through with a short delay. When turning off, this happens in reverse: First, the audio is blocked and then the power is turned off. This prevents annoying clicks and pops during switching on and off.

However, it only switches off after the audio signal has been absent for a reasonable period of time, so that pauses between tracks on an album do not lead to a switch-off.

The circuit consists of 2 parts, namely:

- audio-detection system
- time delay.

Figure 4: The PCB.

The Audio-Detection System

The audio signal is amplified with an op-amp (U2A), then rectified and fed to a comparator (U2B). The intention is to switch the amplifier on at a very small signal. The gain of the opamp is

$$5.6 \text{ M} / 22 \text{ k} = \text{approx. } 250\times$$

However, the audio signal amplitude could be much larger during normal operation. Therefore, the output voltage of the opamp must be limited. We do this with (Zener) diodes or LEDs. The simulations show that Zener diodes differ considerably: With the 1N5225B, the switching threshold is approximately 3 mV, while with the BZX84A3V6, it is approximately 35 mV.

With (green or yellow) LEDs, the sensitivity is also about 3 mV.

If we use the normal 1N4148, then two antiparallel diodes must be connected in series. That also gives a good result; perhaps the best.

The amplified signal is rectified, after which it is compared with a threshold voltage using a comparator. The comparator has a small hysteresis to make switching more stable.

In the simulation, the comparator is directly followed by MOSFET switches so that we can test the principle. In the real world, the comparator is followed by a time delay, which in turn drives the MOSFET switches.

The Time Delay

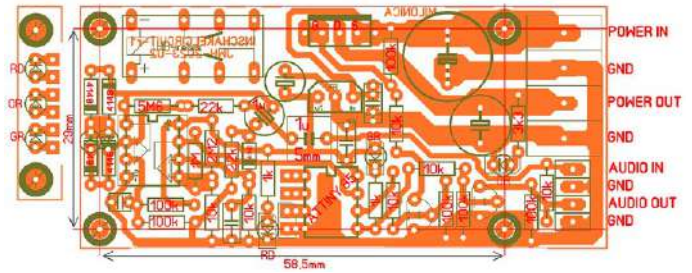
A microcontroller (U3) was chosen for this because the desired behavior can be obtained using only a few additional components. The ATtiny85 is very suitable for this. The μC is controlled by the comparator and, in turn, controls the FET switches.

After the audio signal is detected, the power is turned on immediately and the audio signal is passed through shortly after. When switching off, this is done in reverse order. It will not turn off until there is no audio signal detected for about 5 minutes. This duration can be easily adjusted in software.

The operation of the software is as follows: At power up, if the ATtiny85's PB2 pin goes low, the power is turned on and a timer reading is noted, then comparison of that reading with the present reading follows. If greater than a set value, the audio is passed through.

In the absence of an audio signal, PB2 goes high, initiating the power-down sequence. The audio and power are not turned off immediately — instead, the timer value is noted again. Its position is compared with the previous value and, if the difference exceeds the preset value, the audio is switched off. If the counter reading exceeds the following preset value, the power supply is switched off.

As indicated earlier, the circuit has been tested for functioning with a simulation program. TINA-TI simulation software from Texas Instruments was used for this. The simulation files of the version with diodes and the version with LEDs are shown in **Figure 2** and **Figure 3**, respectively. They include the screenshots.



Some Notes

LED D1 indicates that the supply voltage is present. LED D6 indicates that the power supply has been switched on.

A High output on the ATtiny's PB0 causes the control FET, T3, to conduct, which prevents the audio signal from passing through the circuit. The High on PB0 also turns indicator LED D5 off.

Zener diodes are drawn in the schematic for limiting the output voltage. These can be replaced by signal diodes (e.g. 1N4148) or LEDs. In the final version, an ATtiny85 was used instead of the 45.

For this circuit, a single-sided PCB of modest dimensions has been designed: 35 × 77 mm (**Figure 4**). This is equipped with the necessary decoupling capacitors and smoothing capacitors.

The power FET, with which the current is switched, can possibly be replaced by an ordinary relay. Both TO220 and TO3P versions can be used for the power FET.

The BS170 allows an undistorted voltage of up to approximately 300 mV. ◀

220164-01

Questions or Comments?

Do you need to know anything more about this project? You can reach the Elektor team at editor@elektor.com.

About the Author

Jac Hettema's love for electronics ignited in his youth, when he received a tube radio and an AMROH transistor radio kit. Despite beginning his career in power technology, Jac's path led him to Dutch Railways' research department, focusing on electrical measurements. His early education also involved analog computers, a testament to his enduring interest. Now retired for over a decade, Jac's passion for electronics persists, as he engages in various circuit projects, including a state-variable three-way filter.



Related Products

> **Elektor Audio Collection (USB Stick)**
<https://elektor.com/19892>

WEB LINK

[1] Project files at Elektor Labs: <https://elektormagazine.com/labs/on-and-off-switching-system-for-active-boxes>

10 Unbalanced/Balanced Converter

With RFI Filter and DC Protection

By Thierry Clinquart (Belgium)

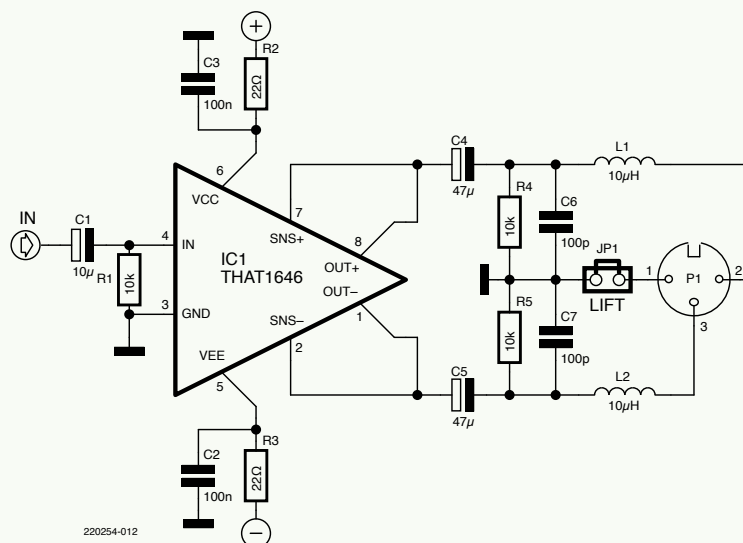
A symmetric or balanced connection provides a good way to transport audio signals over longer distances. The circuit described below converts an unbalanced or asymmetric audio signal into a balanced signal. This project complements the balanced-to-unbalanced converter published in [1].

The circuit presented here is an unbalanced-to-balanced converter that can be used to drive audio transmission lines. In the past, a line amplifier coupled with a $600\ \Omega / 600\ \Omega$ transformer was used for this. The galvanic isolation was good but covering the 20 Hz to 20 kHz audio spectrum was more complicated and expensive.

Therefore, I propose here an active version of the old way of doing things based on the THAT1646, which, with a few external components, functions as a differential amplifier. The SSM2142 from Analog Devices (end of life) and the Texas Instruments DRV134 are fully compatible with this integrated circuit. As with the THAT1240 used in [1], the audio signal travels on two conductors in phase opposition.

Figure 1 presents the simple circuit diagram. C1, C4, and C5 are coupling capacitors that block the DC components

Figure 1: The schematic of the balanced line driver. The (symmetric) power supply should be in the range from $\pm 4\text{ V}$ to $\pm 18\text{ V}$.



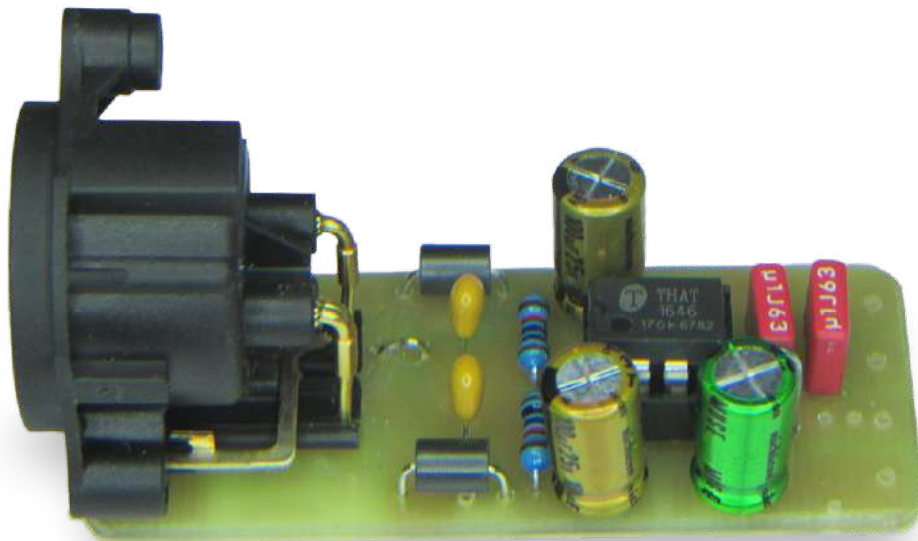


Figure 2: Everything fits on a small PCB. The design files for it can be found at [3].

at the input and two outputs. R1, R4, and R5 are pull-down resistors. C2 and C3 are decoupling capacitors.

R2 and R3 facilitate troubleshooting in case IC1 short circuits. They allow any other modules present on the power bus to continue to operate in this case.

L1/C6 and L2/C7 constitute RFI filtering. 10 μ H inductors L1 and L2 can be replaced with ferrite beads.

P1, an XLR connector (I used a Neutrik NC3MAH series A [2]), is placed on a small PCB (**Figure 2**) [3]. The other components do not extend beyond the width of the connector, allowing for a tight fit when installing in a casing. The pitch can be 23 mm as suggested by Neutrik in its datasheet.

As usual, I always leave the possibility of disengaging pin 1 with a jumper in case of conflicts between Earth, Ground, and Chassis. You can also place a Ground Lift switch there.

Applications

This module can find its place in the restoration of vintage equipment, but also when designing more equipment such as signal splitters and intercom interfaces.

Don't hesitate to visit the manufacturer's website for all specifications [4].

Personally, I use the THAT1646 with its complementary circuit THAT1240 in a signal distribution application where I do not have to face the 48 V phantom power supply of microphone preamps. If you also do so, the manufacturer recommends the use of 4 diodes that limit surges to the V+ and V- rails, in addition to the internal protections of the chip.

Keep in mind that some commercial mixers put 48 V on all microphone inputs. I much prefer a switch per input and only provide 48 V when it's necessary. ◀

220254-01



Related Products

- > **B. Cordell, *Designing Audio Power Amplifiers (2nd Edition)***
<https://elektor.com/19150>

WEB LINKS

- [1] Thierry Clinquart, "Balanced/Unbalanced Converter," Elektor Circuit Special 2022: <https://elektormagazine.com/200378-01>
- [2] Datasheet Neutrik NC3MAH: <https://neutrik.com/en/product/nc3mah.pdf>
- [3] Project files at Elektor Labs: <https://elektormagazine.com/labs/balanced-audio-line-driver>
- [4] All about the THAT1646: <https://thatcorp.com/that-1606-1646-balanced-line-driver-ics>

2023: An AI Odyssey

Where Did It Come From?

Where Is It Going?

By Brian Tristram Williams (Elektor)

While every year comes with its own AI hype, the past one has really grabbed our attention; things are suddenly incredibly fast-paced, and it's tough to keep track. Each day there are new headlines, and that's why we've decided to start this series to help separate the help from the hype.

Humans have been thinking about intelligent machines since long before electronics; look at Talos (*ΤΑΛΩΝ*) [1], a foot-high humanoid made of bronze, from around 400 BC Greece (**Figure 1**).

Mechanical to Electronic

With the arrival of electric, valve-based computers such as ENIAC, and later the transistor revolution that ushered microcomputers into homes in the 1980s, programming became accessible to ordinary consumers, not just scientists or the military.



Figure 1: Talos, a mythical automaton, on a 2,300-year-old coin.
Source: Wikimedia Commons.

As a child, I learned the concept of programming language constructs that implement formal logic, and my mind was blown by *IF-THEN-ELSE*. “You mean, if I input one thing, the computer does X, and if I input another, it does Y?” It could *make a decision*, which is a fundamental first principle in computing. Moreover, *I* could decide what that decision — as well as the resultant tasks — would be!

While there's a lot more to programming, any logical task can be broken down into a series of such constructs. With enough *IF-THEN-ELSE*s in hand, I imagined that something apparently conscious and intelligent could be created (**Figure 2**). It certainly wouldn't be very efficient — it might just take 7.5 million years to get a response, particularly if it's “42.”

Over time, with more and more “compute” available, programmers have made machines *seem* ever more intelligent by artificial means. From text-only adventure gaming through an old *Ghost Town*, to Clippy, the first virtual assistant for Microsoft Office, to Alexa, the voice-based assistant that understands your speech, carries out instructions, and responds appropriately, the growing global corpus of trillions of lines of code is extremely useful, but hardly “sentient.”

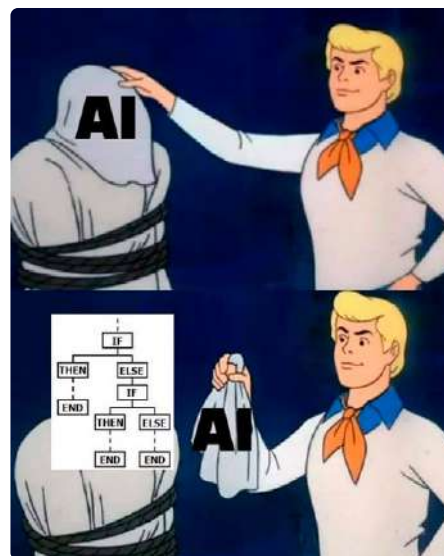


Figure 2: Does AI come down to this?
Source: twitter.com/FullstackDevJS

Do They Think They Think?

Machine sentience in the twentieth century was the stuff of science fiction, from 1927's *Maschinenmensch* (*Metropolis*), to HAL (2001: *A Space Odyssey*) to *The Terminator*. Then, in real-life 2022, there was a seismic shift. All of a sudden, a critical mass was reached. OpenAI's DALL·E 2 went live to the masses in September. Suddenly, Joe Public could simply type some words and get the spectacular hallucinatory imaginings of an alien intelligence in response — hair-raising, sometimes creepy, and quite astonishing.

While DALL·E 2 is multimodal, it's part of an evolutionary backstory that led from OpenAI's release of GPT (generative pre-trained transformer) in 2018. In November 2022, OpenAI's text-only GPT brainchild was introduced to the world: ChatGPT.



Figure 3: ChatGPT-generated tweet.

It's an artificial creation that appears to carry all the hallmarks of intelligence and — perhaps — sentience. Like DALL-E 2, it has heads spinning and tongues wagging. It can do your homework. It can copy other authors' styles. What about ethics? As millions around the world do more with it, more concerns are being raised.

How Can It Help Us?

At Elektor, we've also tinkered. While that doesn't mean that we'll be serving you AI-generated content from now on, we're certainly interested in how these developments help serve us — and thus you — even better. In this series of articles, I invite you to come along for the journey as we explore the field, its tools, and what it can do.

For example, we've seen that ChatGPT can help with natural-language writing. Let's say I want to summarize everything I've written above into something that will fit in a tweet (**Figure 3**) [2].

But, besides holding natural-language conversations, it can design and analyze circuits [3] and even write code. Yes, computers can program computers from natural-language prompts; no longer do humans have to know coding to accomplish computing tasks. The possibilities are endless, but so are human requirements. From Excel formulas to scraping webpages to browser extensions to *physical* computing...

Yes, ChatGPT knows hardware as well, and can help you like a human tutor. I tried it with some hardware I'd never played with: a Pimoroni Blink! [4] hooked up to a Raspberry Pi Zero.

I looked at the official documentation [5], which is more than adequate for an understanding of how to use the Blink!, but I wanted to TL;DR it to get a specific thing done, stat: Make a *Knight Rider*-type running light. So, I tried ChatGPT. I didn't specify a color, just that I wanted running lights like in the hit 80s TV show about an artificially intelligent Pontiac Trans Am [6]. The Python code was output, and I was presented with the (red!) light show I asked for (**Figure 4**).

This intelligence may be a kind of *Blindsight* [7], where the lights are very much on, but no one's home. However, if it delivers results, does it matter?

Where Is It Going?

As to an uncertain future where our creations are smarter than we, predictions range from sci-fi dystopia to science Utopia. How many jobs will go the way of the elevator operator — and suddenly, like dominoes? What's left for humans to do? If there's no work to pay the bills, what then? Universal basic income [8]?

AI is here, and burying our heads in the sand won't change that. We have to stay on top of it if we don't want to end up under it.

This regular series on AI aims to keep you in the loop, with reports on developments in this fast-moving field, as well as its potential uses for our passionate community.

In the *I Robot* film, Del Spooner taunted rhetorically: "Can a robot write a symphony? Can a robot turn a canvas into a masterpiece?" The answer is yes. But, what about us? What exciting things can we make with its help? What are the dangers? Who holds the rights? What do we disclose? Keep reading, and let's find out together! ◀

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Questions or Comments?

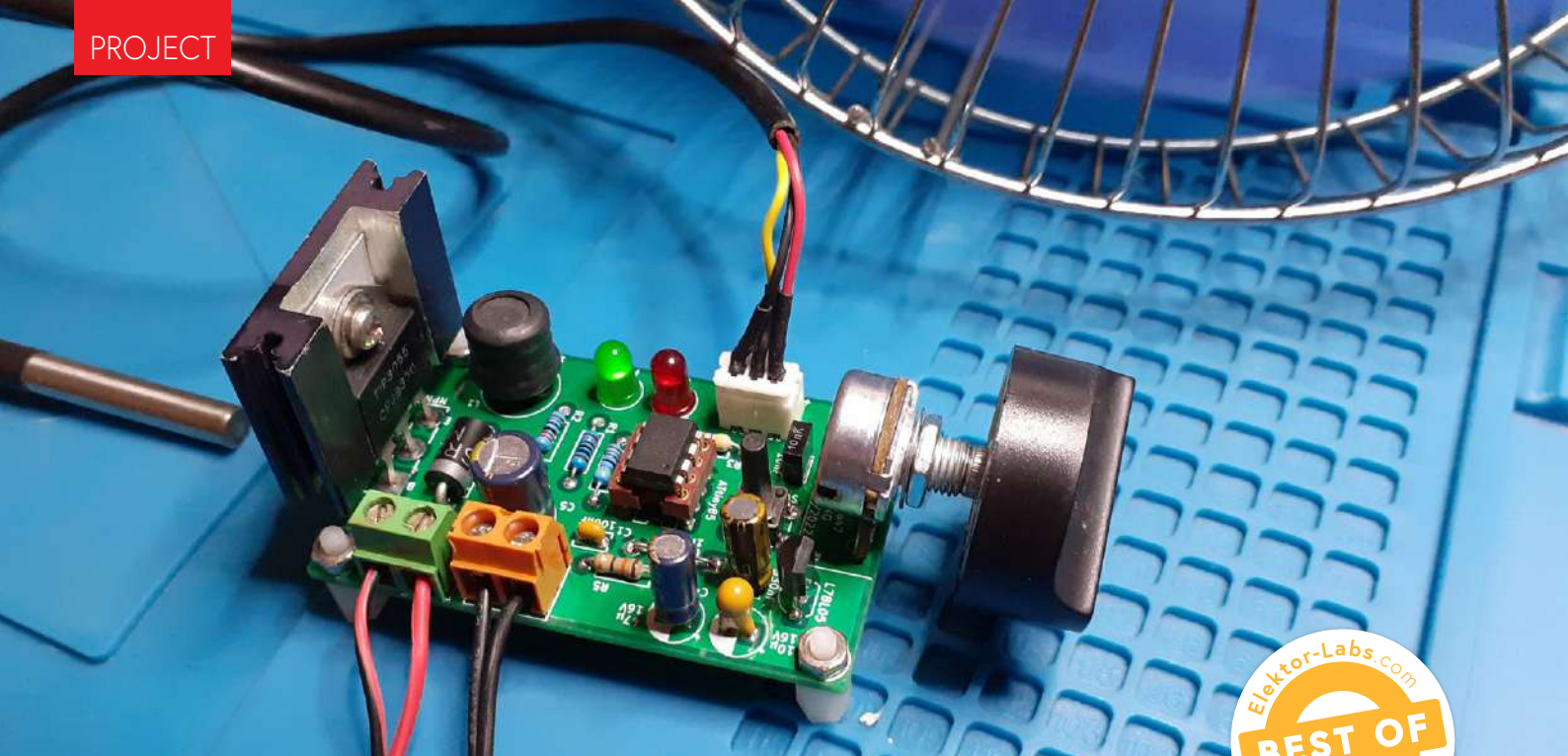
Have you found any amazing uses for AI in your field? Do you have questions or comments about this article? Let me know at brian.williams@elektor.com or contact editor@elektor.com.



Figure 4: Knight Rider running lights coded in Python by ChatGPT!

WEB LINKS

- [1] Talos [Wikipedia]: <https://en.wikipedia.org/wiki/Talos>
- [2] ChatGPT summary of the article thus far, Twitter-ready: <https://twitter.com/briantw/status/1672190152238682113>
- [3] Clemens Valens, "ChatGPT as Embedded Electronics Design Engineer," Elektor TV: https://youtu.be/pM1n_q7q670
- [4] Pimoroni Blink!: <https://shop.pimoroni.com/products/blink?variant=22408658695>
- [5] Blink! Documentation: <http://docs.pimoroni.com/blink/>
- [6] "Knight Rider" (1982 TV Series): [https://en.wikipedia.org/wiki/Knight_Rider_\(1982_TV_series\)](https://en.wikipedia.org/wiki/Knight_Rider_(1982_TV_series))
- [7] Peter Watts, "Blindsight" — full novel: <https://rifiers.com/real/Blindsight.htm>
- [8] What Is Universal Basic Income (UBI), and How Does It Work?: <https://investopedia.com/terms/b/basic-income.asp>



11 Speed Controller for Fan or Ventilator

With Manual and Thermostat Modes

By Bruno Clerc (France)

It's hot outside (or inside), and you need a cool breeze? With this fan controller, you can control a fan's airflow manually or let the device control it for you.

The summer of 2022 was particularly hot, and, like many of you, I was looking for a refreshing breeze. I don't have any air-conditioning (neither in the house nor in the car) but I did have two 12 V car/caravanning fans (**Figure 1**), so I connected one of them to a power supply. However, these fans run at full speed as soon as they are switched on, generating noise as well as an airflow a bit too strong for my taste. I therefore decided to build this fan speed controller.

The article "Keep Cool with an ATtiny" [1] turned out to be a great source of inspiration, as it helped me properly manage the PWM output for controlling a fan. My own PWM experiments made the fan "sing." By using Timer0 in fast-PWM mode as described in the article, the fan got quieter.

The software accompanying the article was not written for Arduino, so I ported it into an Arduino-style sketch



Figure 1: The fan that inspired this project, controlled by a perfboard prototype.

that can be compiled in the Arduino IDE. Even though my application didn't need a temperature sensor, I kept it as an option to keep the spirit of the original article. I replaced the driver for the DS18B20 temperature sensor included in the original program with the OneWire library for Arduino.

The Circuit

The fan controller's schematic, shown in **Figure 2**, is partly based on the article mentioned above [1]. My first prototype used a MOSFET to drive the fan, but it caused glitches in the readings returned by the DS18B20 sensor, making the assembly behave erratically. Maybe applying the lessons from [2] would have helped here? Instead, I preferred a power transistor over a MOSFET, so the PCB has a TO-218 footprint for Q1. This allowed me to use a suitable NPN transistor that I'd salvaged from some old equipment. The maximum output current is 2 A (limited by the inductor), so mount the transistor on a heat sink if necessary.

Resistor R5, which lies between the 12 V supply and the input of U2, a 5 V regulator in a TO-92 package, introduces a voltage drop that lowers the regulator's tempera-

ture rise. The circuit consumes about 30 mA in its full version, so R5 must be capable of dissipating 117 mW.

The DS18B20 sensor connects to J3. LED D3 signals if a sensor was found or not.

Schottky diode D4 could be another type. LEDs D2 and D3 are optional, and so is reset button SW1.

As briefly mentioned, a switch (active Low) can be connected to override the potentiometer control. MCU port PB4 is configured as an input with a pull-up resistor. Note that, when using an override switch, resistor R3 and LED D3 should not be mounted.

In my case, a TTP223 touch key module (J8) is the switch. The TTP223 module has two configuration straps; short Strap A and leave Strap B open. Now, when idle, the output of the module is High. Touching it switches the output to Low until the key is released.

The Software

The program is configured with a few `#define` directives at the top:

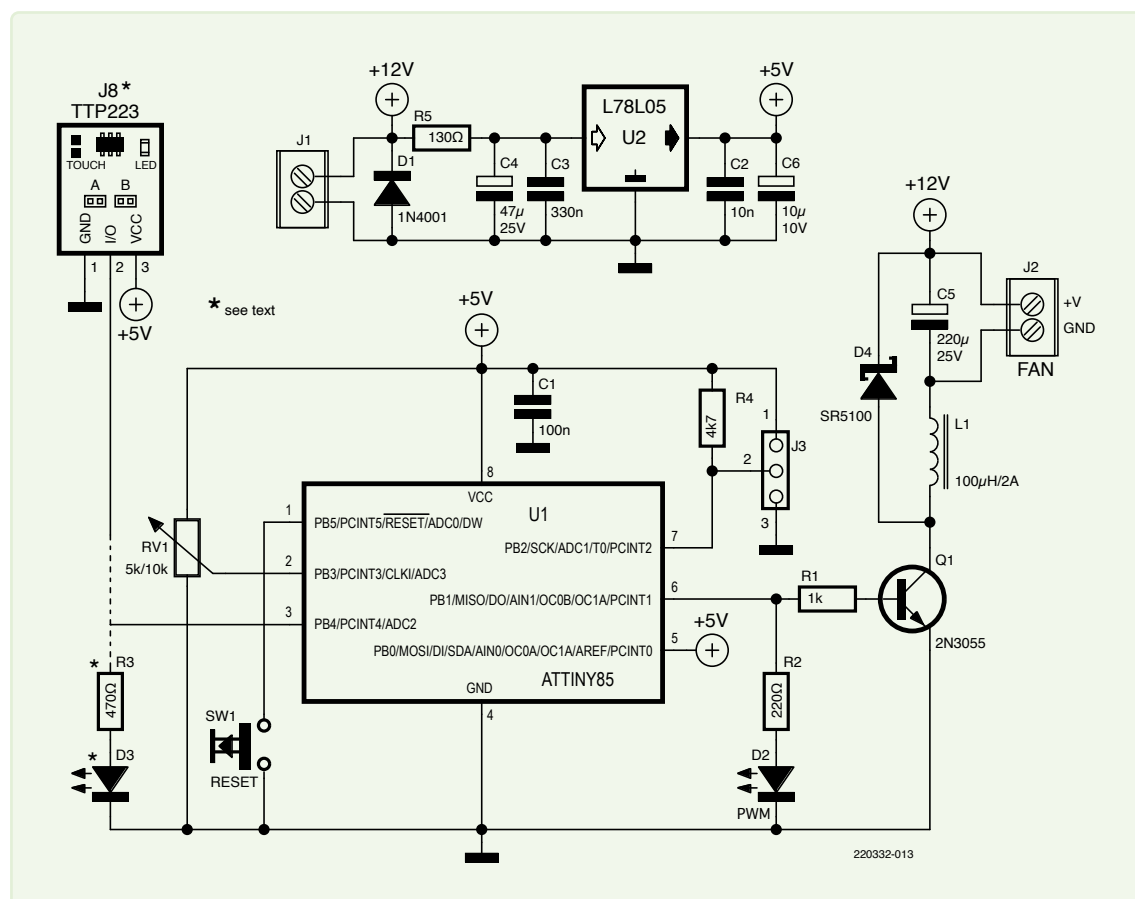
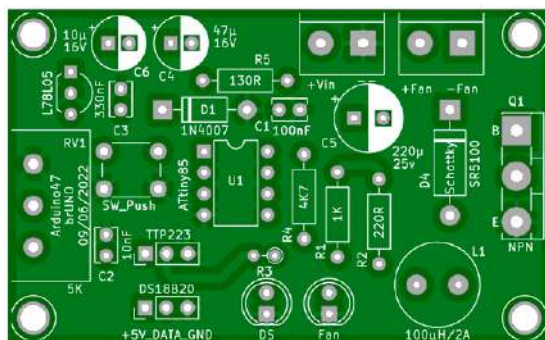


Figure 2: Speed control schematic. To use this circuit as a thermostat, connect a DS18B20 to J3. Also, mount either the TTP223 on J8 or R3/D3, not both.

Figure 3: A design for a printed circuit board (PCB) is available at [3].



- Use an override switch (TTP223) or DS18B20 status LED.
- PWM thresholds `PWM_MIN` and `PWM_MAX`, as well as `PWM_PULSE_UP`, a boost value to ensure that the fan starts spinning when it needs to.
- Temperature range for when a DS18B20 sensor is present, together with a maximum temperature value when the fan should always be at 100%. Temperature values are specified as three-digit integers, e.g. 224 for 22.4 °C. In this version of the software, negative temperature values are not handled. However, it is possible to add this because the sensor works fine below zero.

At startup, the sketch checks whether a DS18B20 sensor is present or not in order to determine the mode of operation: A or B. When no DS18B20 is detected, we are in Mode A. In this mode, the device is a simple manual speed controller with a potentiometer. The speed value (0 to 100%) is obtained from the `map()` function, which maps the analog potentiometer voltage value in the range 0 to 1023 to a PWM range from `PWM_MIN` to `PWM_MAX`. The value of `PWM_MIN` depends on the fan and is the largest value that doesn't make the fan spin. I used 30; I set `PWM_MAX` to 255.

In Mode B, the DS18B20 is present while the potentiometer controls the desired target temperature. The device now functions as a thermostat. The fan will start when the ambient temperature rises above the target value set with the potentiometer. The temperature range is defined in the program by a minimum and maximum value. The `map()` function first maps the potentiometer value to a target temperature within the temperature range. Then, the target temperature value is mapped to a value within the PWM range, as in Mode A.

The software uses the watchdog as a time delay for temperature reading or key reset.

Finally, a few notes on preparing the ATtiny85 for this project:

- Program an Arduino-compatible bootloader on the ATtiny85.
- Run the processor from its internal 16 MHz oscillator.
- Install the ATtiny Boards Package by David Mellis to program the ATtiny85 from within the Arduino IDE.

All the design files, including the PCB (see **Figure 3**), can be downloaded from [3].

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Questions or Comments?

Do you have technical questions or comments about his article? Contact Elektor at editor@elektor.com.

About the Author

Bruno Clerc discovered electronics around age 12, thanks to his older brother. Curious about everything and thirsty for knowledge, he decided to study electronics at Bordeaux. He worked in tertiary low-voltage systems and then aeronautics and various other jobs. When microcontrollers arrived, not knowing programming, he concentrated on the maintenance of vintage hi-fi equipment. All this changed when, some years ago, his brother gave him an Arduino UNO. Bruno found a new passion and became "Arduino47". Today, he thanks the whole Arduino community that helped him advance in his learning.



Related Products

- **W. A. Smith, *Explore ATtiny Microcontrollers using C and Assembly Language*, Elektor, 2021**
<https://elektor.com/20007>
- **Fan SHIM – Active Cooling for Raspberry Pi 4**
<https://elektor.com/19039>

WEB LINKS

- [1] Stephan Laage-Witt, "Keep Cool with an ATtiny," Elektor 7/2017:
<https://elektormagazine.com/magazine/elektor-201707/40518>
- [2] Stuart Cording, "Why Do MOSFETs Need Drivers?" Elektormagazine.com:
<https://elektormagazine.com/articles/why-do-mosfets-need-drivers>
- [3] Project files at Elektor Labs: <https://elektormagazine.com/labs/variateur-for-ventilateur-or-fan>

Turn your ideas into reality!

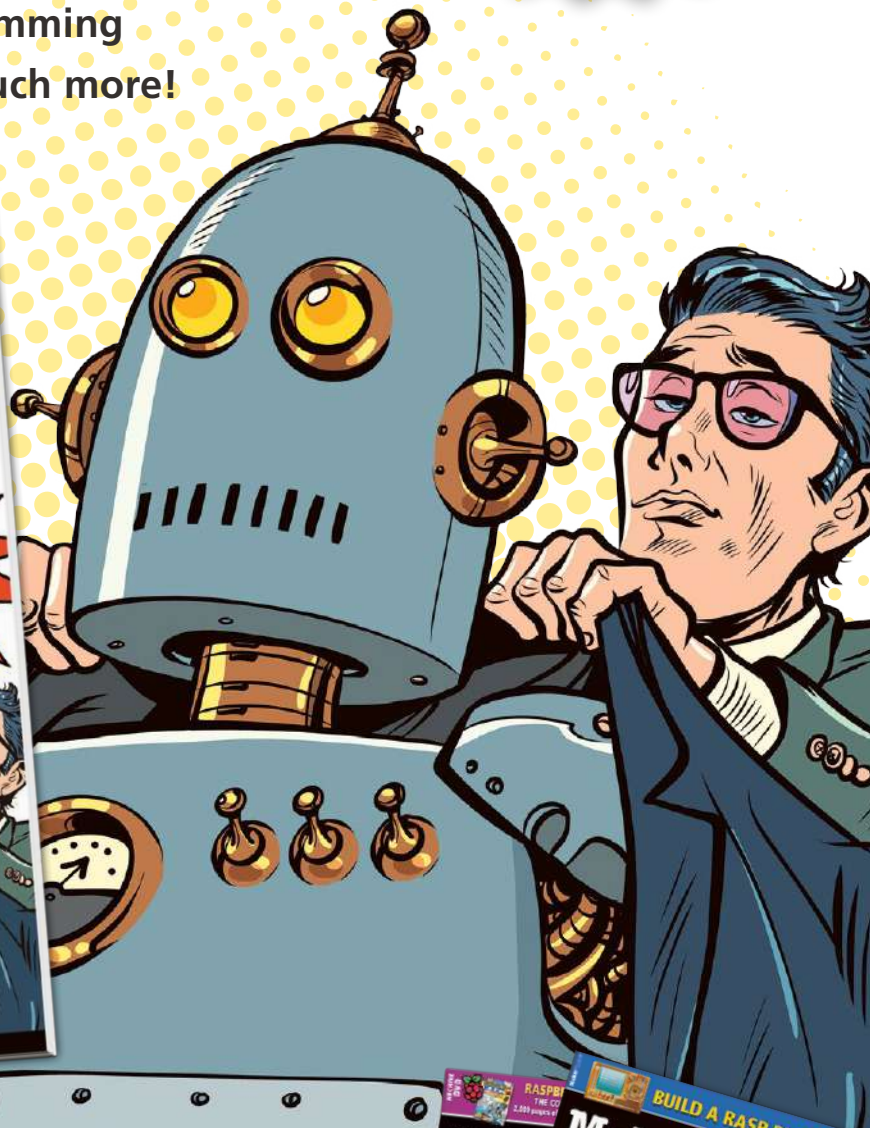
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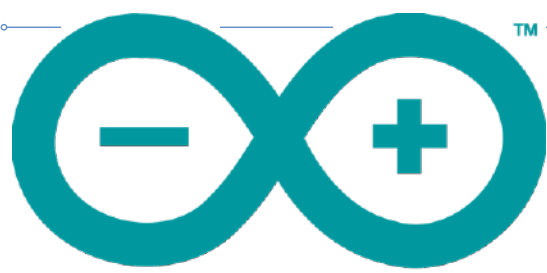
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The latest from ARDUINO Project Hub

New Innovations from the Community

By The Arduino Team

Arduino is a digital platform made of open-source components that's been helping and inspiring engineers, designers, and artists across the globe since 2005. As a platform, Arduino not only has boards, but also IDEs, online tools, and a very appealing cloud service for makers, educators, and professionals. The following projects are just a few examples of what Arduino staffers and community members have created and posted into Project Hub, the official open repository for Arduino projects.



Figure 1: The Bakerino leavening chamber in action.

12

Bakerino Leavening Chamber

Bakerino, made by Flavio Ceresi, won the 2022 Cloudgames Arduino contest. It's a fully functional leavening chamber controlled with Arduino's Oplà kit. In this chamber, illustrated in **Figure 1**, temperature and humidity are controlled through a heating cable, an ultrasonic vaporizer, and a standard DHT21 sensor.

The chamber has an option menu where the user can decide the language and the temperature measurement unit. The menu is simple, and data is saved using the flash storage library to address the memory chip on the Oplà kit. In this case, the Arduino MKR 1010 board is responsible for controlling the system, and connecting to Arduino Cloud. Once the system boots, it will first connect to the Cloud, then it will ask the user for the preferred temperature and humidity. In **Figure 2**, you can see the wiring of the complete system. Upon validation, it will remind us about the need to have water in the chamber's reservoir; otherwise it won't be possible to control the humidity. Once the chamber begins the process, an ultrasonic sensor monitors the distance between the top of the chamber and the dough, which will be used to monitor the size of it and whether it has grown as needed. You'll find the complete project at [1].

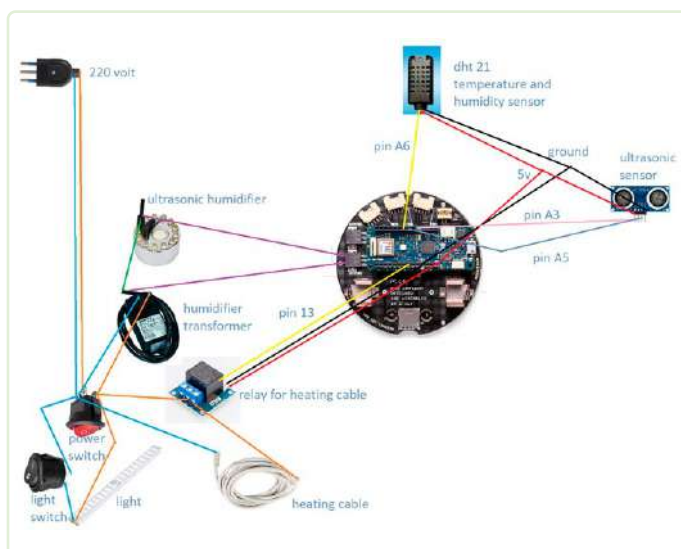


Figure 2: Wiring the Oplà kit to sensors and modules.



Figure 3: The project mounted on the front suspension of a bike. On the top, the servo motor that adjusts the stiffness of the damper.

13 Smart Bike Suspension

Community member @jalls introduces a smart bike suspension system built around the Arduino Nano 33 BLE Sense, a servo motor, a battery charger, and a machine-learning process implemented with Edge Impulse. The project's site describes it as "an automatic suspension adjustment on a bicycle that can understand the character of the terrain and the activities of the rider."

The makers used data from the motion sensor on the Arduino Nano 33 BLE Sense by mounting it on a bike's suspension, shown in **Figure 3**, and using it under different road conditions. The data was cut into 5 seconds and labeled according to the surface variation and activities, to later process it in Edge Impulse Studio through different Neural Network blocks. At that point, the suspension is being controlled by a servo motor that can set the suspension to any of the three available modes: Lock, Medium, Open. **Figure 4** shows the overall wiring diagram, while at the project's webpage [2], you'll have access to all the 3D-printed parts.

The one trick @jalls used in the making of this project is to handle data logging using the Arduino Science Journal app. He connected it to the Nano BLE Sense to capture the data that would later be used to feed the Edge Impulse platform and train the neural network.



Figure 5: Recycle it: The author used a box salvaged from a previous project to host the display and the sensor.

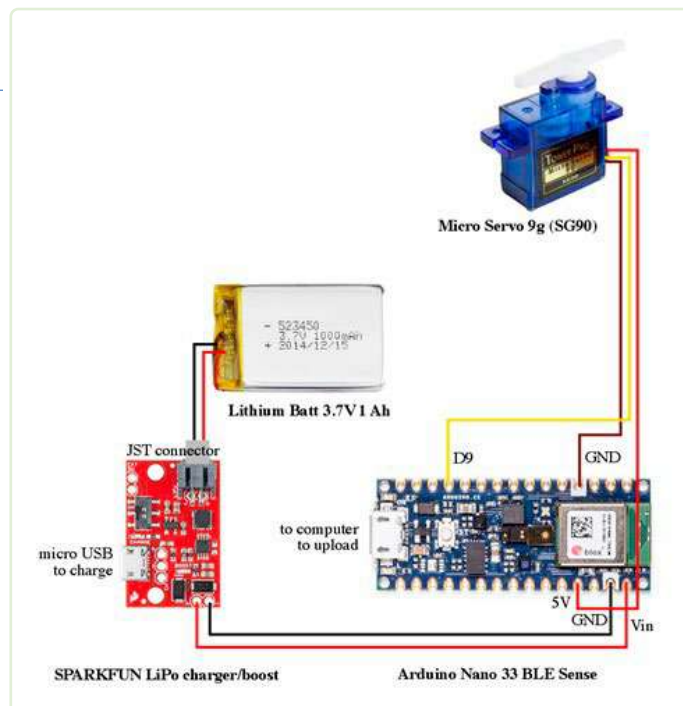


Figure 4: Project wiring diagram.

14 Tachometer with IR Sensor Module

This project, by community member @mircemk, describes how to make a tachometer out of a simple module, a display, and one Arduino Nano. **Figure 5** shows how the maker reused a box from a previous project to host the screen and the sensor, where the button and the light sensor on it have no function. The overall project wiring diagram is shown in **Figure 6**.

A tachometer is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on an analog dial or a digital display. In this project, the tachometer is made using an IR Sensor module as a unit for measuring the number of rotations.

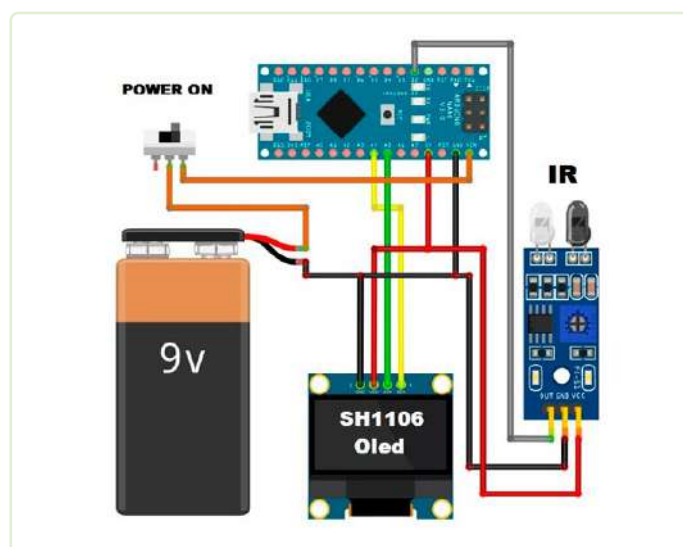


Figure 6: Tachometer wiring diagram.

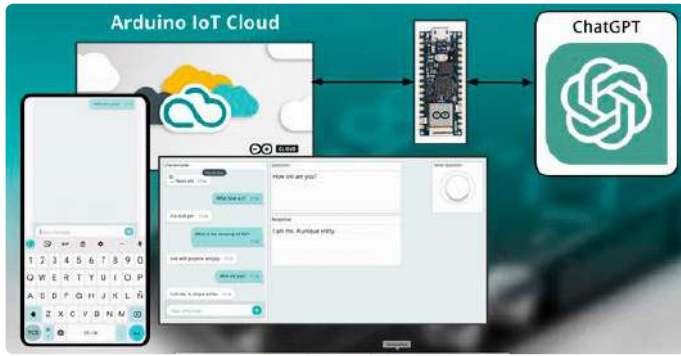


Figure 7: The Arduino Board between ChatGPT and Arduino IoT Cloud.

The sensor module consists of an IR transmitter/receiver pair that can be used for speed measurement of any rotating object. The IR transmitter will send light that, when reflected by the rotating object, is detected by the receiver. Thus, when measuring, you need to place the sensor at a certain distance from the rotating object to ensure the best possible measurement. This distance can be calibrated by the trimmer potentiometer on the IR module. At [3] you'll find the webpage for this project.

15 Chat with ChatGPT through Arduino IoT Cloud

Who has not heard of ChatGPT in the last months? The revolutionary use of Large Language Models has already helped plenty of engineers develop complex projects. We have seen people using this machine learning tool to write code for them, but this project is not about that. David Beamonte, Telecommunications Engineer and Product Manager for Arduino IoT Cloud, helps you get your Arduino board to act as an intermediary between the ChatGPT API and Arduino IoT Cloud, as shown in **Figure 7**.

The project involves using an Arduino IoT Cloud-compatible device, such as an Arduino Nano RP2040 Connect or any ESP32/ESP8266 device, as middleware between IoT Cloud and OpenAI's GPT-3.5 language model. The device receives prompts (questions) from IoT Cloud, sends them to the OpenAI API, receives and parses the replies, and sends them back to IoT Cloud.

To get started, you need to create an OpenAI account, create an API key, and have enough credits. Then, you can create your device on IoT Cloud, program it, and set up the dashboard — also on IoT Cloud. The dashboard allows you to write questions (prompts) and receive ChatGPT's replies. In order to chat, you can access your dashboard using either your browser or the IoT Remote mobile app, as illustrated in **Figure 8**.

In testing, there are two ways to interact with ChatGPT that can be used indistinctly: in the chat window, or using the question-response-send question mechanism. If an error is received, the error code and a description are provided.

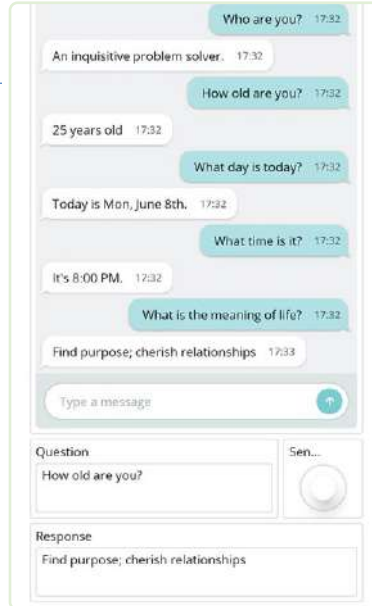


Figure 8: Screenshot of the IoT Remote mobile app.

The complete project at [4] offers some final considerations, such as variable-tweaking, defining the maximum number of tokens that ChatGPT will use in generating a response, and bearing in mind the limits on OpenAI API usage. ◀

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About Arduino

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WEB LINKS

- [1] Bakerino project: <http://bit.ly/3NObBRT>
- [2] Smart Bike Suspension project: <http://bit.ly/3JBnhFa>
- [3] Tachometer with IR Sensor project: <http://bit.ly/44ocLJq>
- [4] Chat with GPT through Arduino IoT Cloud project: <http://bit.ly/3Nz5lfb>

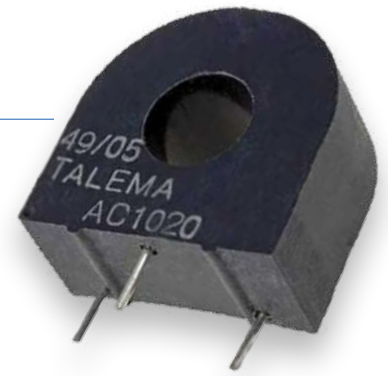


Figure 1: The AC1020 current sensor.
Source: Talema Elektronik GmbH.

16 Power

Overload **Monitor**

Monitor Power Lines for Excessive Current

By Giuseppe La Rosa (Italy)

This circuit measures the power consumption of typical loads such as lamps, household appliances, and heaters. It features an LED bar and an acoustic alarm that warns if an adjustable threshold is exceeded. Loads from 200 W to 6 kW can be monitored.

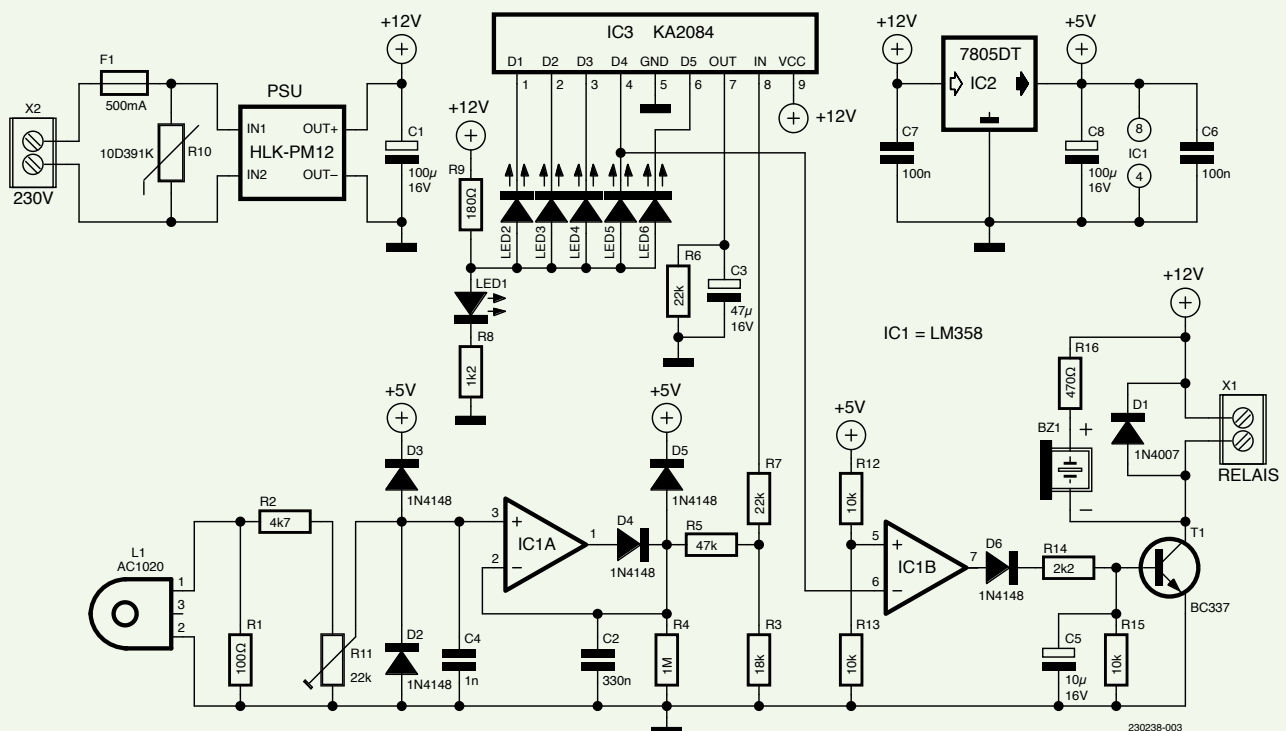


Figure 2: Power Overload Monitor schematic.

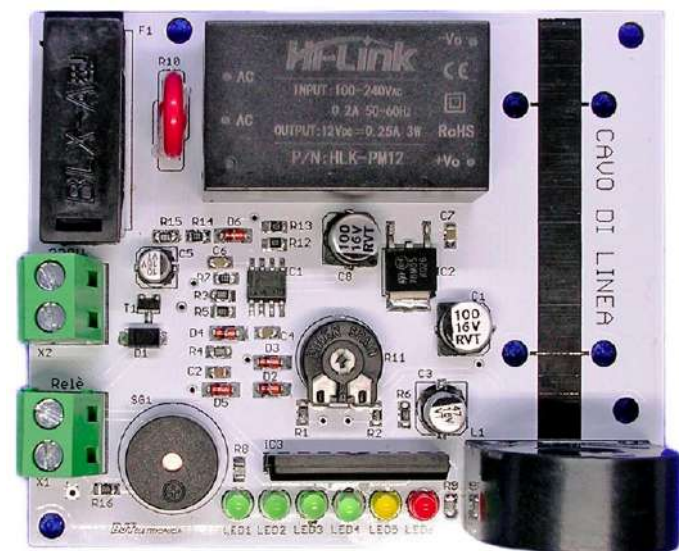


Figure 3: Complete, assembled PCB for my prototype.

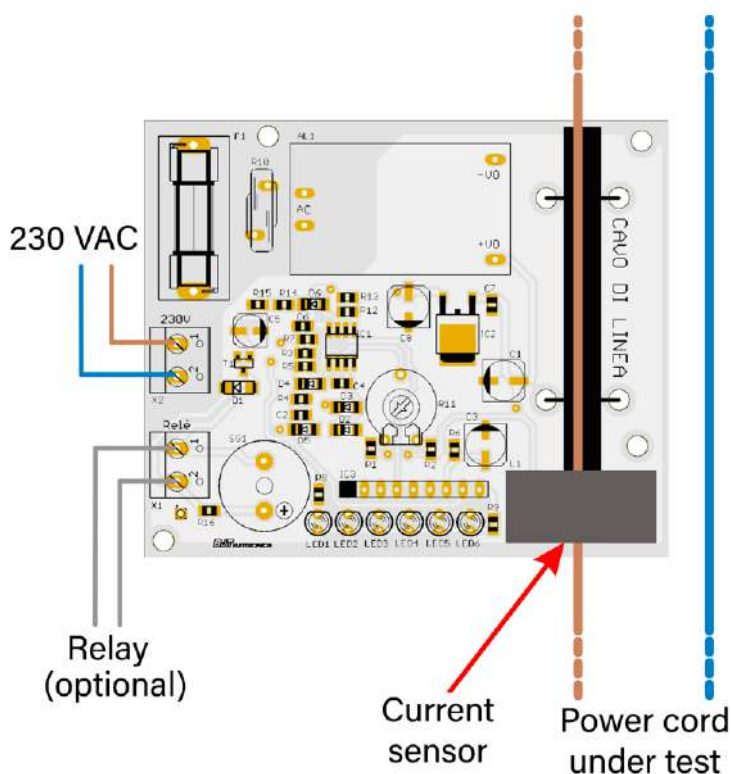


Figure 4: PCB external connections.

Who has never had the experience of suddenly hearing the typical “clack” of a blown fuse in the evening and then suddenly finding themselves in the dark? The reasons are always the same. A washing machine, an oven, a cooker, or an electric hot cooker over the limit were switched on, and then things got a little “too warm” for the fuse. A typical overload situation. A fast-reacting overload monitor can prevent this.

Circuit

For the purpose of monitoring a wire carrying alternating current, a so-called current transformer is used here as a current sensor (**Figure 1**). The wire is simply looped through the hole of the sensor and a voltage proportional to the flowing current can then be tapped at the output. In the circuit of **Figure 2**, L1 takes over this role.

L1 and the rest of the circuit serve to detect alternating currents with a frequency of 50 or 60 Hz, as is customary in power grids. The voltage at the output of the current transformer is galvanically isolated, therefore potential-free and completely harmless. With trimpot R11, you can adjust the sensitivity, and thus the voltage that is processed by the rest of the electronics. D2 and D3 protect the electronics from excessive voltage peaks. IC1A functions as a rectifier in combination with D4. The DC voltage applied to C2 is proportional to the current of the conductor passing through L1. This voltage, reduced by the network made up of R5, R3, and R7, reaches the input of IC3, a driver for an LED bar display consisting of five LEDs.

LED1 lights up as soon as the power supply unit is supplied with voltage and thus functions as a power-on indicator light. The actual bar display consists of three green LEDs (LED2, 3, and 4), one yellow LED (LED5) and one red LED (LED6). LED5 lights up if the set limit value of the current is reached. The level at its cathode is further evaluated and reaches the base of T1 inverted through IC1B. If LED5 lights up, the buzzer switched on by T1 gives alarm. This signal is simultaneously connected to the screw terminals at X1, to which the coil of a 12 V relay can be connected.

Some Notes

The 12 V supply comes directly from the small 12 V power supply unit. Voltage regulator IC2 derives the 5 V supply from that.

To calibrate the alarm threshold, connect a suitably powerful load (such as a toaster or a hair dryer) and run one (and only one) wire of the supply line through L1. Then, set R11 so that the threshold where the buzzer switches on is just barely reached.

I have designed a circuit board for this circuit: **Figure 3** shows the completed prototype, and, in **Figure 4**, you can see how external connections to the board are made. The PCB layouts in **Figure 5** can serve as a template for making your own PCB. These are available for download at [1].

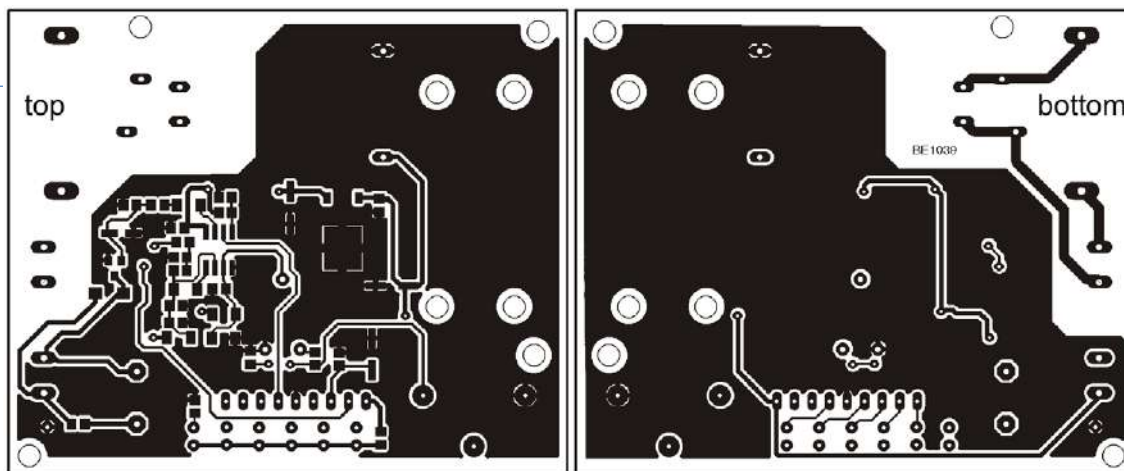


Figure 5: Top and bottom layout.



Component List

Resistors

(SMD 1206 if not otherwise noted)

R1 = 100 Ω

R2 = 4k7

R3 = 18 k

R4 = 1 M

R5 = 47 k

R6, R7 = 22 k

R8 = 1k2

R9 = 180 Ω

R10 = Varistor 10D391K

R11 = 22 k trimpot

R12, R13, R15, = 10 k

R14 = 2k2

R16 = 470 Ω

Capacitors

(SMD 1206 if not otherwise noted)

C1, C8 = 100 μ / 16 V, electrolytic, \varnothing 5 mm

C2 = 330 n

C3 = 47 μ / 16 V, electrolytic, \varnothing 5 mm

C4 = 1 n

C5 = 10 μ / 16 V, electrolytic, \varnothing 3.5 mm

C6, C7 = 100 n

Semiconductors

D1 = 1N4007, DO213AB

D2...D6 = 1N4148, minimelf

T1 = BC337, SOT23

LED1...LED4 = LED, green, 3 mm

LED5 = LED, yellow, 3 mm

LED6 = LED, red, 3 mm

IC1 = LM358, SO8

IC2 = 7805DT, TO252 (DPAK)

IC3 = KA2284, SIP9

Miscellaneous

BUZ1 = Buzzer, Diameter 1/2"

L1 = Current transformer Talema AC1020

X1, X2 = 2 poles screw terminals

F1 = Fuse 500 mA

PSU = PCB Power Supply HLK-PM12

About the Author

Passionate about electricity from an early age, Giuseppe La Rosa graduated in Electronics and Telecommunications at I.T.I.S. of Acireale, Sicily. Later, Giuseppe became involved with microcontroller systems, especially with the PIC series and the Arduino UNO platform. Over the years he has published many projects in electronics magazines. He is currently working on video surveillance, intrusion protection and point-of-sale management software.

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WEB LINKS

[1] Layout download: <https://elektormagazine.com/230238-01>



Blink in the Dark without Transistors

An Oscillator from Simple Two-Lead Passive Components



By Raymond Schouten (The Netherlands)

Is it considered cheating when you make an electronic oscillator that needs light to work? Is it a paradox when this oscillator only works in the dark? Then, is it magic when it requires just five two-terminal parts to build it? Read on and find out.


This circuit uses only four passive components to make an LED flash when it's in the dark. Note that a regular LED is used here, not a blink-chip version. The circuit runs for about two years on two AA batteries and could serve as a warning sign or a "fake" alarm indicator. The supply voltage can be anything from 2.3 V to 6 V.

How Does It Work?

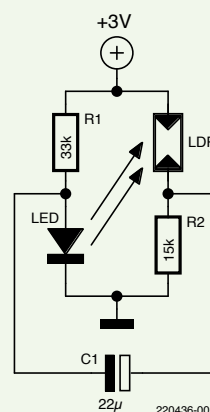
The LED-LDR combination acts as a sort of amplifier. Increasing the LED current (the "input" signal) lowers the LDR resistance, thereby increasing the "output" voltage on the right circuit node. Capacitor C1 then creates positive feedback from the output to the input by having its charging current running into the LED, that is, as long as the output voltage keeps increasing. When the output voltage reaches a maximum, close to the supply voltage, the charging of the capacitor stops, and the LED dims. This causes the LDR resistance to increase, making the output voltage go down. The LED now shuts off completely (via C1 being charged). Resistor R1 drives a small current that slowly makes the LED positively biased again, discharging C1. The LED intensity increases, and the cycle repeats itself.

This type of oscillator is called a relaxation oscillator.

In high ambient light conditions, the LDR remains in a low-resistance state, so the output voltage stays high, and the LED remains at a very low current bias without flashing.

To have enough gain to start the oscillator, a high-intensity LED should be used, facing the LDR within 5 mm. The red LED used in this circuit was a model OVLBR4C7, with an intensity specified as 3700 mcd at 20 mA. When flashing in the dark, enough stray light is left to see the LED flashing clearly, as demonstrated in the demo video accessible on the project page at Elektor Labs [1] or by scanning the QR code shown here. 

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How do these five two-terminal components work together as an oscillator?



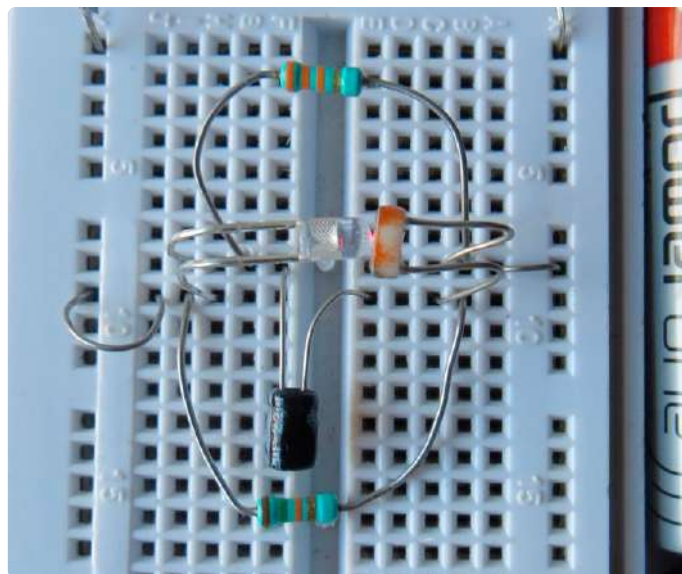
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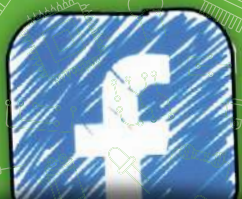


Notice how the LED and LDR are coupled in this breadboard assembly.

WEB LINK

[1] This project at Elektor Labs: <https://elektormagazine.com/labs/blink-in-the-dark-without-transistors-1>

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18 Morse Code Generator

Use It as Beacon or Learning Device!

By Rob van Hest (The Netherlands)

Build a customizable Morse code transmitter project using a tiny microcontroller. Send preprogrammed messages while adjusting speed and pitch — perfect for beacon transmitters or fox hunts.

Most readers will probably know Morse code [1] from the beeps that can be heard on the shortwave bands or in the movies. Some may even have had (the chance) to learn Morse code to transmit and receive messages to obtain a radio license. But why would you still need Morse code nowadays? There are plenty of alternatives.

Indeed, there are. Still, there are reasons to consider using Morse, such as the simple hardware that is required. A Morse code transmitter basically consists of an RF oscillator that is turned on and off by pressing the key. This is a so-called (interrupted) continuous wave (CW) transmitter. The device presented here can drive such a transmitter. You can use it for a beacon transmitter or a fox hunt. However, my original goal was to have people decipher a message coded in Morse.

Hardware

The device's schematic is shown in **Figure 1**. At its heart is IC1, a small PIC12F1840 microcontroller. Pin 2 drives a relay that can control a CW transmitter, for example. Pin 5 is the Morse code audio signal output. Low-pass filter R1/C4 turns this modulated square wave into something more sine-like for a nicer sound. It is also possible to connect a speaker or headphones directly to Pin 5, but you may need a series resistor to limit the current.

The maximum output current is 25 mA; therefore, the impedance must be at least 200 Ω .

Potentiometer R8 lets you adjust the signaling speed, while R7 controls the pitch.

The device can send a preprogrammed message of up to 32 characters at fixed intervals. The MCU's EEPROM can hold up to three of these messages that you can adapt to your own needs (see below). Jumpers JP1 and JP2 determine which one of the three messages will be sent.

Without JP1 and JP2, the generator listens to its serial input on Pin 6, where you can connect the device to a computer to make it convert (or store) the messages you type into a serial terminal program to Morse code.

Software

The associated program can be downloaded from the project page on Elektor Labs [2]. Both the source and the compiled HEX file

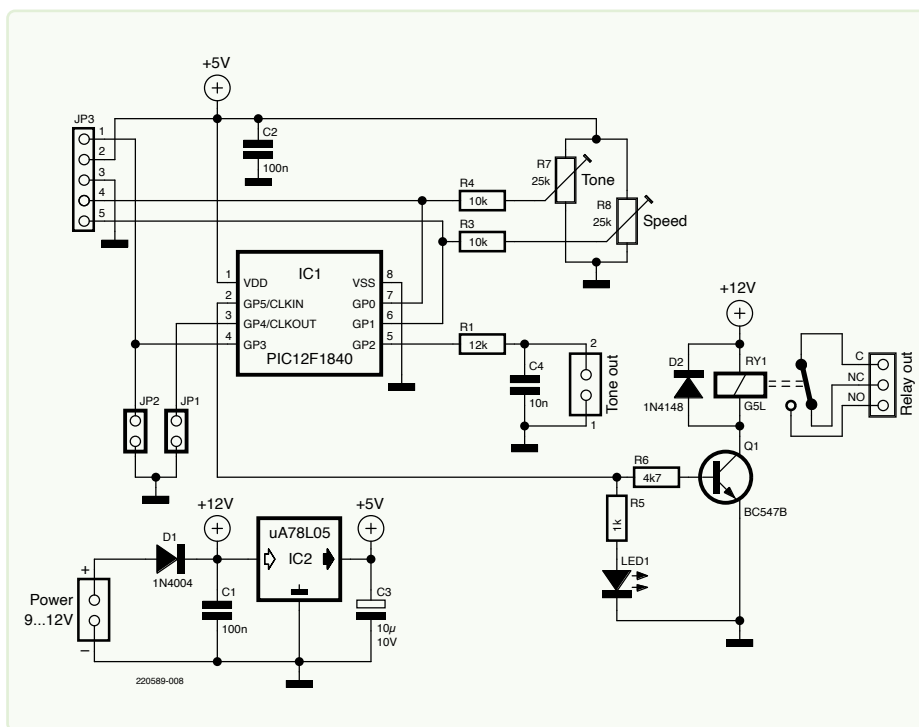


Figure 1: The complete schematic of the Morse Code Generator. It may be simplified depending on how it is being used.

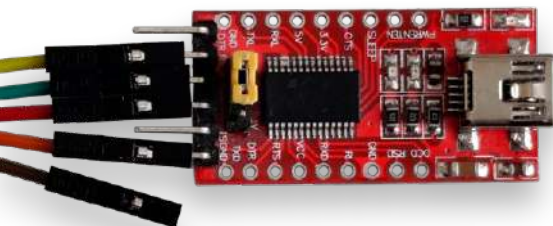


Figure 2: With a USB-to-serial adapter, you can type messages on a computer and use the Morse Code Generator to turn them into Morse code.

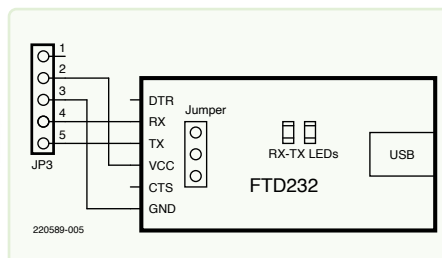


Figure 3: Schematic showing how you connect a USB-to-serial converter to JP3.



Figure 4: The Morse Code Generator built on the author's universal 8-pin PIC project board.

are available there. If you want to modify the program yourself, you will also need the B. Knudsen CC5X C Compiler [3].

While a Microchip PICkit programming interface can be connected to JP3, you can also connect a PC or terminal via a suitable converter. I used an FTD232-type USB-to-serial converter for this purpose (Figure 2). For the wiring diagram, see Figure 3. A terminal program must be running on the PC. I use PuTTY [4] for this, but there are other suitable programs. Choose the virtual serial port that the driver software creates (for me, that was COM6) and set the speed to 9600 baud.

Things such as pitch, speed, and the preset messages can also be configured via the serial port. Type 'H' or '?' in the serial terminal to obtain an overview of the available commands. A more detailed description can be found on the project page [2].

Additional Notes

Even though the signaling speed and pitch are controllable using the two potentiometers, the user-configurable settings stored in EEPROM can also be used for this purpose. To do so, turn R8 to max and reset the device.

Note that the potentiometers do not work when a USB-to-serial device is connected to JP3.

The Morse Code Generator (Figure 4) was constructed on a universal printed circuit board (PCB) [5]. I use this PCB for all sorts of projects with the same type of 8-pin PIC microcontroller.

R4, R7, and R8 may be omitted if they aren't needed. In that case, connect R3 to +5 V. If the PCB from [5] is used, R3 can also be omitted and SJ4 of the PCB (not in the schematic) is bridged.

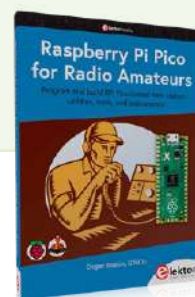
When a USB-to-serial converter is used, a separate power supply is no longer necessary. In that case, the relay must be replaced by a 5 V version. Also bridge the input and output of IC2. Of course, if only the audio output is needed, the relay may be omitted as well. ◀

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Related Products

- ▶ Bert van Dam, *50 PIC Microcontroller Projects (E-book)*
<https://elektor.com/18091>
- ▶ Dogan Ibrahim, *Raspberry Pi Pico for Radio Amateurs*
<https://elektor.com/20041>



WEB LINKS

- [1] Morse code [Wikipedia]: https://en.wikipedia.org/wiki/Morse_code
- [2] Project Files at Elektor Labs: <https://elektormagazine.com/labs/morse-code-generator>
- [3] B. Knudsen Data, CC5X compiler: <https://bknd.com/cc5x>
- [4] PuTTY: <https://putty.org/>
- [5] Universal MCU Printed Circuit Board: <https://elektormagazine.nl/labs/board-for-simple-microcontroller-project>

19

Programmable Video DAC

Handles Any Format up to RGB888



By Mathias Claussen (Design) and Clemens Valens (Text)

When you experiment with microcontrollers and VGA-quality video for retro gaming or some other application, you will need a digital-to-analog converter. This flexible design lets you try out all sorts of video formats before fixing the final resolution.

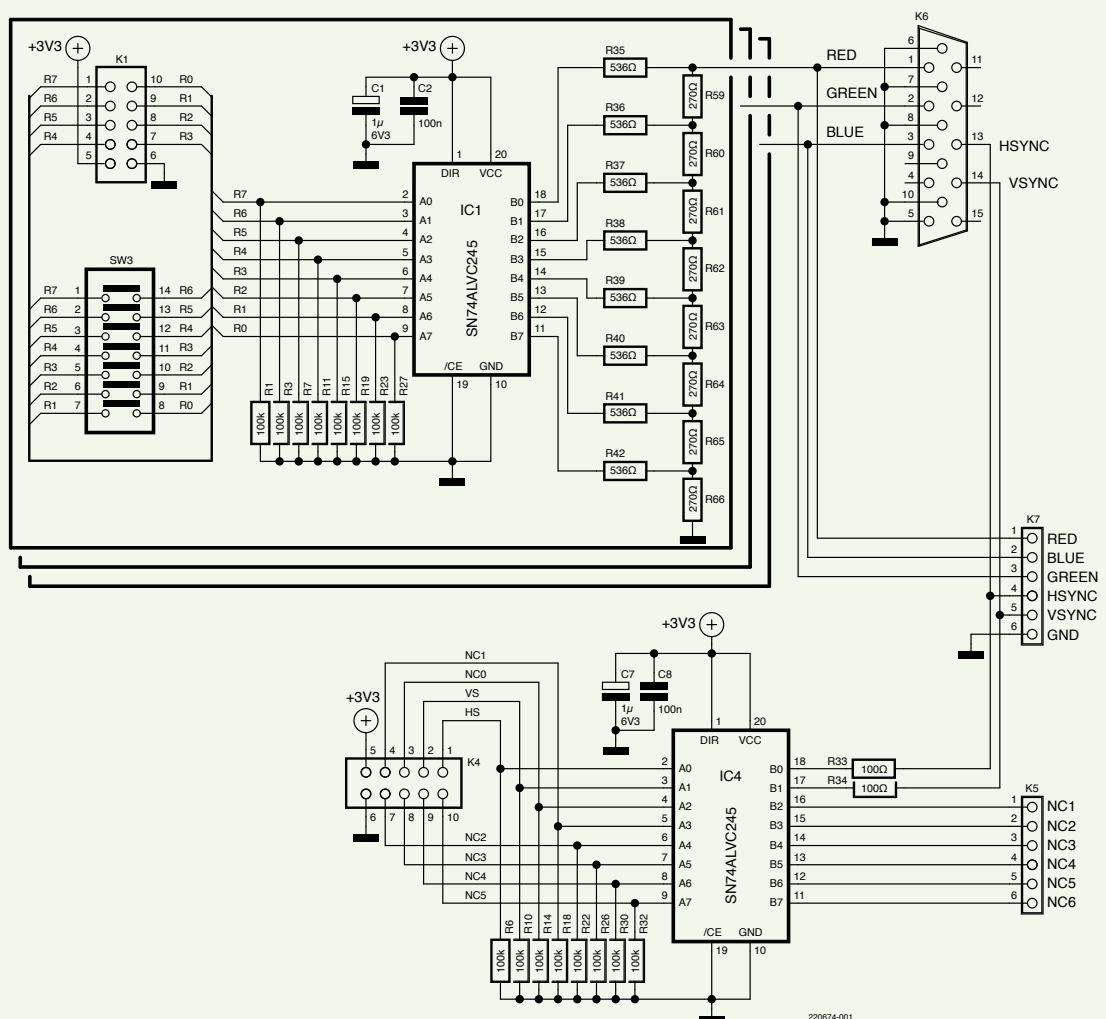


Figure 1: Only one color channel is shown; the two others are identical.

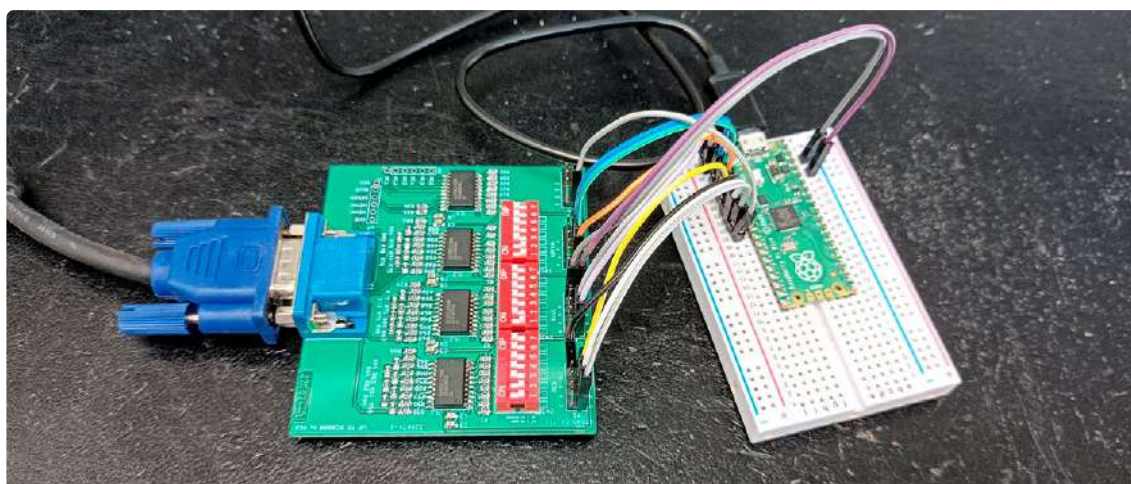


Figure 2: The prototype, in RGB332 mode, driven by a Raspberry Pi Pico.

In the not-so-distant past, if you wanted to add a video output to your computer system, you needed special video ICs. But today, almost any microcontroller can produce a VGA video signal on the fly. The resolution and color depth depend on the amount of available RAM and the speed of the MCU. A simple digital-to-analog converter (DAC) is all that is needed to turn the digital bit streams into analog voltages for the red, green, and blue channels of the VGA monitor.

The DAC's required word width will be determined by the target video signal's resolution and color depth. These two parameters, in turn, depend on the computing resources available in the MCU generating the video signal. What your system is capable of may not be clear at the start of the project, and so you might prefer to start with a narrow-word DAC. On the other hand, when a project is almost done, you may find that there is room left to improve the quality of the video signal. In that case, you would want a DAC with a greater word width.

Circuit

The circuit presented here can be used in both situations, and everything in between. It's a 3-channel video DAC with programmable word width, where each channel can be set up independently of the others. Therefore, it can be used for anything from RGB111 up to RGB888 (8-bit resolution for all colors). Each digit can take on any of the values in the range 1 to 8, e.g. RGB535 and RGB221 are possible video color formats.

The circuit is shown in **Figure 1**. It shows only one color channel (red), as it is the same for each color. The digital video enters at K1 with up to eight bits per channel. The bits are buffered by IC1, which drives an R2R resistor ladder DAC. The DAC output is a video signal in the range from 0 V to 0.7 V. Pull-down resistors at the inputs ensure that unconnected bits are seen as zeroes.

The number of bits per color is set with the SW3 dip switches. For an 8-bit signal, all the switches should be off. To reduce the word width, close the switches starting at the bottom with the one that is labeled R1 and R0. As an example, for a 4-bit word width, close the four lower switches. Connect the bits top-down, i.e., connect the most-significant bit to R7, G7, or B7, respectively, and then work your way down. Doing things this way ensures that the video output can always reach its maximum value (0.7 V) instead of getting weaker.

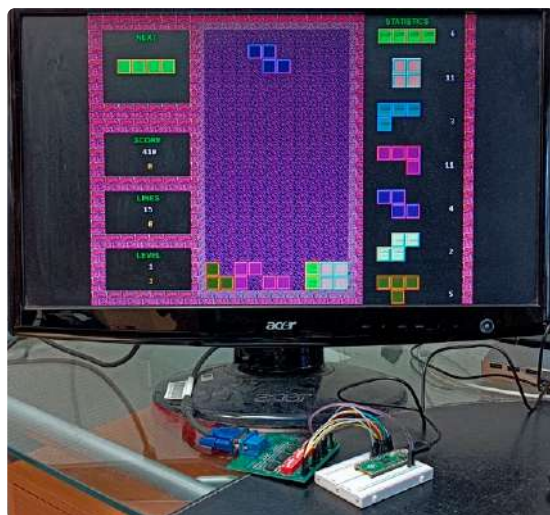
IC4 buffers the horizontal and vertical synchronization signals. The remaining six buffers can be used for something else. They are exposed on K5.

To try out the video DAC quickly without spending hours on programming, connect it to a Raspberry Pi Pico board and a VGA monitor (see **Figure 2** and **Table 1**).

Table 1: Raspberry Pi Pico pin map for the RGB332 video demos from [1].

Raspberry Pi Pico	Signal
GP0	B0
GP1	B1
GP2	G0
GP3	G1
GP4	G2
GP5	R0
GP6	R1
GP7	R2
GP8	HS
3V3	3V3
GND	GND
(GP19)	(Audio)

Figure 3: Watch the Pico play Tetris!



Use HSYNC as a synchronization signal. Download a demo from [1], program it into the Pico and enjoy the graphics (**Figure 3**). The demos on [1] are in RGB332 format. Therefore, you must close the lower five switches for red and green and the lower six switches for blue:

number of switches to close = 8 – word width for color

Some of the demos have sound output on the Pico's GPIO19. Put a 1.5 kΩ resistor in series with the output and add a 10 nF capacitor to ground to create a simple low-pass filter for the audio signal.

The project design files are available on [2].

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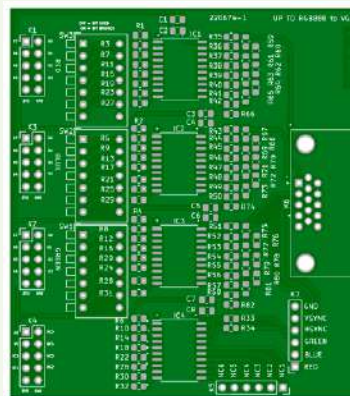
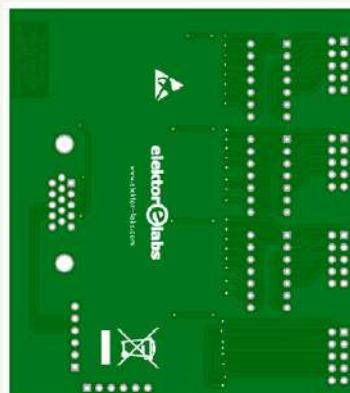


Related Products

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<https://elektor.com/18266>
- > **Raspberry Pi Pico RP2040 H**
<https://elektor.com/20223>



Component List



Resistors (0805)

R1...R32 = 100 kΩ
R33, R34 = 100 Ω
R35...R58, R66, R74, R82 = 536 Ω
R59...R65, R67...R73, R75...R81 = 270 Ω

Capacitors (0805)

C1, C3, C5, C7 = 1 μF
C2, C4, C6, C8 = 100 nF

Semiconductors

IC1, IC2, IC3, IC4 = SN74ALVC245 (SOIC-20W)

Miscellaneous

K1, K2, K3, K4 = 2 row, 10-way pin header (2.54 mm pitch)
K5, K7 = 6-way pin socket (2.54 mm pitch)
K6 = DB15 high-density connector
SW1, SW2, SW3 = 7-way DIP switch (SPST)

WEB LINKS

[1] Example programs: <https://github.com/Panda381/PicoVGA>

[2] Project files at Elektor Labs: <https://elektormagazine.com/labs/up-to-rgb888-to-vga>



20 A T(eeny) Tiny Piano

Without Moving Parts

By Bruno Clerc (France)

There are all sorts of tiny keyboards, pianos and organs based on NE555-type oscillators, Arduino boards, and microcontrollers such as the ATtiny range. This one adds touch keys to the mix, keeping the mechanical side as simple as possible.

After Paolina challenged her dad by demanding “a toy in 48 hours!” I poked around in my lab and found a bag of TTP223 touch button modules and an ATtiny85. Hmm..., I thought, a keyboard printed on paper, which can be placed on any support, means no drilling and no push buttons to manage (see **Figure 1**).

First Try

Using the resistor-ladder-based key string principle, I connected the outputs of a few TTP223 modules in series, sort of, to create a single-wire capacitive keypad. Having found a library for generating musical notes with an ATtiny on the ‘net [1], I wrote down the following specifications:

- The piano must be powered from a (rechargeable) battery.
- Power supply from 3.7 V to 5 V (allowing the use of an 18650-type cell recovered from a PC battery, for example).
- Eight-note keyboard with capacitive keys.
- A Power On/Off key.

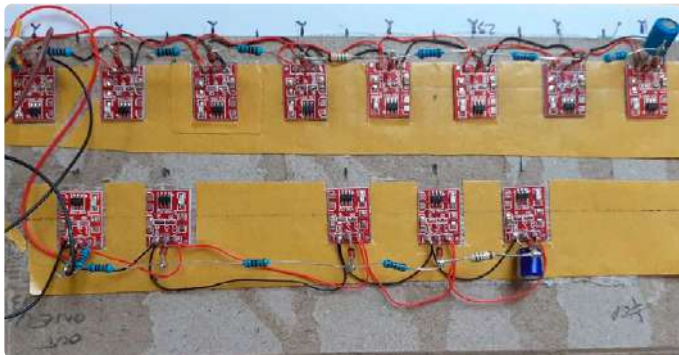


Figure 1: Thanks to the use of TTP223 touch key modules, assembling the musical instrument doesn't require advanced mechanical skills.

The keyboard should have three operating modes:

1. Keyboard mode: the user plays the notes.
2. PlayStore mode: the user can choose different melodies to listen to by touching different keys.
3. Metronome mode: the user's dad can adjust the speed.

After building the keyboard's prototype, it was quickly tested and validated by little fingers and a child's smile. Then, it being the holiday season, I published this project on Elektor Labs [2]. Quickly, I received a comment saying:

“Not bad as doorbell or basic keyboard. However, dividing an octave by 8 does not give a harmonious decomposition of the scale. Dividing by 12, adding the black keys, would be much better. But then, an ATtiny won't do... Happy Holidays!”

To prove the contrary, I added five black keys to the prototype, which resulted in the design below.

The Circuit

There are four analog input channels available in an ATtiny85, three of which were still available on unused pins: ADC0, ADC1 and ADC3. I therefore connected a second string of five touch keys to ADC3 on pin 2. While doing so, I also added a touch key to ADC1 to use as the Octave Transpose key. Everything else remained the same. The complete schematic is shown in **Figure 2**.

The black and white key-strings are read as a voltage using the analog-to-digital converter (ADC). The reference voltage for the ADC is the supply voltage.

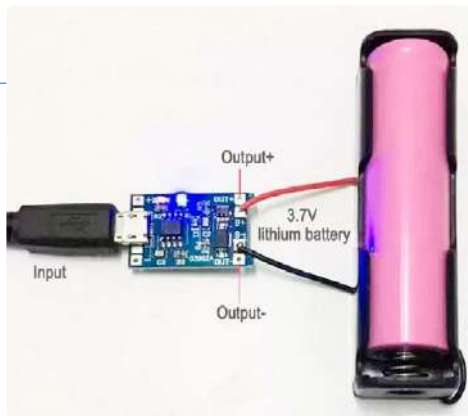


Figure 3: A rechargeable battery with a little charger module attached to it powers the keyboard.



Figure 4: The finished keyboard. The power and Octave Transpose switches are mounted on the side.

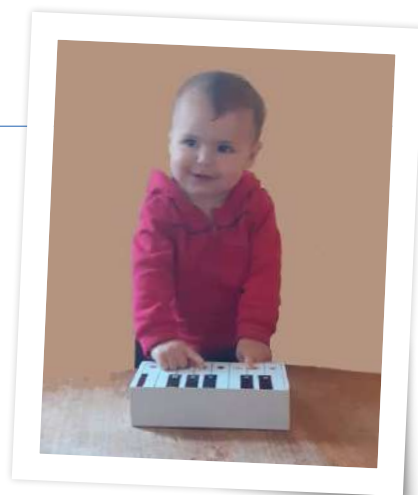


Figure 5: Paolina playing her new piano.

Figure 4 shows the finished instrument. Figure 5 shows how to play it.

Playing the Keyboard

After switching on the keyboard, the user has two seconds (can be changed in the software) to select the operating mode. Pressing the left C (or "Do") selects PlayStore mode; pressing D (or "Re") selects Metronome mode. If no key is pressed during the startup delay, the keyboard enters Keyboard mode. When the delay is over, a short tune indicates that the device is ready to be played.

The Octave Transpose key increases the pitch by one octave.

PlayStore Mode

In PlayStore mode, the white keys select one of seven possible melodies hard-coded in the program. Currently, only four melodies are defined; you can add three more yourself. Of course, you can also modify the four predefined melodies.

Pressing the right C key exits PlayStore mode to return to Keyboard mode.

The Octave Transpose key has no function in this mode.

Metronome Mode

In Metronome mode, the black keys control the tempo (in beats per minute, bpm):

- > C# - Start
- > D# - Pause
- > F# - Tempo -10 bpm (minimum is 20 bpm)
- > G# - Return to default values (120 bpm and default pitch)
- > A# - Tempo +10 bpm (maximum is 250 bpm)

The white keys select the pitch of the click sound. Pressing the right C key exits Metronome mode to return to Keyboard mode.

The Octave Transpose key functions normally in this mode.

Last Notes

The ATtiny85 is programmed from within the Arduino IDE. For this, you'll need to install the Boards Package from D. A. Mellis [3] and the TinyTone library from [1]. An Arduino UNO can be used to program the sketch into the MCU. All the design files can be found at [4].

Enjoy! ◀

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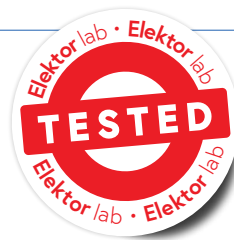


Related Products

- > **W. A. Smith**, *Explore ATtiny Microcontrollers using C and Assembly Language*, **Elektor**, 2021
<https://elektor.com/20007>
- > **Phambili Newt 2.7" IoT Display (powered by ESP32-S2)**
<https://elektor.com/20230>

WEB LINKS

- [1] TinyTone library: <http://technoblogy.com/show?KVO>
- [2] The 8-key keyboard at Elektor Labs:
<https://elektormagazine.com/labs/tiny-piano-8-notes-tow-modes-keyboard-capacitive-keys-one-wire>
- [3] ATtiny Boards Package for Arduino IDE:
https://raw.githubusercontent.com/damellis/attiny/ide-1.6.x-boards-manager/package_damellis_attiny_index.json
- [4] Project files at Elektor Labs: <https://elektormagazine.com/labs/piano-one-octave-with-attiny85>



21 Dual Dice Without an MCU

Dual Dice on a Single PCB — Plus Some Design Tricks

By Mathias Claußen (Germany)

This is an extended version of the circuit “Dice without MCU” from Elektor’s 2022 Circuit Special [1]. The circuit has been recreated, and some small extensions added. Also, some tricks in board construction are worth mentioning.

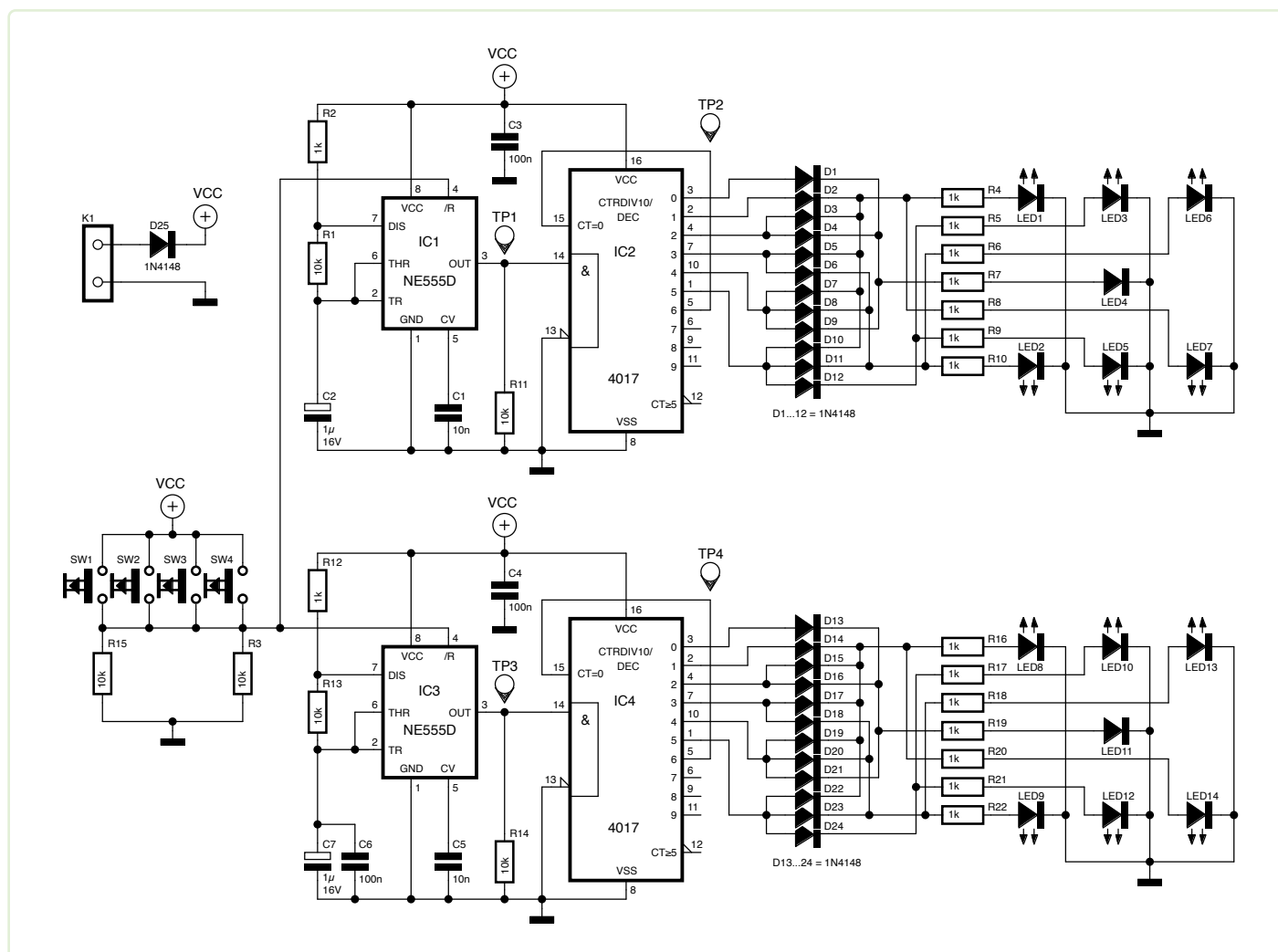


Figure 1: The schematic of the double dice.

This dual dice is a variation on one of the so-called classic circuits. It uses the good old NE555 in combination with the 4017 decade counter and some LEDs (and other diodes).

The Circuit

The principle of operation is simple. A clock generator in the form of an NE555 (IC1, IC3) supplies a clock signal per die to a 4017 decade counter (a.k.a. Johnson or ring counter (IC2, IC4)). As long as the clock signal is present (i.e., when a pushbutton is being pressed), the 4017 counts up. Because output Q6 is connected to the reset pin of the 4017, the counter restarts every time as Q6 goes high. Therefore, the counter can only count to six before starting over, perfect for a single die.

With no button pressed, the two 555s (**Figure 1**) are held in reset (pulled to ground) with 10 kΩ resistors R3 and R15. Pushbuttons SW1 through SW4 connect the reset input of IC1 and IC3 to VCC, allowing them to provide a clock signal for the 4017s.

The capacitors that determine the clock frequency are not the same for the two dice. The 100 nF capacitor C6 reduces the output frequency of IC3 by 10% to about 63 Hz (compared to the 70 Hz of IC1). This improves the independence of the dice. Test points TP2 and TP4 allow checking the output frequency of the two timer ICs.

The LEDs

The seven LEDs of each die are arranged on the top side of the board to represent the die's dots. Some are wired in parallel so that any die pattern from 1 to 6 can be represented (**Figure 2**). The schematic in Figure 1 shows how the corresponding LED groups for the six possible die faces have been logically OR-ed with diodes.

Compared to the original version in [1], the following changes have been made:

- Some lessons have been learned from the first version of the dice, and the circuit and PCB have been improved.
- Doubling the dice makes it suitable for many family games.
- Every LED has a 1N4148 diode in series. This was not the case in the previous version of the circuit and resulted in brightness differences when operated at 5 V (not so noticeable at 9 V).
- Finally, the reset lines now have a pull-down resistor to prevent unwanted rolling.

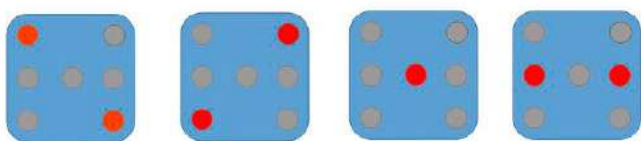
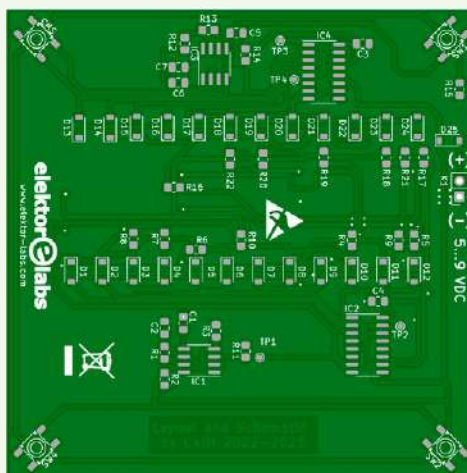
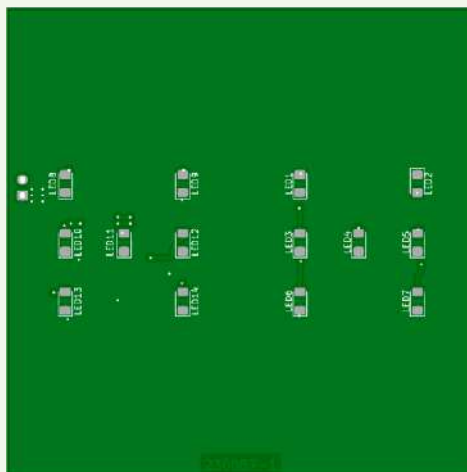


Figure 2: All six die values can be shown with a few LEDs in parallel.



Component List



Resistors:

(0.25 W, 5%, SMD 0805)
 R1,R3,R11,R13..R15 = 10 kΩ
 R2,R4..R10,R12,R16..R22 = 1 kΩ

Capacitors:

(SMD 0805)
 C1,C5 = 10 nF, 16 V
 C2,C7 = 1 μF, 16 V
 C3,C4,C6 = 100 nF, 16 V

Semiconductors:

D1..D25, = 1N4148, SOD-123
 LED1..LED14 = LED, red, SMD 1206
 IC1,IC3 = NE555D, SOIC8
 IC2,IC4 = CD4017, SOIC16-NARROW

Miscellaneous:

K1 = 9V Battery Clip
 SW1..SW4 = push button switch (PTS647SK70SMTR2L)

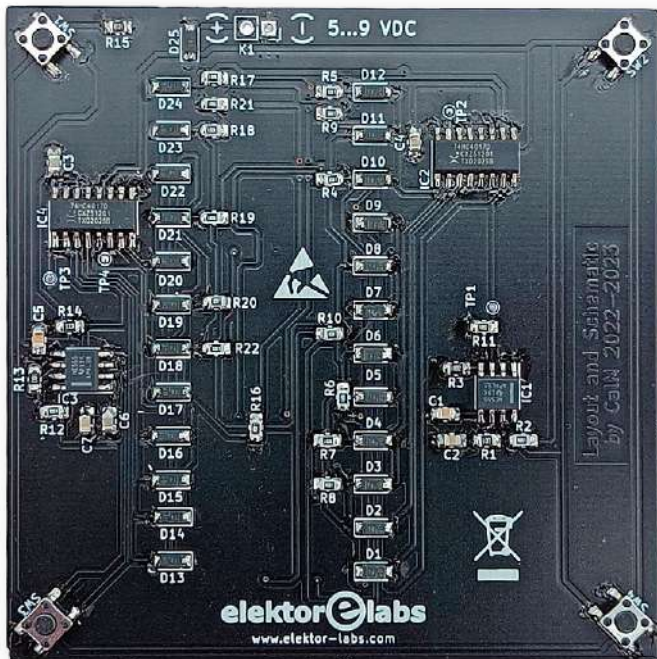


Figure 3: Even though it is all SMD, there is enough space for comfortably assembling the dice.

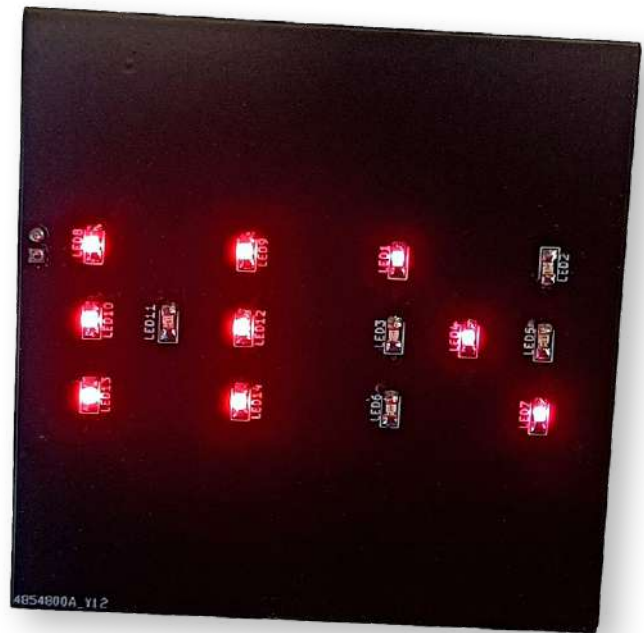


Figure 4: *Alea iacta est!* ("The die is cast!")

About the PCB

Only the LEDs are mounted on the top side of the board; all the other parts are hidden underneath. This gives the dice a clean look from the top and provides protection for the circuit itself. Even though the components are SMD types, there is plenty of space in between them. This makes soldering easier and allows SMD newbies to populate the board without encountering too many difficulties (Figure 3).

The board can be powered with between 5 V and 9 V from a small power supply or battery. D25 protects the circuit in case of reverse polarity.

The PCB design files (in KiCAD 6 format) can be found at this article's webpage [2].

Roll the Dice

The four pushbuttons on the board serve as feet for the dice. To roll the dice, simply place the board on its feet and press it somewhere (in a corner or in the middle, pressing on the side may make the board jump up a bit).

The circuit is simple, and the components are cheap. Therefore, this project can serve as an — hopefully fun — SMD soldering exercise. And, just like last time, the Latin saying, *Alea iacta est*, applies (Figure 4). ◀

230087-01

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Related Products

- > **2-in-1 SMD Hot Air Rework Station ZD-8922**
<https://elektor.com/20141>
- > **PeakTech 3710 R/C-Pen Meter for SMD**
<https://elektor.com/19319>

WEB LINKS

- [1] Mathias Claussen, "Electronic Cubes without an MCU," Elektor Circuit Special 2022:
<https://elektormagazine.com/magazine/elektor-261/60699>
- [2] Project files: <https://elektormagazine.com/230087-01>



Electronic Scarecrow

By Burkhard Kainka (Germany)

Looking for a friendly way to scare away annoying birds? Here's a simple do-it-yourself electronic solution.

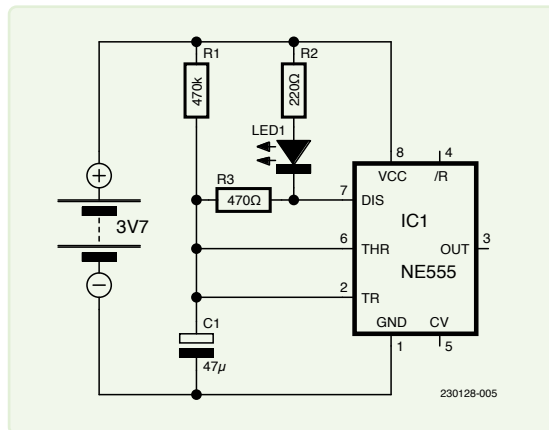


Figure 1: The timer module makes the LED flash twice per minute.

If pigeons want to build a nest very close to the bedroom window, they incur the wrath of even the world's best wife because they simply make too much noise and dirt. Breeding is allowed, but somewhere else, please. I offered my support and wanted to try an electronic scarecrow. A green LED was supposed to flash brightly twice a minute. I first built the circuit with an NE555 (Figure 1) on a breadboard (Figure 2) and then modified it until the result was convincing.

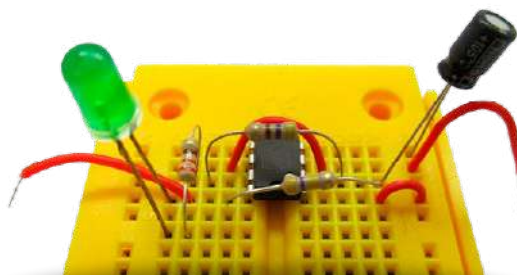


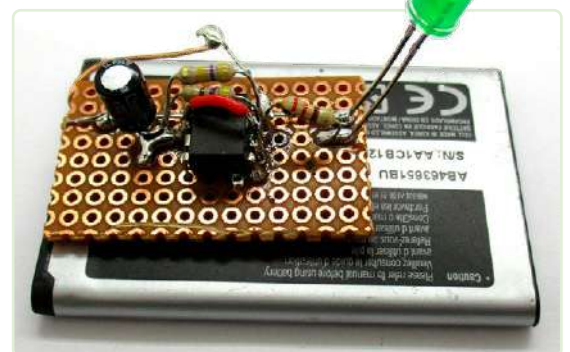
Figure 2: Test setup.

Everything was then placed on a grid-style PCB in my proven style. The bottom side remained flat so that it could easily be placed on the lithium battery (Figure 3). With a power consumption of less than 1 mA, the battery should last around 500 hours, long enough for the pigeons to find a new nesting site. One risk remained, however: It was unknown whether the animals would be impressed by the light flashes.

The result after a few days: The pigeons have built a nest in a higher tree at a distance of 15 m. It is still unclear though whether the light flashes were effective. Perhaps it was rather the measures taken by the world's best wife: She built a competition nest from longer sticks, which the pigeons likely perceived as the work of a very big and very messy bird — reason enough to stay at a safe distance! ◀

Translated by Jörg Starkmuth — 230128-01

Figure 3: Grid-style PCB and battery.



Circuits to Amuse, Inspire, and Amaze



More projects and products
from SparkFun!



By Rob Reynolds (SparkFun)

Since 2003, SparkFun has been helping students, engineers, and even rocket scientists take their ideas from concept to completion. From blinking the first LEDs to sending the first UAV to Mars, SparkFun has been instrumental in helping thousands of people see their project ideas come to life. Here's a look at some recent SparkFun user projects, from the fairly simple to the wonderfully ridiculous.

23

Rethinking a Classic

When starting out in engineering, one of the best ways to learn is to take a known circuit and make adjustments to it. Let's face it, the very first thing that most of us did when we started working with the Arduino platform was to take the *Blink* sketch, read through it until we could understand it completely, and then alter the frequency at which the LED blinks. In this example, Instructables user jebeandiah uses the SparkFun Inventor's Kit [1] to reimagine the classic balance bot (**Figure 1**), but without the use of an inertial measurement unit (IMU).

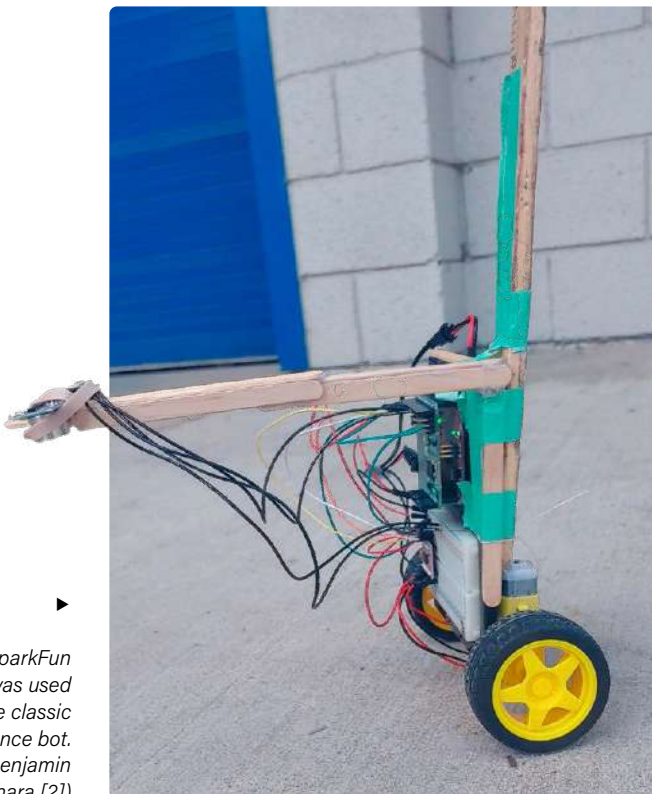
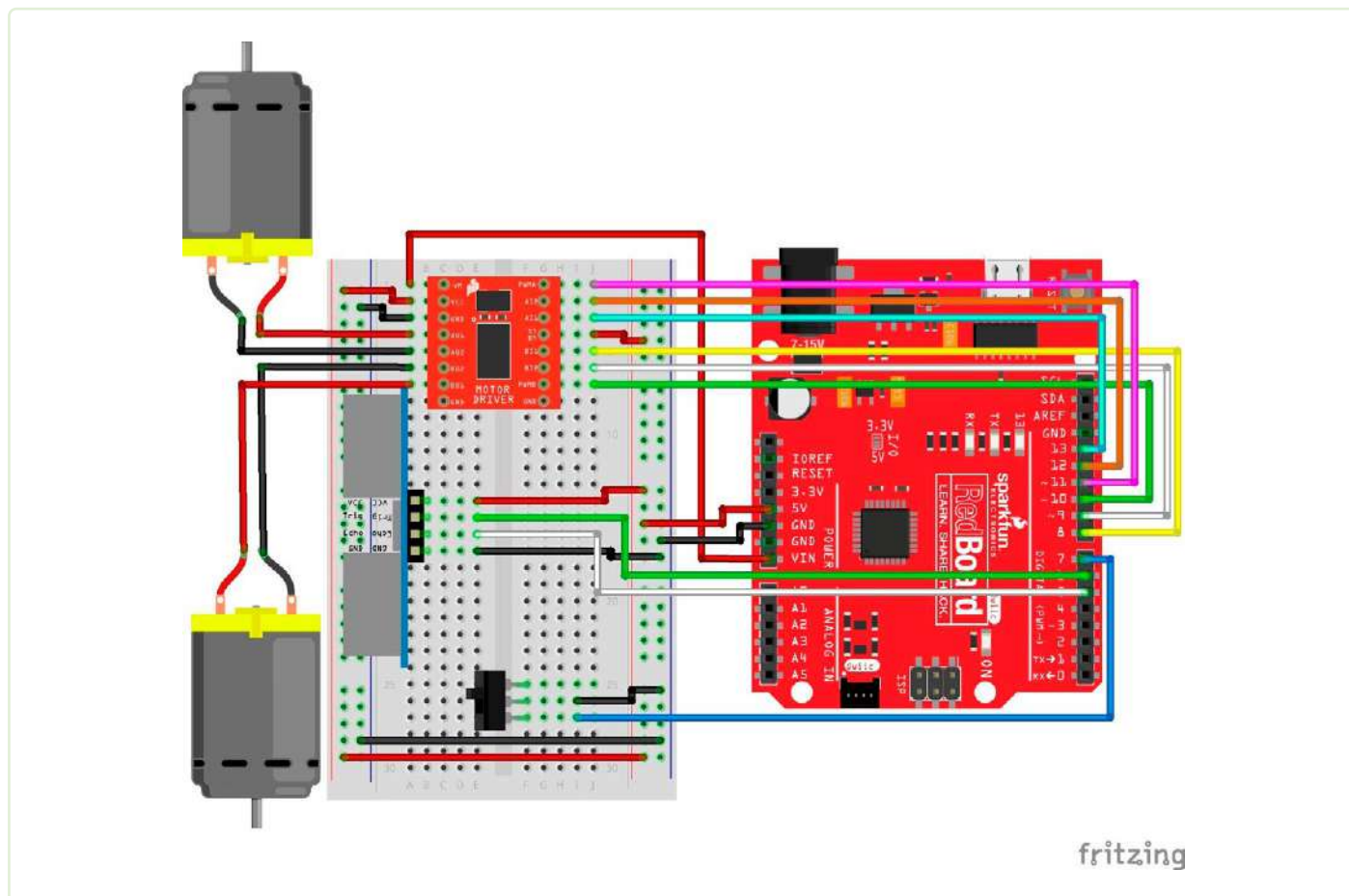


Figure 1: The SparkFun Inventor's Kit was used to reimagine the classic balance bot.
(Source: Benjamin Lertwachara [2])



This very interesting take on the standard balancing bot uses an ultrasonic distance sensor on the end of an arm — okay, a stick — to measure and maintain an established distance from the floor [2]. The circuit itself is basically identical to the circuit used in Example 5C of the SparkFun Inventor's Kit Hookup Guide. The only changes are to connect the motor controller's VIN and GND directly to the battery pack, and to create, by either soldering or using jumper wires, a way to extend the distance sensor away from the breadboard (**Figure 2**).

The exciting, or interesting, or tricky part, depending on how you see it, comes in the sketch, where the designer here implements a PID loop. The PID (Proportional-Integral-Derivative) algorithm is a closed-loop control mechanism that continually calculates an error value, or deviation value, and constantly adjusts to correct it. In this instance, it works to keep the ultrasonic distance sensor at a constant distance from the ground. Take a look at the sketch — it's very well written and notated.

24 Mapping the Unmappable

Sometimes, you don't want to take the time to create the circuit that best fits your needs because your main goal is to use that circuit or project to collect data, distribute information, or perhaps even both. With the recent surge in interest in global positioning boards and projects, SparkFun found that more and more users wanted a GNSS module that was as close to a turnkey solution as possible. They also wanted, and even expected, a level of accuracy beyond what had been capable at a maker level. The answer came in the form of a series of GPS-RTK modules, with options ranging from the SparkFun GPS-RTK Board NEO-M8P-2 [3], which required the user to do all of the work to create a working project, including adding an antenna, to the SparkFun RTK Facet L-Band [4], a fully enclosed, fully functioning global positioning unit that requires no coding on the user's part to get up and running.

When searching for a GNSS solution, most people want high accuracy, low cost, and portability. Of course, the

Figure 2: The BalanceBot Fritzing diagram. (Source: Benjamin Lertwachara [2])

Figure 3: Mapping in the mountains.
(Source: SparkFun)



DataLogger IoT 9DoF

Taking the idea of being able to collect, store, and transmit data with minimal to no code writing, SparkFun has recently released the DataLogger IoT 9DoF, a data logging board that automatically detects, configures, and starts logging information not only from its onboard IMU, but also from almost 50 of SparkFun's Qwiic-connected sensor boards. It is built around the ESP32, which allows it to log to a variety of network IoT platforms (currently supported services include MQTT, Amazon AWS IoT, Microsoft Azure, Mathworks ThingSpeak, and URL-HTTP), and provides log outputs in CSV or JSON.

<https://sparkfun.com/products/20594>



Figure 4: RTK accuracy.
(Source: SparkFun)

answer to this search was always: "Choose two, but you can't have all three." However, when French caver Eric Sibert was looking for just such a solution for mapping everything from city streets to French caves, he turned to SparkFun, and the SparkFun GPS-RTK2 Board with the ZED-F9P GNSS module from u-blox (**Figure 3**). By utilizing the full features of the board, especially Real Time Kinematics, Sibert is able to get millimeter accuracy when recording his location [5].

The accuracy of these boards derives from the fact that they are able to receive positional data not just from four separate satellite constellations (GPS, GLONASS, Galileo, and BeiDou), but they can also receive correction data from a fixed base, or, in some cases, even a cellphone (**Figure 4**). Sibert has spent his life mapping caves not only throughout France, but also in Madagascar, where he helped lead the team exploring and mapping the Marosakabe Cave System in Madagascar, the longest known cave in Africa.



A Clock Made of Clocks

Some projects are more complex than others. This next project, called The ClockClock (**Figure 5**), is complex not only in its construction, but also in the coding language that it uses. It uses the Alchitry AU FPGA Development Board. [6] FPGA stands for Field Programmable Gate Array, and these devices are part of a class of devices known as programmable logic. Basically, an FPGA doesn't do anything itself, but it can be configured to be just about

Figure 5:
The ClockClock project.
(Source: SparkFun)

any digital circuit you need. You simply load a configuration into the FPGA, and it starts behaving like the circuit you wanted. Now, I say simply, but that may be a bit misleading. Programming for FPGAs has a fairly steep learning curve, but, once mastered, opens a world of possibilities without the need for soldering or jumper wires.

Justin, the creator of this amazing project, as well as the creator of the Alchitry FPGA boards, used 48 stepper motors with their accompanying stepper motor drivers, along with the Alchitry Au board, a SparkFun Redboard Turbo [8], a Real Time Clock board, and a handful of buttons and Qwiic cables. He also did some beautiful woodworking to create a project as beautiful as it is functionally impressive, along with quite a bit of custom-designed 3D printing (**Figure 6**).

As difficult and as time-consuming as this project looks, Justin admits that it turned out to be even more work than he originally anticipated. He says that the most time-consuming parts were the physical build and the wiring, while the coding turned out to be fairly easy. Of course, as an Electrical and Electronics Engineer, I would expect that. On the other hand, I, with a background more in mechanical engineering, and having worked with FPGA boards, am quite certain that I probably wouldn't describe the coding part of the project as "fairly easy." However you look at it, this is a truly impressive project.

26

A Payphone Like No Other

Have you ever wanted to create a project simply for the sheer joy of it? Not because it serves a useful purpose, or because it's something that makes sense to build, but just because it seems so ridiculous that you simply can't help but see if you can build it. That's what SparkFun founder Nathan Seidle decided to do with his HA-JOKES Payphone Project (**Figure 7**). [9] He went all in, too, buying a complete public payphone (with pedestal), and finding an existing concrete pad in Boulder, Colorado, on which to mount it.

There aren't a lot of us out here that would be capable of making a project like this happen, but Nathan's electrical engineering skills, combined with his amazing sense of humor and whimsy, made this the perfect project for him. He wanted the phone to actually work like a payphone, but he was very cavalier with charges. For five, 10, or 25 cents (your choice), you could call anywhere, even internationally.

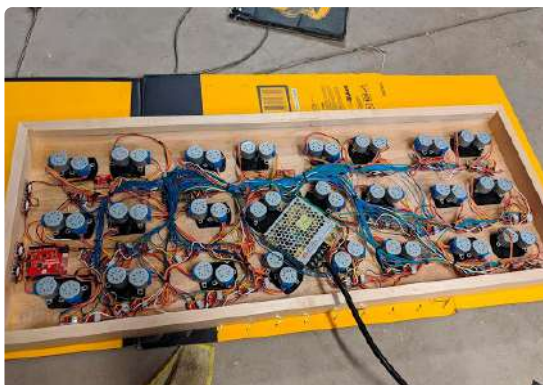
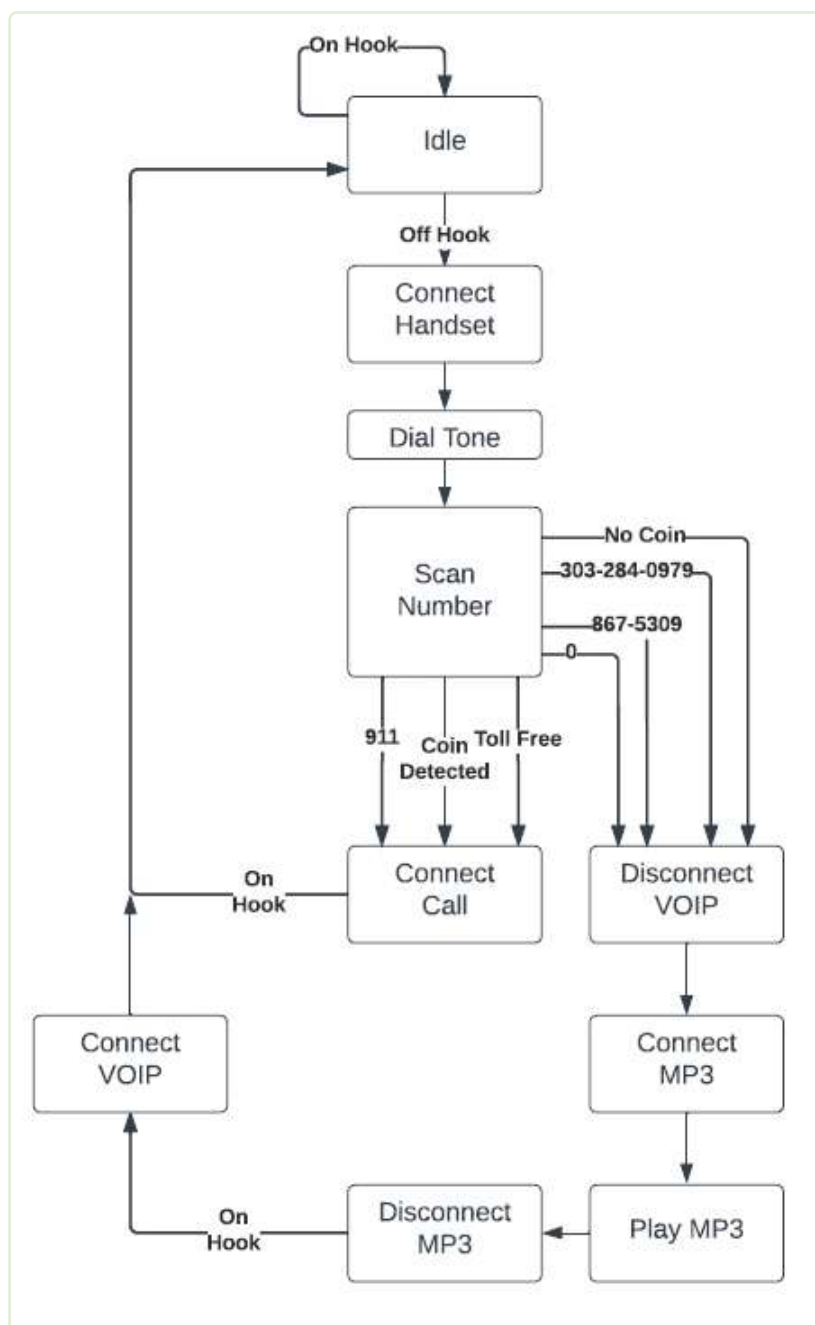


Figure 6:
The back of the
ClockClock.
(Source: SparkFun)



Figure 7: The SparkFun
Payphone project.
(Source: SparkFun)



◀ Figure 8: The SparkFun Pay Phone state diagram.
(Source: SparkFun)

Of course, there are a number of toll-free numbers and toll-free area codes in the United States, so those had to be dialable without the need for any coins at all (Figure 8).

The Payphone Project was a huge success, and Nathan went into great detail describing and explaining the entire build process in an extensive blog post on SparkFun's website. The next time you see a payphone, maybe give it a second look. ◀

230357-01

About the Author

Rob Reynolds (@thingsrobmade) has been at SparkFun since 2015, and in the role of Creative Technologist for the past five years. With an extensive background in the arts, his experience helps him to create projects, tutorials, and videos that are usually as entertaining and amusing as they are informative.



Related Products

- **SparkFun Inventor's Kit v4.1**
<https://elektor.com/19618>
- **SparkFun GPS-RTK-SMA Breakout - ZED-F9P (Qwiic)**
<https://elektor.com/19650>
- **Alchitry Au FPGA Development Board (Xilinx Artix 7)**
<https://elektor.com/19641>
- **SparkFun DataLogger IoT (9DoF)**
<https://elektor.com/20487>

WEB LINKS

- [1] SparkFun Inventor's Kit: <https://sparkfun.com/products/15267>
- [2] jebeandiah, "SparkFun Inventor Balancing Robot (No Gyroscope)," Instructables, April 19, 2023: <https://bit.ly/3MfxHe4>
- [3] SparkFun GPS-RTK Board - NEO-M8P-2 (Qwiic): <https://sparkfun.com/products/15005>
- [4] SparkFun RTK Facet L-Band: <https://sparkfun.com/products/20000>
- [5] SparkFun, "Caving with RTK": https://sparkfun.com/caving_with_rtk
- [6] Alchitry AU FPGA Development Board: <https://sparkfun.com/products/16497>
- [7] Alchitry, "The ClockClock Project": <https://learn.sparkfun.com/tutorials/the-clockclock-project/all>
- [8] SparkFun Redboard Turbo: <https://sparkfun.com/products/14812>
- [9] N. Seidle, "The 970-HA-JOKES Payphone Project": <https://learn.sparkfun.com/tutorials/the-970-ha-jokes-payphone-project>

27 LC-LP-HA Thermometer

Accurate Measurements and a Binary Display

By Walter Ribbert (Italy)

With the accurate readings of a DS18B20 1-Wire sensor, this project will not just show your exact room temperature, but also train you to read binary thanks to its binary-coded display.

The acronym LC-LP-HA stands for: **L**ow **C**ost, **L**ow **P**ower, **H**igh **A**ccuracy: a very challenging task! The recent energy crisis has led us to keep a closer eye on the temperature in our homes. To do so we must be able to measure this parameter with adequate accuracy, but the cost of a good, certified, thermometer is not negli-

gible. I personally tried to make measurements using no less than five different commercial thermometers — mercury, alcohol, and electronic — and I obtained five values that differed from each other by as much as two degrees. I found a solution by examining the data sheet of the well-known DS18B20 [1], currently manufactured by Analog Devices (formerly by Maxim and even earlier by Dallas Semiconductor). This device has an accuracy of $\pm 0.5^\circ\text{C}$ (see the chart in **Figure 1**) in the measurement range of -10°C to $+85^\circ\text{C}$, which is very good.

Quite interestingly, it is very difficult to find a commercial thermometer with such accuracy, but, on the other hand, we need a microcontroller to read the temperature measured by the sensor. Although not so straightfor-

Figure 1: DS18B20 typical performance curve (Source: Analog Devices [1]).

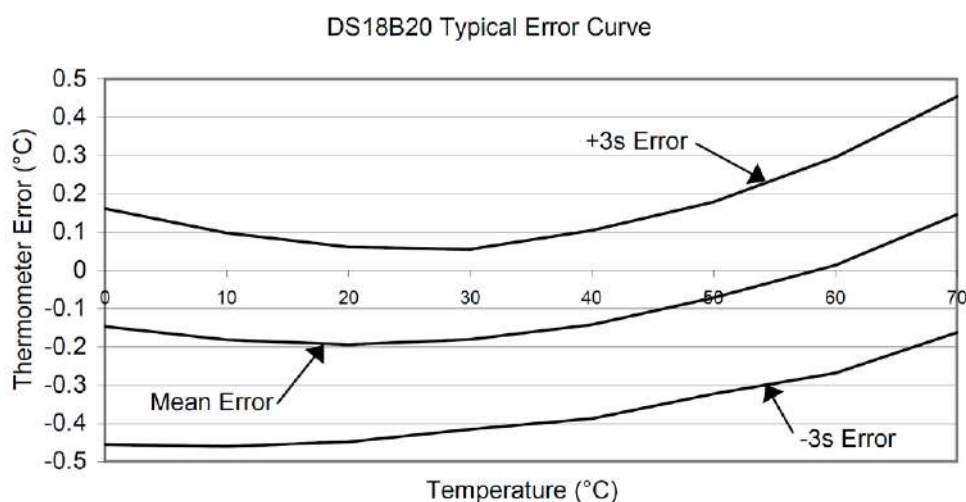


Figure 2: Schematic diagram of the binary-display thermometer.

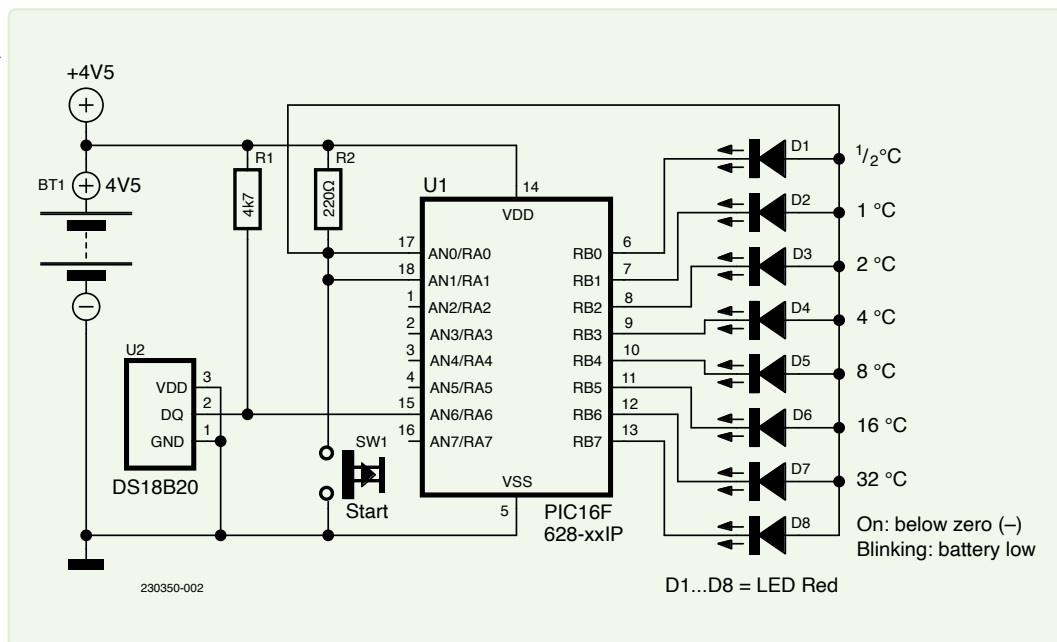
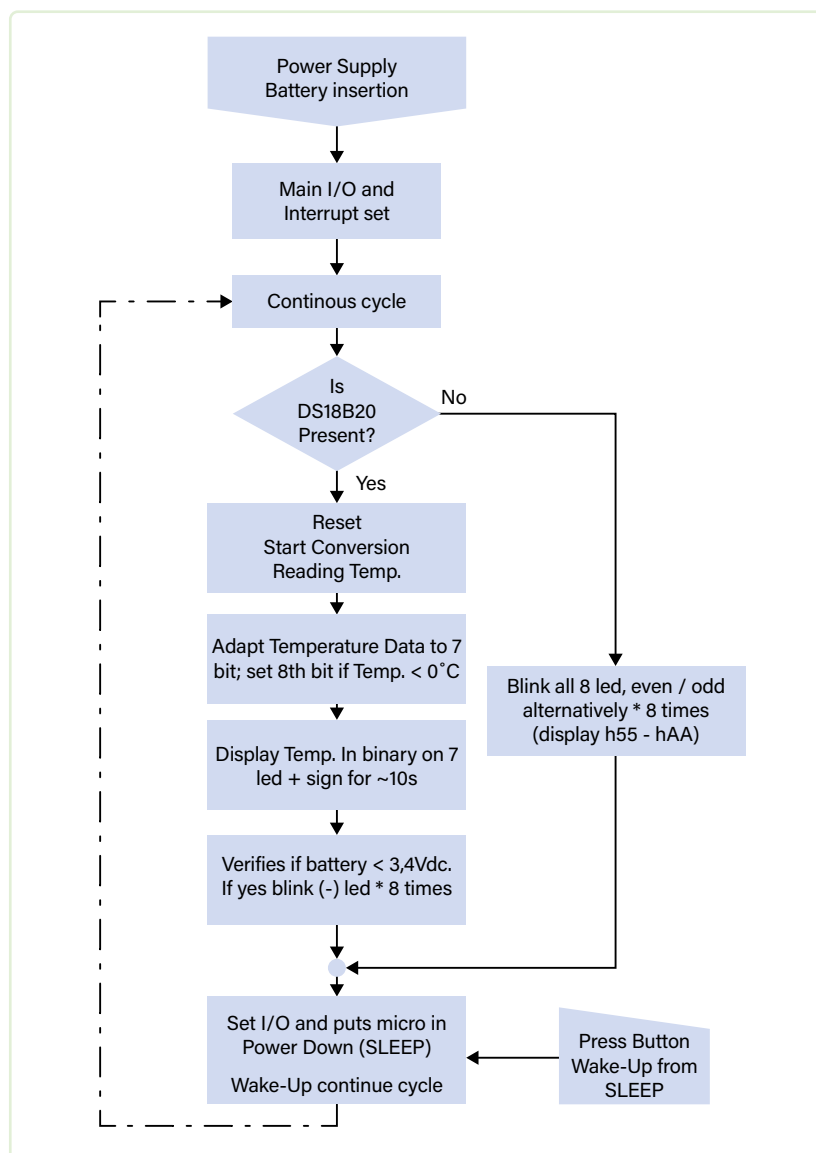


Figure 3: Software flow diagram.



ward, the reading and display process is quite simple and does not require calibration or compensation because it is completely digital. Having found the component that satisfies the last part of the acronym (HA), a circuit that meets the other two criteria (LC-LP) is needed. The circuit in **Figure 2**, along with its firmware [2], does.

Circuit Diagram

The number of components is limited: Besides the sensor, there's a Microchip Technology PIC16LF628 micro, eight red/orange LEDs, two resistors, and a pushbutton. The DS18B20 is connected in "parasite" power configuration to reduce consumption — the 4.7 kΩ resistor, R1, acts as a "feed" resistor to provide the phantom supply, while a 220 Ω resistor (R2) acts as a pull-up.

Normally, the microcontroller is in Power Down (sleep) state. The wake-up is controlled by pushbutton SW1, which generates an interrupt by changing the state of pins RB4...RB7 (these pins drive the LEDs, but, in Power Down state, they are configured as inputs). After the readout, the temperature is displayed for about 10 s on the seven LEDs, D1...D7, in binary format with exponential weighting from 0.5°C to 32°C. The temperature value is obtained by summing the binary value of the LEDs that are lit. If the temperature is negative, LED D8 also lights up.

Software

The diagram of **Figure 3** shows the program flow (written in C with Microchip's XC8). If the DS18B20 sensor does not work or is not connected and does not respond during verification, the temperature will not be displayed, and the eight LEDs will flash alternately.

This is because the sensor may be installed remotely and/or connected only at the time of measurement.

After the temperature reading, the battery voltage is checked. The circuit operates from 3 V to 5 V and the PCB is designed to accommodate a battery holder for 3×AAA 1.5 V cells (4.5 V supply) on the back, which can be applied with double-sided adhesive tape. The battery control threshold is set at approximately 3.4 V. During the temperature display, the PIC's internal comparators read the LED knee voltage (approximately 1.9 V) via pins AN0...AN1 and compare it with the battery voltage using the internal resistive divider normally used to generate reference voltage V_{ref} from the VDD supply. If the battery voltage is low, LED D8 flashes.

Power Consumption

Since the PIC's clock reference is its internal oscillator, there is no need for a quartz crystal. There's no power switch either, given the circuit's very low power consumption. During temperature measurement and display (for about 10 s) the current consumption is around 15 mA, while in Power Down it drops to less than 300 μ A. If you shield the LEDs from ambient light, the current drops to 30 to 40 μ A, which is roughly the sum of the values given in the PIC and DS18B20 data sheets for Power Down mode. This is probably due to the LEDs' photoelectric effect.

A PCB is shown in **Figure 4**. The files (and the software) can be found in the downloadable Zip file on this article's webpage [2].

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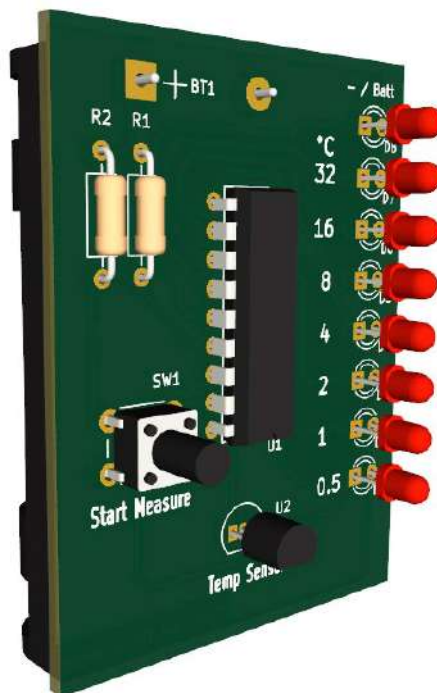
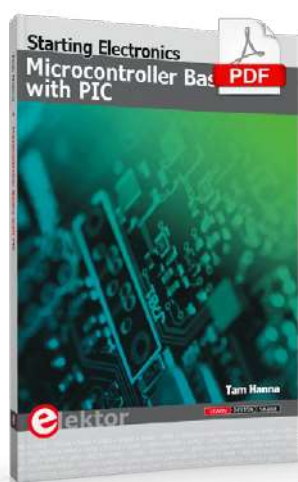


Figure 4: A rendered 3D view of the PCB.

Questions or Comments?

Do you have any technical questions or comments about this article? Contact the author at w.ribbert@elettronicaemaker.it or the Elektor team at editor@elektor.com.



Related Product

> Tam Hanna, *Microcontroller Basics with PIC* (E-book)
<https://elektor.com/19189>

WEB LINKS

[1] DS18B20 Datasheet: <https://analog.com/media/en/technical-documentation/data-sheets/DS18B20.pdf>

[2] Software and PCB files for download: <https://elektormagazine.com/230350-01>

28 THD Generator

Generating Distortion on Purpose

By Alfred Rosenkränzer (Germany)

For a change, this circuit is not about avoiding distortion, but instead about intentionally generating distortion. It can be useful for checking a test setup or for listening tests. The circuit is entirely passive and very simple.

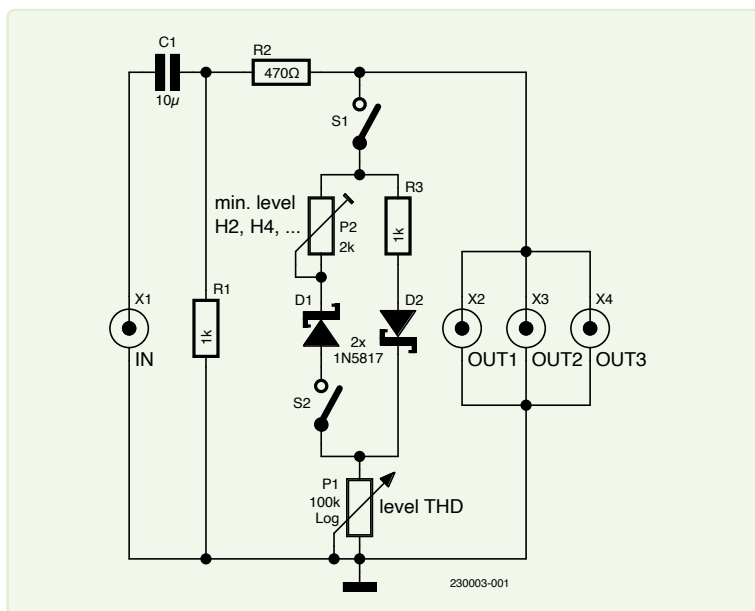


Figure 1: The circuit of the THD generator is very simple and almost self-explanatory.

When developing audio amplifiers, we normally try to build circuits with the least possible distortion — with the exception of guitar amplifiers. A good example of this is the latest power amplifier published in Elektor magazine, the Fortissimo-100 [1], which features a total harmonic distortion (THD) of only about -100 dBc at virtually full load. In contrast, the circuit described here is intended for generating adjustable harmonic distortion. It can be used, for example, to check whether a test setup for measuring distortion actually works the way it should. You can also use it to find out the relative distortion level, where you actually notice changes in the sound.

In this regard, I can remark that my personal listening test was disillusioning. Depending on the frequency, I was only able to hear distortion at -40 to -50 dB. Consider yourself warned: Most likely I'm not the only one to overestimate their hearing capacity in this regard.

The Circuit

The purely passive circuit shown in **Figure 1** is easy to explain. The input signal, which is usually a sine wave with the least possible distortion, is connected to jack X1. The signal level should be around $2 V_{pp}$ at minimum. Any DC signal components are removed by C1

and R1. A good-quality film capacitor should be used for C1.

Resistor R2 is part of a voltage divider whose other part is made up of R3, P2, D1, D2, and P1. The second part can be completely disabled by S1. The two diodes generate harmonics of the input signal, and their amplitudes can be adjusted with P1. If you use Schottky diodes, the circuit can work with a lower input signal level than if you use ordinary silicon diodes.

The signal is symmetrically limited when S2 is closed, which leads primarily to the generation of odd harmonics (harmonics that are odd multiples of the input frequency, such as the third and fifth harmonics). P2 can be adjusted to compensate for differences between the two diodes to minimize the amplitudes of the even harmonics (second harmonic, fourth harmonic, etc.). Of course, this only works properly if the distortion level is sufficiently high or P1 is set to a very low resistance. When S2 is open, the circuit generates both even and odd harmonics.

Use

The output signal is available on the three parallel output connectors, X2—X4. It's useful to have three outputs because this allows, for example, a spectrum analyzer to be connected in parallel with an amplifier to measure the distortion present at the amplifier inputs.

The procedure for a listening test is as follows: Connect an audio spectrum analyzer to one output, so you can measure the distortion level, and use the other two outputs to drive an amplifier or a headphone amplifier, either stereo or dual mono, that is connected to loudspeakers or to headphones, respectively. Headphones have better acoustical properties, so they are generally preferable for a listening test.

Close S1 and set P1 for maximum distortion (least resistance). After the previously

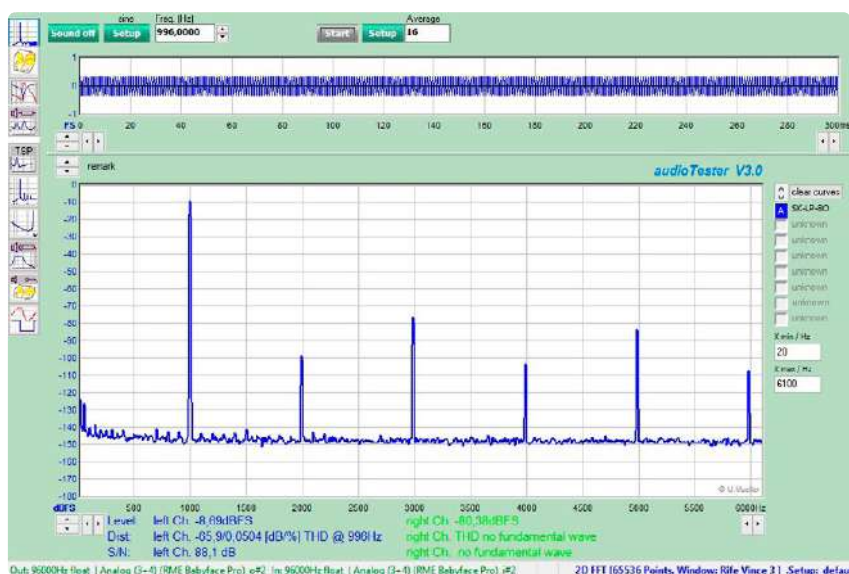


Figure 2: The spectrum with S2 closed corresponds to that of a limited sine wave signal. The even harmonics can be adjusted to a minimum level with trim pot P2.

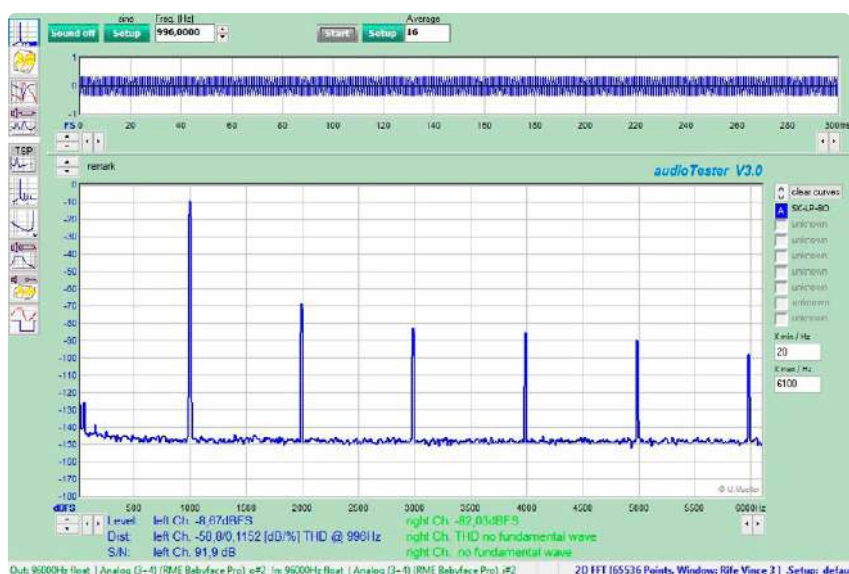


Figure 3: The spectrum with S2 open shows a series of harmonics with successively decreasing amplitude.

with the two diodes and the three resistors, can simply be soldered between the jacks and potentiometer P1. **Figure 4** shows what my finished prototype looks like. I salvaged the block with the four RCA (cinch) jacks from an old device. ◀

Translated by Kenneth Cox — 230003-01

About the Author

Alfred Rosenkränzer worked for many years as a development engineer, initially in the field of professional television equipment. Since the late 1990s, he has been developing high-speed digital and analog circuits for IC testers. Audio is his personal hobby.

Questions or Comments?

If you have technical questions or comments about this article, feel free to contact the author by email at alfred_rosenkraenzer@gmx.de or the Elektor editorial team at editor@elektor.com.



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described adjustment with P2, there should be a distinctly audible difference between switch S1's open and closed positions. Now, gradually increase the value of P1 to the point where the distortion becomes barely inaudible. Then, read the distortion level (THD) from the spectrum analyzer.

You can repeat this listening test at different frequencies and with S2 open to create a table of readings. **Figures 2** and **3** show the signal spectra with S2 open and closed, respectively. Of course, you can also repeat the test with a music signal, but the results will only be quali-

tative because there's not much point in using a spectrum analyzer to make measurements with non-sinusoidal signals.

The THD generator can also be put to good use in comparing the measurement results of different spectrum analyzers.

Construction

Since the circuit has so few components, it can be built without a circuit board using point-to-point wiring and fitted in a small plastic enclosure. If you use components with wire leads, the capacitor and the trim pot, together



Figure 4: The author's prototype: The inputs and outputs, along with the two switches and the potentiometer for adjusting the distortion level, are located on the top.

WEB LINKS

[1] Ton Giesberts, "Fortissimo-100 High-End Amplifier," Elektor 11-12/2022: <https://elektormagazine.com/magazine/elektor-280/61057>

29

Thyristor-Based Overtemperature Indicator

Electronic Components Used Unconventionally

By Raymond Schouten (The Netherlands)

This circuit indicates when the temperature of an object has become too high. The thyristor is attached to the object to be monitored. If the object becomes too hot even once, the thyristor switches and an LED lights up until the circuit is reset.

This circuit uses a thyristor that acts as a combined sensor, switch, and memory. Interestingly, only three resistors and one LED are needed for this. The circuit can be used for the applications described below, and at the same time shows alternative use of common components.

The thyristor should be mounted with direct thermal contact to the object to be monitored, such as a heat sink, for example, by using its mounting hole for fixing. If the object now exceeds the set temperature, the thyristor switches on and lights an LED, which remains lit until a reset is performed. In this way, it can still be determined later that the object temperature has become too high at least once.

The reset can be performed by briefly interrupting the supply voltage or by pressing a normally-closed pushbutton connected in series with the LED.

Concept

The gate of a thyristor has a diode-like structure (p-n junction between gate and cathode). The voltage drop across a diode is known to decrease as the temperature increases. Therefore, the threshold voltage of a thyristor, which triggers switching, decreases when the temperature increases. If one now applies a fixed, constant voltage to the gate with a level at which the thyristor does not switch through at room temperature, it will only switch at a correspondingly higher temperature.

The detection temperature of the overtemperature indicator can be adjusted by the values of the two gate resistors and/or the voltage supplied to this voltage divider. Of course, this simple circuit is not very accurate. You can easily be off by 10°C, but, in many cases, this is enough for it to function as a thermal overload indicator for, say, a power amplifier etc.

If you let the thyristor switch a relay with an opening contact, the arrangement could act as a protection circuit that shuts off too large a load. With the values given in **Figure 1**, the LED switches at about 50°C.

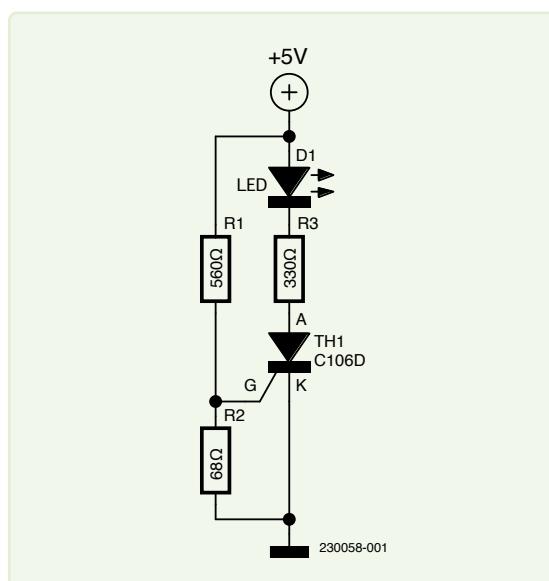


Figure 1: The simple circuit of this thyristor-based overtemperature indicator uses just three resistors and an LED plus the thyristor itself.

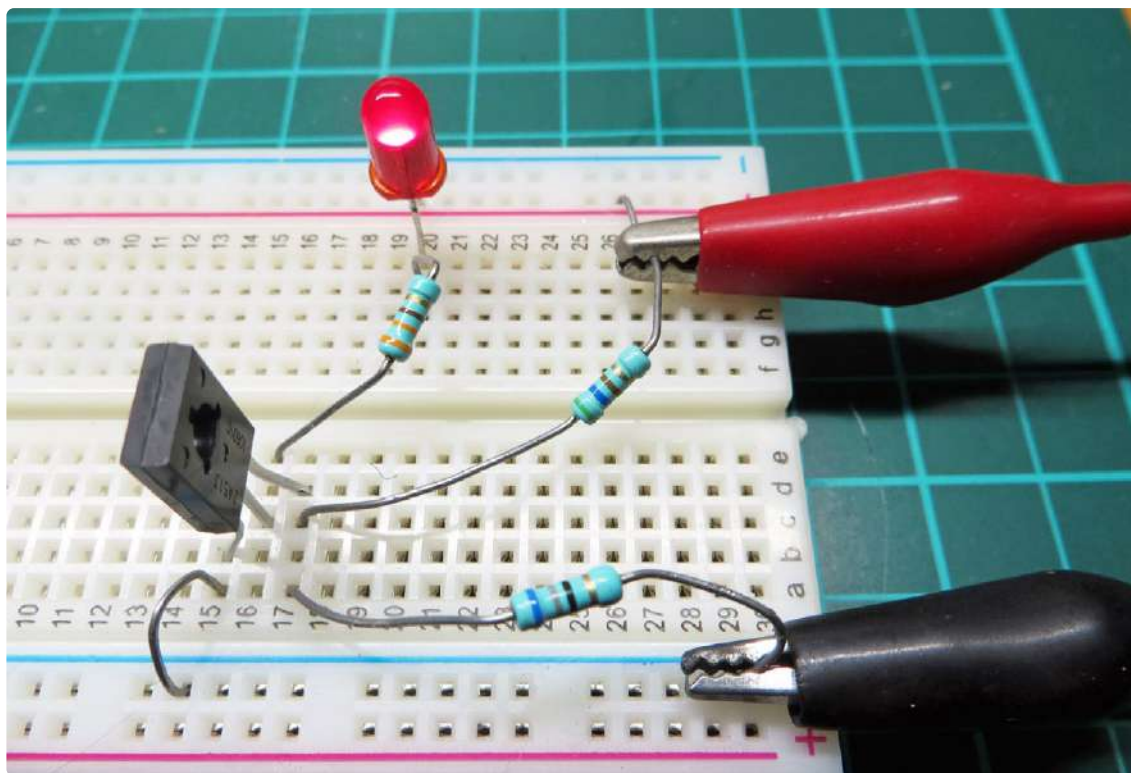


Figure 2: Experimental setup on a breadboard.

This circuit on YouTube:
<https://youtu.be/aBBPa8t5No>



Details

The thyristor used, type C106D, is a standard 400-volt, 4 A specimen available everywhere for well under € 1. With the resistor values from the Figure 1 and a 5 V supply, the voltage applied to the gate was 545 mV. At room temperature, the thyristor does therefore not conduct. The moment the LED turns on, the gate voltage jumps up to 650 mV due to the latching behavior.

If you do not have a thyristor in the junk drawer, you can use a TRIAC instead. Just check with a multimeter if pin M1 or M2 forms a diode with the gate. I tried a TIC206 and the circuit worked fine with it, too. Here was the diode path between M1 and the gate. I also had to change 560 Ω resistor R1 to 470 Ω.

Figure 2 shows the experimental setup on a breadboard. I posted a video on YouTube showing the behavior of this circuit. ◀

About the Author

Aside from developing low-noise instrumentation electronics professionally, Ray Schouten works on hobby projects, designing tiny music synthesizers and other compact circuits. Most designs are aimed at getting maximum results with the simplest of hardware.

Questions or Comments?

Do you have technical questions or comments about his article? Email the author at rs.elc.projects@gmail.com or Elektor at editor@elektor.com.



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230058-01

PTC Fuse Flip-Flop

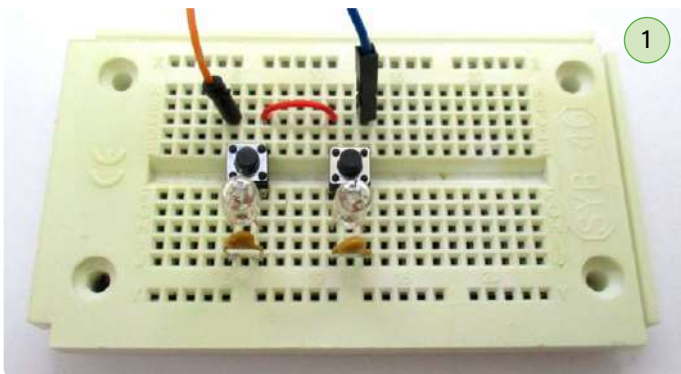
By Burkhard Kainka (Germany)

Familiar with PTC fuses?
Here is a circuit with two
PTC fuses, each designed for
100 mA.

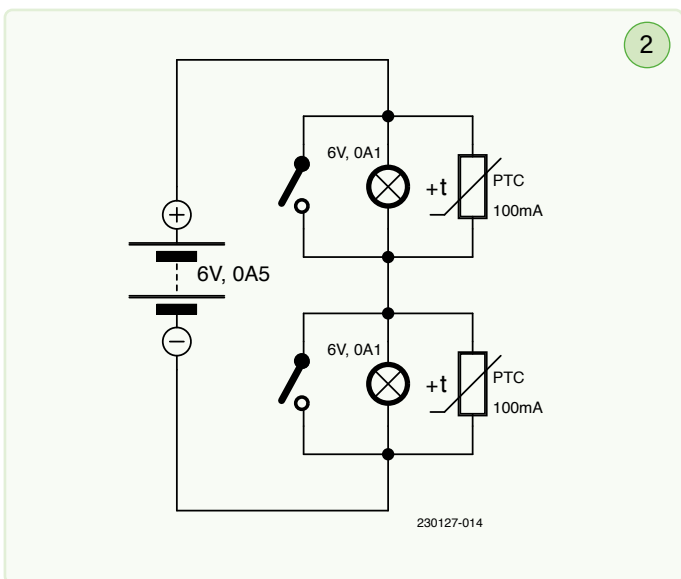
What happens when you connect two fuses in series to a power source? They both blow. Or maybe only one blows. It's hard to say which. One of the two fuses might heat up a bit faster and take the load off the other one because it has a higher resistance and therefore absorbs more power. Self-resetting PTC fuses show similar behavior. They have a positive temperature coefficient, which means the resistance rises with increasing temperature.

I built a circuit with two PTC fuses, each designed for 100 mA. The circuit also includes two incandescent lamps rated at 6 V / 100 mA, and two pushbuttons (**Figures 1 and 2**).

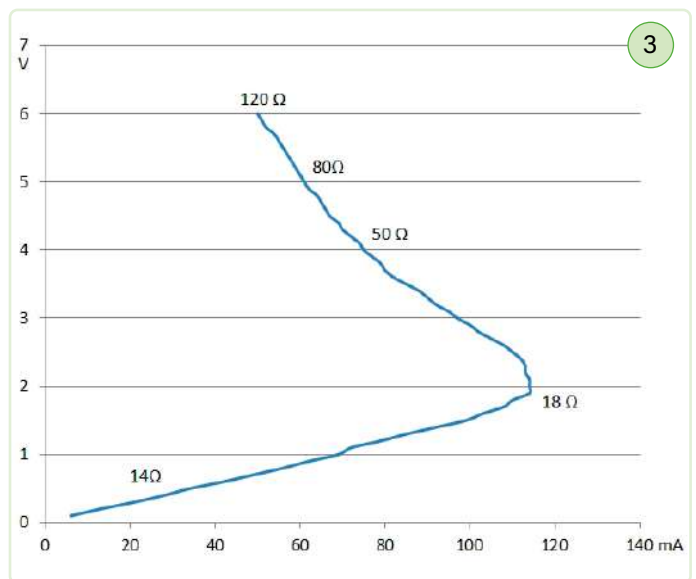
To make it easier to understand how these fuses work, I measured their characteristic curve (**Figure 3**). As you can see, the fuse has a cold resistance of 14 Ω , which rises to 18 Ω due to heating at a voltage of 2 V and a current of approximately 110 mA. At even higher voltages, the resistance becomes much larger, causing the current to drop significantly. In this situation, the fuse becomes hot, reaching a temperature of around 60 $^{\circ}\text{C}$.



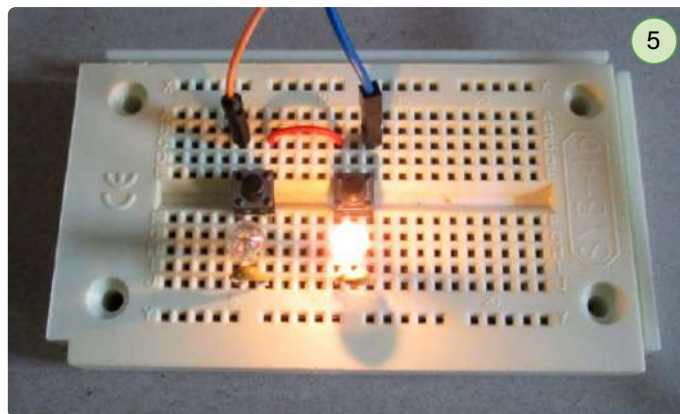
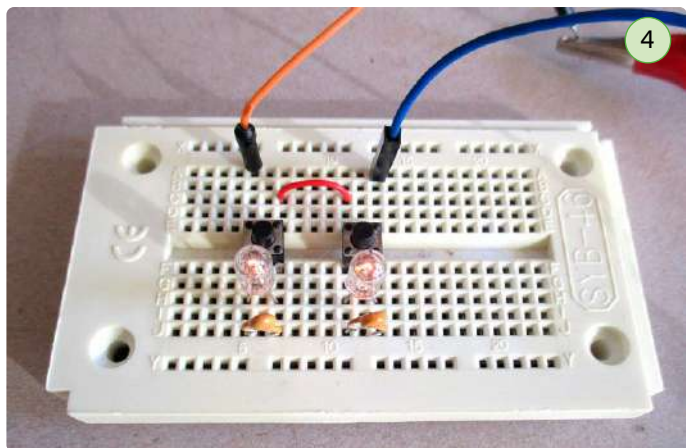
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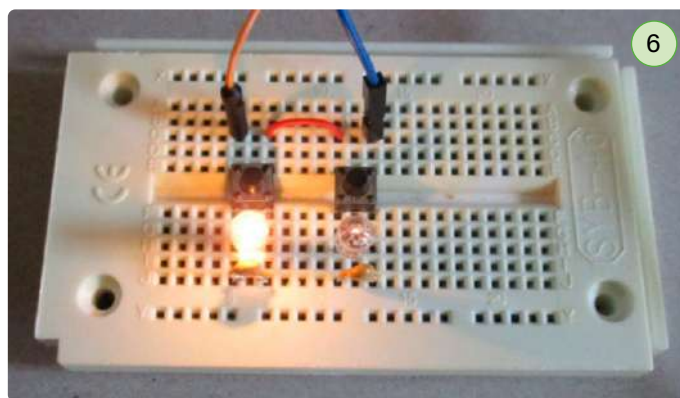
3



If this circuit is connected to a 6 V / 0.5 A power supply, at first both lamps are half lit (**Figure 4**). Then one of them gets brighter and the other gets darker, all very slowly. After one minute, only one of the two lamps is still lit (**Figure 5**). The current at this point is 150 mA. Of this, 100 mA flows through the lamp and 50 mA flows through the PTC fuse connected in parallel, so that it stays warm.

If you then press the button connected in parallel to the illuminated lamp, it goes out due to this short-circuit and the other lamp goes on (**Figure 6**). However, you have to press and hold the button for a few seconds until the first fuse has cooled down and the other one has heated up enough. If you don't press long enough, the circuit returns to its previous state. This means the circuit is an RS flip-flop with delayed switching.

When you look at the characteristic curve in detail, you may have doubts whether it can work this way. The PTC fuse is designed to pass a maximum current of 110 mA, but a current of 150 mA is flowing. The reason it actually works is due to the PTC characteristic of the incandescent lamps. At 6 V with a current of 100 mA, they have a working



resistance of 60 Ω , but the cold resistance of an incandescent lamp is a factor of 10 less, which in this case means 6 Ω . When they are both cold, the incandescent lamp and the PTC fuse share the current between them, so together they manage to keep cool. ◀

Translated by Kenneth Cox — 230127-01



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Funny Bird

A Chirping Elektor Classic



By Kurt Diedrich (original project) and
Ton Giesberts (PCB design and adaptations)

Although birds of all sorts are lovingly owned, fed, and spotted by many people, sadly, most of them have not yet learned to communicate with us. This all-electronic bird takes a step in the right direction: When you whistle at it, it chirps back!

Like the "One-Armed Bandit," also featured in this edition, "Funny Bird" is from Elektor's 1984 Summer Circuits edition published in the glory days of the 4000-series CMOS logic ICs, especially the type 4093! Both little projects were given a technical makeover without compromising their original component use and look and feel too much. Almost 40 years on, lo and behold, both are now Elektor Classics!

Whistle and Harken

To make Funny Bird chirp back at you, set the PCB in the wooden holder and switch on the circuit. Whistle not too far from the microphone and marvel at the birdlike sound returned through the little loudspeaker. If necessary, adjust the trimpots on the board for the best experience. "Look, Mom — No DSP or AI inside!"

How It Works

Let's take a look at the circuit diagram in **Figure 1**, drawn in great Elektor style and unsurpassed by any competing magazine. The circuit comprises two sections. The first is actually opamps IC1A...IC1D and associated parts. The incoming whistle received by the electret microphone is amplified in IC1A, whose gain factor can be set between 20 and 500 by trimpot P1. To ensure that the virtual bird really reacts to your whistle, the input signal is filtered in IC1B. Next, it's rectified by D1 and decoupled by C5.

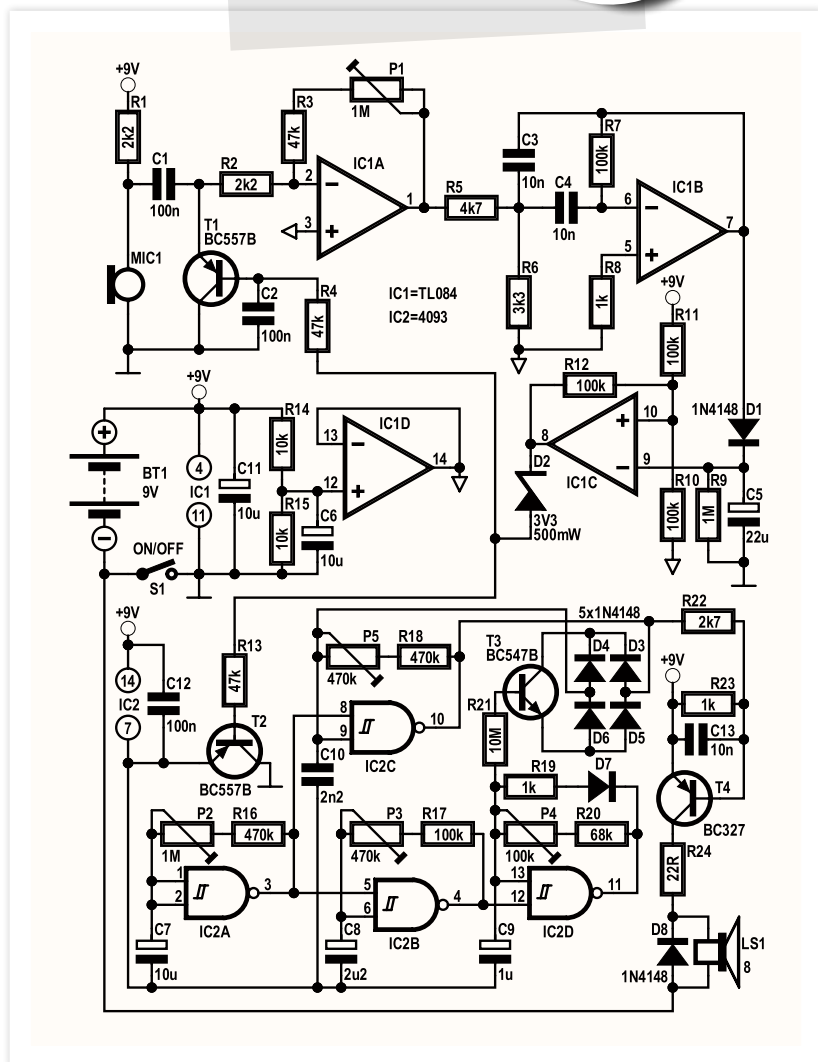


Figure 1: Definitely not of the feathered variety, this chirping "bird" is a bunch of controlled oscillators in a VCO configuration, triggered by whistling into an electret microphone.



Component List

Resistors

R1,R2 = 2.2 k Ω , 5%, 250 mW
 R3,R4,R13 = 47 k Ω , 5%, 250 mW
 R5 = 4.7 k Ω , 5%, 250 mW
 R6 = 3.3 k Ω , 5%, 250 mW
 R7,R10,R11,R12,R17 = 100 k Ω , 5%, 250 mW
 R8,R19,R23 = 1 k Ω , 5%, 250 mW
 R9 = 1 M Ω , 5%, 250 mW
 R14,R15 = 10 k Ω , 5%, 250 mW
 R16,R18 = 470 k Ω , 5%, 250 mW
 R20 = 68 k Ω , 5%, 250 mW
 R21 = 10 M Ω , 5%, 250 mW
 R22 = 2.7 k Ω , 5%, 250 mW
 R24 = 22 Ω , 5%, 250 mW
 P1,P2 = 1 M Ω , 100 mW, trimpot, top adjust (Piher PT6 series)
 P3,P5 = 470 k Ω , 100 mW, trimpot, top adjust (Piher PT6 series)
 P4 = 100 k Ω , 100 mW, trimpot, top adjust (Piher PT6 series)

Capacitors

C1,C2,C12 = 100 nF, 10%, 50 V, ceramic X7R, lead spacing 5 mm
 C3,C4 = 10 nF, 10%, 100 V, PET, lead spacing 5 mm
 C5 = 22 μ F, 20%, 16 V, diam. 5mm, lead spacing 2 mm
 C6,C7,C11 = 10 μ F, 20%, 16 V, diam. 5mm, lead spacing 2 mm
 C8 = 2.2 μ F, 20%, 100 V, diam. 5 mm, lead spacing 2 mm
 C9 = 1 μ F, 20%, 50V, diam. 5 mm, lead spacing 2 mm
 C10 = 2.2 nF, 10%, 400 V, PET, lead spacing 5 mm
 C13 = 10 nF, 10%, 50 V, ceramic X7R, lead spacing 5 mm

Semiconductors

D1,D3,D4,D5,D6,D7,D8 = 1N4148, DO-35
 D2 = 3V3 zener diode, 500 mW, DO-35
 T1,T2 = BC557B, TO-92
 T3 = BC547B, TO-92
 T4 = BC327-40, TO-92
 IC1 = TL084CN, DIP-14
 IC2 = 4093, DIP-14

Miscellaneous

BT1 = wired battery clip for 6LR61/PP3
 LS1 = KSSG1708 miniature speaker, 8 Ω , 0.5 W max., diam. 17 mm
 S1 = switch, slide, SPDT, 0.1 A/12 V (C&K OS102011MS2QN1)
 MIC1 = electret microphone, 10 V/0.5 mA,
 MCKPCM-97H45P-40DB-4808
 PCB 230153-1 v1.1

Opamp IC1C — essentially a trigger with hysteresis — acts as a monostable multivibrator (MMV). With an incoming whistle, its output remains logic Low until C5 has discharged, via R8, to a voltage level below the hysteresis threshold of IC1C. As long as output pin 8 is Low, p-n-p transistor T2 conducts and effectively connects the supply Ground return to the second section of the circuit.

Since the opamp package, IC1, requires a symmetrical supply voltage, IC1D is wired as an impedance inverter to produce half the supply level, which is applied to the other opamps. As long as the output of IC1C is low, T1 conducts, short-circuiting the microphone to avoid positive feedback. Delay network C2/R4 ensures that T1 continues to conduct for an instant after IC1C has toggled.

Funny Bird's "response" emanates from the second section of the circuit, a VCO formed by IC2C, D3...D6, T3, and associated components. If the base of T3 is fed with a sawtooth pulse of a few hertz, a chirping noise is produced. The sawtooth signal is generated by Schmitt trigger NAND gates IC2A-B-D. IC2A provides a square wave signal to oscillator IC2B. When IC2B's output swings High, sawtooth generator IC2D responds by producing a pulse train. As soon IC2B's output drops Low, IC2D stops oscillating and its output voltage starts to rise to the positive supply level. Because IC2B and IC2D oscillate at different frequencies, a quasi-arbitrary sawtooth signal ensues. That signal is then frequency-modulated by IC2C to drive LS1 with the help of amplifier T4.





Although birds of all sorts are lovingly owned and watched by many people, sadly most of them have not yet learnt to communicate with us. This all-electronic bird takes a step in the right direction: when you whistle at it, it chirps back!

The necessary circuit comprises two sections. The first section is an op-amp (IC1A) which is associated with the incoming whistle received by the electret microphone. The output of IC1A is amplified in IC1B, whose gain factor can be set between 20 and 500 by trimpot P1. To ensure that the virtual bird really reacts to your whistle, the input signal is filtered in IC1B. Next, it's rectified by D1 and decoupled by C5. Op-amp IC1C — essentially a trigger with hysteresis — acts as a monostable multivibrator (MMV). With an incoming whistle, its output remains logic Low until C5 has discharged, via R9, to a voltage level below the hysteresis threshold of IC1C. As long as output pin 8 is Low, p-n-p transistor T2 conducts and effectively keeps the output supply Ground return to the circuit at a low level of the circuit.

As long as the output of IC1C is Low, T1 conducts, short-circuiting the microphone to avoid positive feedback. Delay network C2/R4 ensures that T1 continues to conduct for an instant after IC1C has toggled.

Hummingbird's "response" emanates from the third section of the circuit, a VCO formed by IC2C, D2–D3, and associated components. If the base of T3 is fed with a sawtooth pulse of a few hertz, a chirping sound is produced. The sawtooth pulse is provided by Schmitt trigger NAND gates IC2A–B. IC2A provides a square wave signal to oscillator IC2B. When IC2B's output swings high, sawtooth generator IC2C responds by producing a sawtooth pulse. When IC2B's output drops low, IC2D stops oscillating and its output voltage starts to rise to the positive supply level. Because IC2B and IC2D oscillate at different frequencies, a quasi-square wave is produced. This signal is then frequency modulated by IC2C to drive L5L with the help of amplifier T4.

The various oscillator frequencies in the project may be varied with P2–P5 to enable a range of bird sounds to be produced.

The circuit should be switched off when not in use.

elektor CLASSIC

Elektor Classics are products dear to our hearts. Projects that continue to inspire and hold their merit for learning and sharing — projects that should not be forgotten and now deserve our animated tribute through a fresh rendition on a circuit board, as a Classic from Elektor!

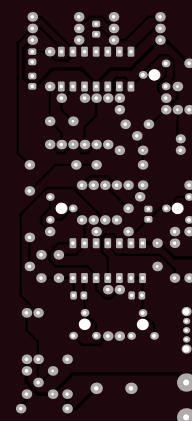



Figure 2: PCB design for the Funny Bird project. The board is designed as a desktop ornament for e-techies to show off.

The various oscillator frequencies in the project may be varied using P2...P5 to enable a range of bird chirps. Starting with all pots at mid-position, you'll soon discover that finding your favorite bird sound is trial-and-error, courtesy of the 4093 IC.

The standby current consumption from the 9 V battery is around 10 mA, mainly depending on the TL084 brand. The circuit should be switched off when not in use.

Building the Chirper

Basically, everything to know about building up these Elektor Classics kits is found in the “One-Armed Bandit” article. Although the Funny Bird PCB is larger than the other two Classics published so far (One-Armed Bandit and US-Style Siren [1]), it’s all plain sailing, as everything is contained in a kit you can buy from the Elektor Store. No worries, you’ll be soldering through-hole (TH) parts only, no tiny SMD parts which fly off at a whiff of air and keep disappearing in the vacuum cleaner. **Figure 2** shows the artistically styled PCB layout. 

Elektor Classics

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Related Product

➤ **Funny Bird Kit**
<https://elektor.com/20523>

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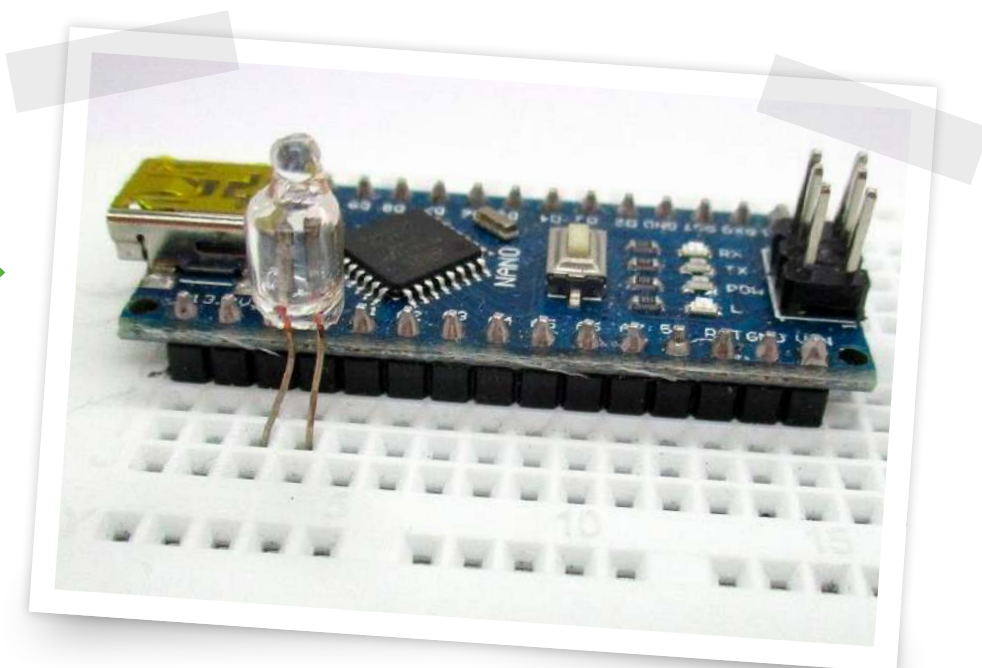
[1] L. Libertin and C. Valens, "US-Style Siren," Elektor Circuit Special 2022: <https://elektormagazine.com/el-us-siren>



Neon Lamp with a Microcontroller

By Burkhard Kainka (Germany)

Let's take a look at how a neon lamp can be used as a photocell.



Why would you want to mate an Arduino board with a neon lamp, which actually needs a much higher voltage? In this circuit, it is connected between AREF and A0 and acts as a photocell. If the A/D converter is operated slowly enough, the open input has a very high impedance and, after a while, settles to around 1 V. The Arduino ADC is so sensitive that it can easily detect the neon lamp's very low photocurrent. When light shines on the lamp, the voltage rises significantly.

The program contains a low-pass filter and works with a sampling rate that should be far enough away from the line frequency (in Europe, 50 Hz) and integer fractions of the line frequency. This suppresses interference from line frequency signals.

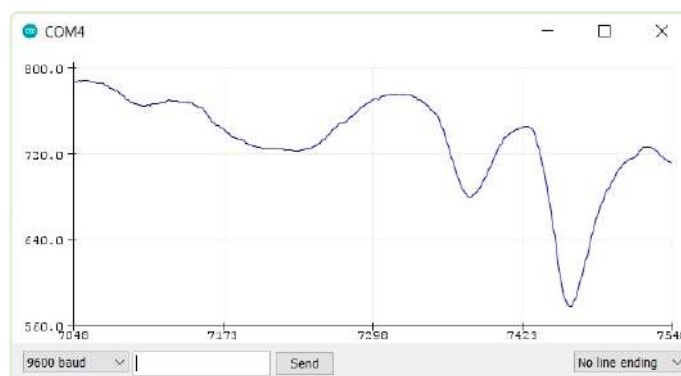
The measured curve shows changing light conditions: on the left caused by a passing cloud, and on the right due to additional shading. [▶](#)

```
//Analog input A0, filtered
int u;

void setup() {
  Serial.begin(9600);
}

void loop() {
  u = (u * 9 + analogRead(A0)) / 10; // IIR filter
  Serial.println(u);
  delay(505); // Must be different from 20 ms
              // and multiples
}
```

Translated by Kenneth Cox — 230130-01





Temperature-Stabilized IC Current Source

Neutralizing the Temperature Drift of Integrated Current Sources

By Dr. Thomas Scherer (Germany)

Integrated three-pin current sources are a well-tried means to simplify many analog circuits and take up very little space on the board. Unfortunately, however, these ICs exhibit significant temperature drift. But, with an additional diode plus an extra resistor, you can make them temperature-stable to a large extent.

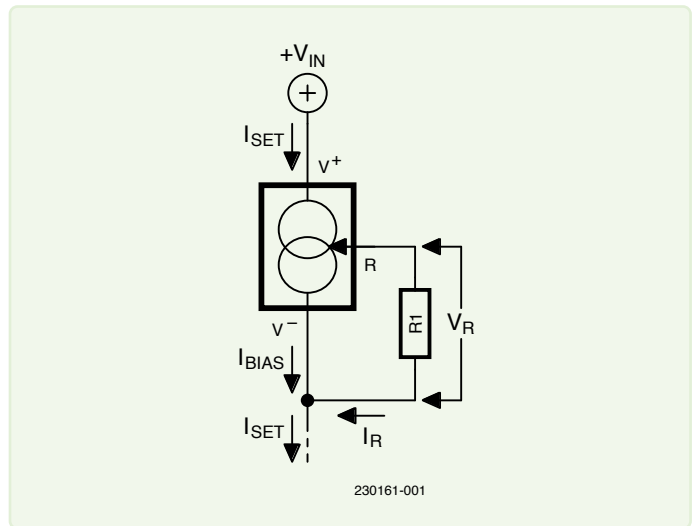


Figure 1: Basic circuit of the LM334 integrated current source.

There is hardly an electronics engineer who doesn't know these three-legged ICs that allow their current output to be adjusted to the desired value by means of an external resistor. An application example: With only two components, the common-emitter current of a differential transistor amplifier can be adjusted particularly easily and conveniently. Unfortunately, these ICs have a not-negligible temperature coefficient for some applications. But, with only two additional components, such a current source can be made very temperature-stable.

LM334

The current sources of the LM124 / LM224 / LM334 series are not only typical representatives of this IC class, but also widely used. These ICs' current output range, adjustable via an external resistor, is 1 μ A to 10 mA. The inexpensive LM334 variant has the highest component tolerance. In the following, the LM334 type is referred to due to its widespread use, but the considerations apply equally to the LM124 and LM224.

Figure 1 shows the typical wiring. Between pins R and V-, there is voltage V_R of about 64 mV at 25 $^{\circ}$ C. Total current I_{SET} through the IC consists of I_R (= the current through R_{SET}) and the smaller I_{BIAS} . I_R

is about 14 to 18 times as large as I_{BIAS} , which is why I_{BIAS} is almost negligible. The following equation is therefore suitable as a rule of thumb:

$$I_{SET} = 64 \text{ mV} / R_{SET} \times 1.06$$

Thus, for a current of 1 mA, for example, a resistor of 68 Ω would be well-suited for R_{SET} . The typical accuracy of the current achieved in this way is about 3%.

Everything would be fine with this if the voltage, V_R , did not have its hefty temperature drift of 214 μ V/K, which is 0.33%/ $^{\circ}$ C in the 25 $^{\circ}$ C range. In the TO-92 package, the thermal resistance between the silicon and the ambient air is still 180 $^{\circ}$ C/W. With a current of 10 mA and a voltage drop of 10 V, there would be a power dissipation of 100 mW and thus a temperature increase of 18 $^{\circ}$ C. This would then result in a current increase of 6 %. This may be acceptable in many cases with small currents (and correspondingly small power losses), but not in all cases. Interestingly, the temperature drift is so significant and so linear that you can even implement a decent temperature sensor using the LM334. This application is described in the datasheet [1].

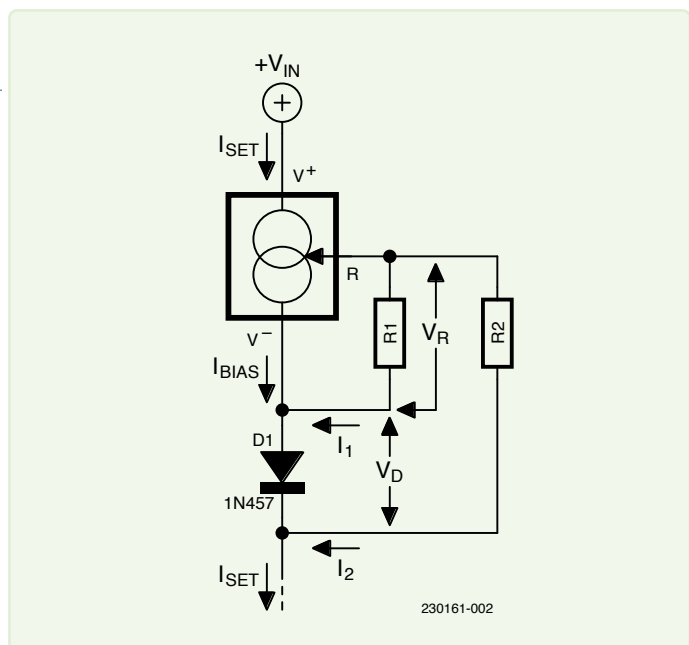


Figure 2: With an additional resistor and a diode, the current source becomes temperature-stable.

Compensating for the Temperature Drift

The datasheet also describes how to compensate for the positive temperature coefficient of the LM334 almost completely by adding another resistor and a diode. **Figure 2** shows the corresponding circuit.

The operating principle is based on the fact that a silicon diode's voltage has a negative temperature coefficient, which can thus be used to compensate for the LM334's positive temperature coefficient. I_{SET} now is the sum of I_1 , I_2 , and I_{BIAS} . The current, I_2 , with its negative temperature coefficient, is now added to the "normal" current, I_1 , with its positive temperature coefficient.

The characteristics of the IC's temperature coefficients and the diode are largely the same, except that the voltage across the diode is about 630 mV (at 1 mA and 25°C), which is about ten times the voltage drop across V_R . Thus, I_2 depends not only on the temperature of the diode, but also on the current flowing through it. But, this relationship leads to the ratio of the currents of $I_1:I_2$ having to be about 1:1. This results in the ratio of the resistors $R1:R2$ being 1:10, so that the temperature drifts cancel each other out. The exact derivation can be found in the datasheet.

Accurate enough for practical purposes, the temperature-compensated current can be estimated in simplified terms as follows:

$$I_{SET} = 136 \text{ mV} / R1$$

where $R2 = 10 \times R1$. For a temperature compensated current of about 2 mA, a resistor of 68 Ω is needed for $R1$ and 680 Ω for $R2$. Instead of a 1N457, one can also use the more common 1N4148 diode in Europe. Since both the diode's temperature drift and that of the LM334 IC depend on the flowing current, the lower voltage drop at the diode is also compensated for acceptably at low currents. ◀

Translated by Jörg Starkmuth — 230161-01

Questions or Comments?

Do you have technical questions or comments about this article? Email Elektor at editor@elektor.com.

WEB LINKS

[1] LM334 datasheet from Texas Instruments: <https://ti.com/lit/ds/symlink/lm334.pdf>

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34 Second-Order Adjustable Treble Boost

A Special Hearing Aid for the Elderly

By Ton Giesberts (Elektor Lab)

Getting older often means hearing high frequencies less well. The intent of this circuit is to compensate for this by using a steeper correction starting at a higher frequency than a standard Baxandall tone control, usually working around 1 kHz. This can improve acoustic perception and increase speech's intelligibility.

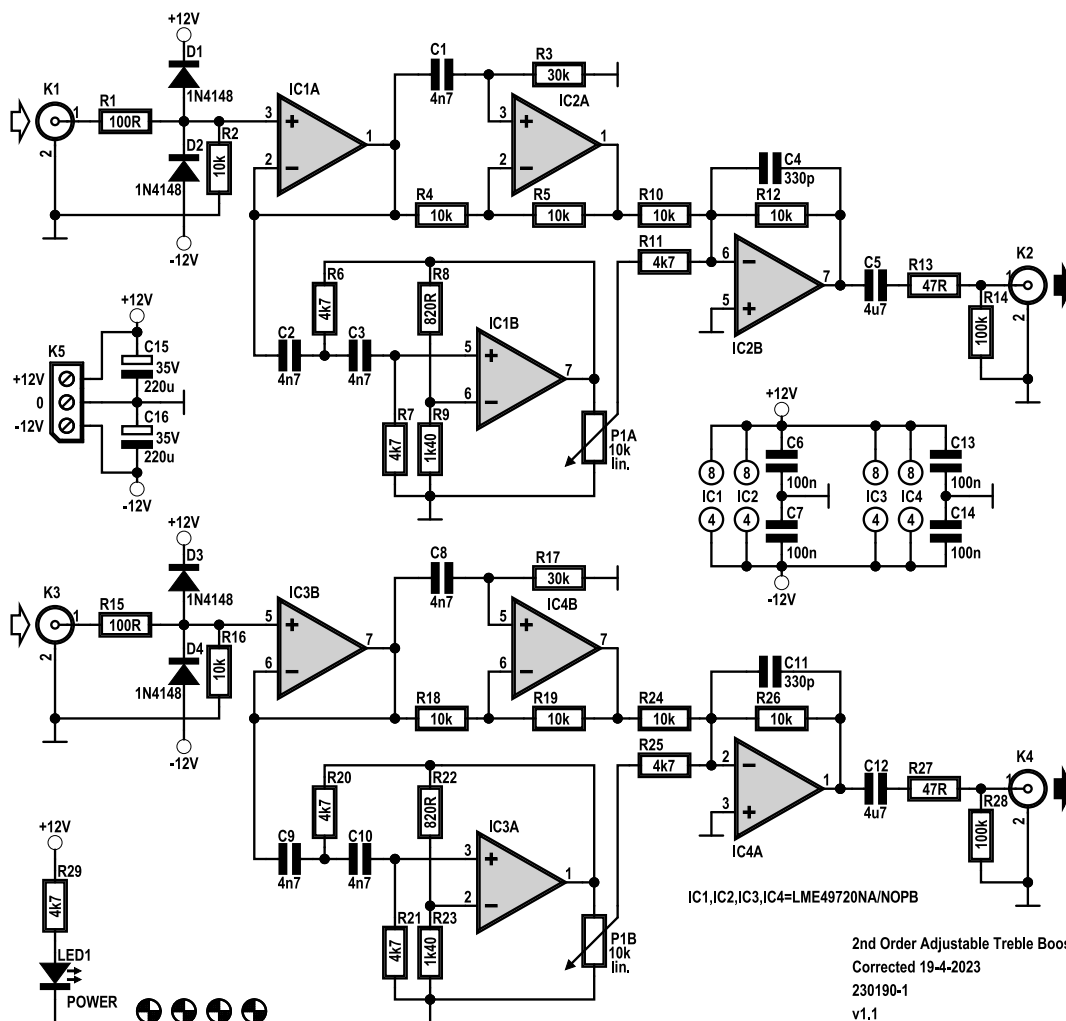


Figure 1: The circuit of this special hearing aid.

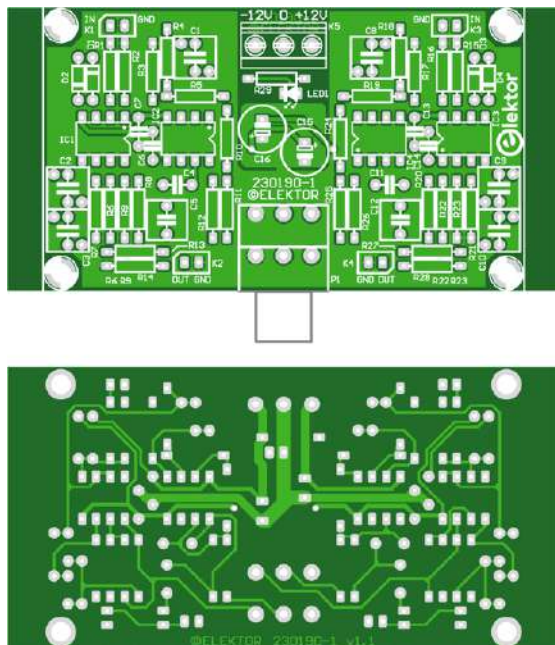


Figure 2: Bottom and top side of the PCB.

Of course, where exactly such a correction should start is very personal. With the values here, the operating point (start of gain increase) shifts from approximately 6 to 3 kHz, depending on the position of the potentiometer. The higher the set gain, the lower the operating point is. Maximum amplification is 12 dB (factor 4) at 17 kHz (P1 at maximum). The bandwidth of the output stage is limited to 48 kHz to prevent amplification of frequencies far outside the human hearing range and thus reduce the susceptibility of the circuit for high-frequency interferences.

Principle

The principle of the circuit (see **Figure 1**) is simple: Sum the output of a second-order high-pass filter and the unfiltered input signal. To make the description easier, the second channel around IC3 and IC4 is ignored by now. Back to the first channel: Just adding the two signals will have an unwanted effect on the desired summation caused by the phase change of the filter. To correct this, the input signal of filter buffered by IC1A runs through the all-pass filter around IC2A before summation with the signal of the high pass filter by IC2B. A second order critically damped filter has the same phase change over frequency as an all-pass filter. However, the slope of this type of high pass filter is not as steep as desired. Using a Butterworth filter instead causes the phase change to be a bit different, and therefore the all-pass can't completely correct this steeper filter. This results in a small variance of the gain at lower frequencies, but with less than +0.2 dB around 900 Hz and -0.3 dB around 3 kHz (depending on the operating point of the all-pass filter) this error can be neglected.

D1, D2 and R1 protect the input of the first op-amp against possible overvoltage and spikes. Input impedance is mainly defined by R2 (10 kΩ). The output signal of the all-pass filter is directly connected to the summing amplifier. The gain is defined by the ratio of R10 and R12 (unity gain). The gain of the output signal of the high pass filter is set by the ratio of R11 and R12 (factor 2 = 6 dB).

To make it easier to change the frequency of the operation point, the Butterworth filter also has a small gain of about factor 1.6 (4 dB). At the theoretical gain of $3 - \sqrt{2}$ (= 1.5858) the frequency determining resistors and capacitors have the same values, so $C2 = C3$ and $R6 = R7$. If

Component List

Resistors

(0.25W, 1%)

R1, R15 = 100 Ω

R2, R4, R5, R10, R12, R16, R18, R19, R24, R26 = 10 k

R6, R7, R11, R20, R21, R25, R29 = 4k7

R3, R17 = 30 k

R8, R22 = 820 Ω

R9, R23 = 1k4

R13, R27 = 47 Ω

R14, R28 = 100 k

P1 = 10 k, dual potentiometer, linear, e.g. Piher

PC16DH-10IP06-103A2020-TA

Capacitors

C1..C3, C8..C10 = 4n7, 1%, 63 V, radial, polystyrene, 7.5 x 7.5 mm

C4, C11 = 330 p, 1%, 630 V, axial, polystyrene, 12.9 x 5 mm

C5, C12 = 4μ7, 10%, 50 V, pitch 5 mm

C6, C7, C13, C14 = 100 n, 10%, 50 V, X7R, pitch 5 mm

C15, C16 = 220 μ, 20%, 35 V, electrolytic, pitch 3.5 mm, ø 8 mm

Semiconductors

D1..D4 = 1N4148, DO-35

LED1 = LED, green, 3 mm

IC1..IC4 = LME49720NA/NOPB, DIP-8

Miscellaneous

K1..K4 = 2x1 pin header, pitch 2.54mm

4 RCA audio connectors, chassis mount, connect to K1..K4

K5 = 3 pole screw terminal block, pitch 5 mm

4 DIP-8 IC sockets for IC1..IC4

PCB 230190-1 v1.1

a change is needed, the circuit is simple enough to simulate it to find out what effect the change of component values has on the characteristic of the treble boost. Furthermore, C1 has the same value as C2 and C3 what makes it easy to change the operating point. Of course, changing R3 and R6 and R7 proportionately is also an option. The value of 4.7 nF (C1, C2, and C3) is chosen because it is available as 1 % polystyrene type and this dielectric is an excellent choice to guarantee low tolerance and low distortion. This also is the reason why C4 is a 1 % polystyrene capacitor (axial, placed upright). A low tolerance of all filter components minimizes the phase change between the two signal pathways and between the two stereo channels. Any difference in phase change of the latter could influence stereo perception. A cheaper but lower quality solution with higher tolerance is the use of standard 5 mm PET capacitors for C1...C3 and 5 mm ceramic for C4 (use at least NP0 / C0G dielectric).

To achieve a total gain of 12 dB around 17 kHz in addition to the ratio of R12 / R11 the gain of the high pass filter and the small attenuation by the bandwidth limiting capacitor C4 also have to be taken into account. Without C4, the maximum gain of the highest frequencies would be $3.37 = 10.5 \text{ dB}$: $(1 + R8 / R9) \times (R12 / R11)$. For frequencies much lower than the operation point the total gain of the circuit is 1 (0 dB). At about 17 kHz the signal from the all-pass with its gain of 1 is added to the signal of the high path with its gain of 3.37. This addition leads to a total gain of $4.37 = 12.8 \text{ dB}$ with P1 at maximum position. The attenuation of C4 included the planned 12 dB are achieved quite exactly.

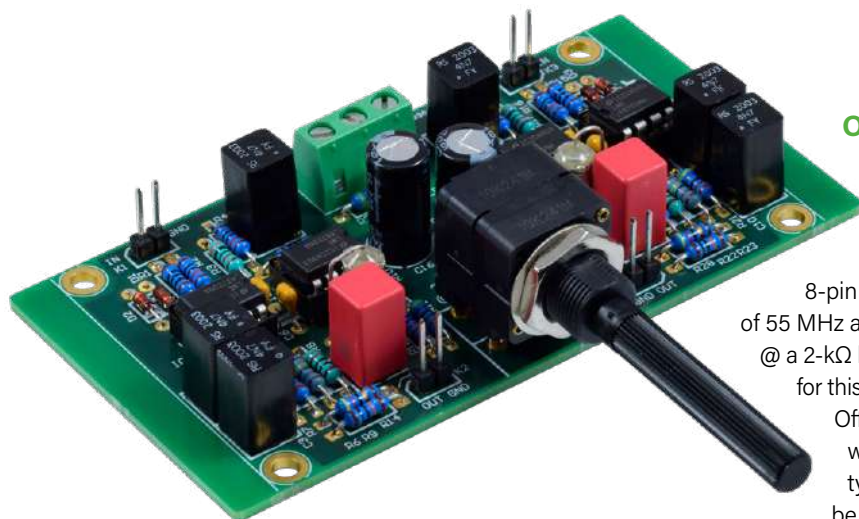


Figure 3: The populated prototype board.

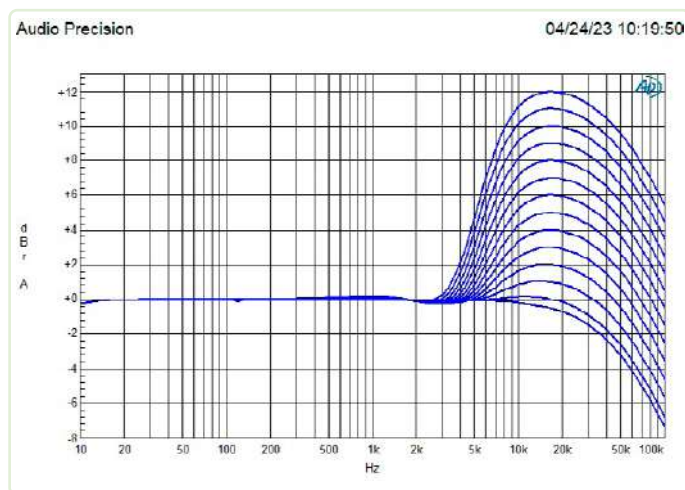


Figure 4: Plot A: The effect of the adjustable treble boost shown from 10 Hz to 100 kHz.

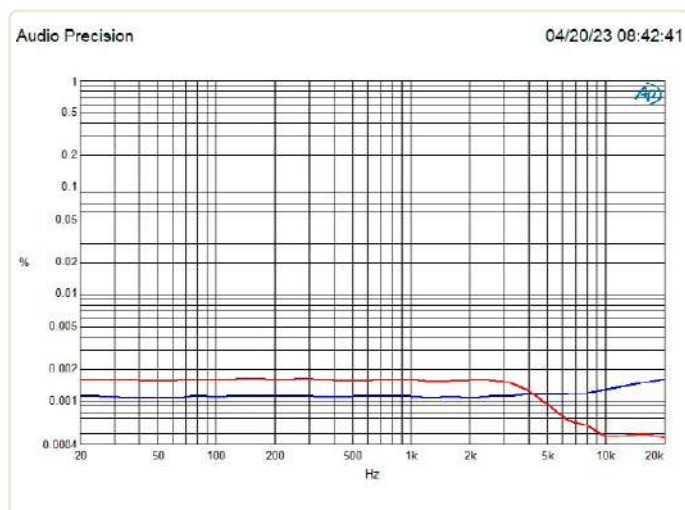


Figure 5: Plot B: THD+N from 20 Hz to 20 kHz at an input signal of 1 V and a bandwidth of 80 kHz: Blue curve: P1 set to minimum; red curve: P1 set to maximum.

Other aspects

Although a quad op-amp could have been used for each channel, affordable high-quality dual op-amps have much better properties. An excellent choice is the LME49720, which is also (still) available in an 8-pin DIP package. Its high GBP (**G**ain **B**andwidth **P**roduct) of 55 MHz and its extreme low distortion of $< 0.00007\%$ at 20 kHz @ a 2-k Ω load (3 V_{RMS} @ $\text{PS} = \pm 12\text{ V}$) make it an excellent choice for this type of circuit. It also has a very low input offset voltage.

Offset at the output of the summing amplifiers varies slightly with the position of P1 but stayed below 1 mV in the prototype. Should another op-amp be used, the offset could be much higher. C5 blocks any DC voltage at the output. The cutoff frequency with a 10-k Ω load is 3.7 Hz.

Total quiescent current of the prototype is +44.7 / -42.6 mA for both channels combined. The current through LED1 is 2.1 mA. The quiescent current of a LME49720 is typically rated 10 mA at $\pm 15\text{ V}$. To use a standard AC adapter as power supply, a DC-DC converter is one way of creating a symmetrical power supply for the treble boost. The total

Prototype Measurements

V_{in} max (@ 1 kHz, THD = 0.1 %):	7.9 V _{PP}
Treble boost:	starting at 6 kHz to 3 kHz
Max. gain @ 17 kHz (P1 max.):	12 dB
Quiescent current (PS = $\pm 12\text{ V}$):	+44.7 / -42.6 mA
Bandwidth (load 10 k Ω , P1 min.):	3.7 Hz...48 kHz
THD+N (1 kHz, 1 V, P1 min.):	0.0008 % (B = 22 kHz)
THD+N (1 kHz, 1 V, P1 max.):	0.0012 % (B = 22 kHz)
THD+N (1 kHz, 1 V, P1 min.):	0.0012 % (B = 80 kHz)
THD+N (1 kHz, 1 V, P1 max.):	0.0016 % (B = 80 kHz)

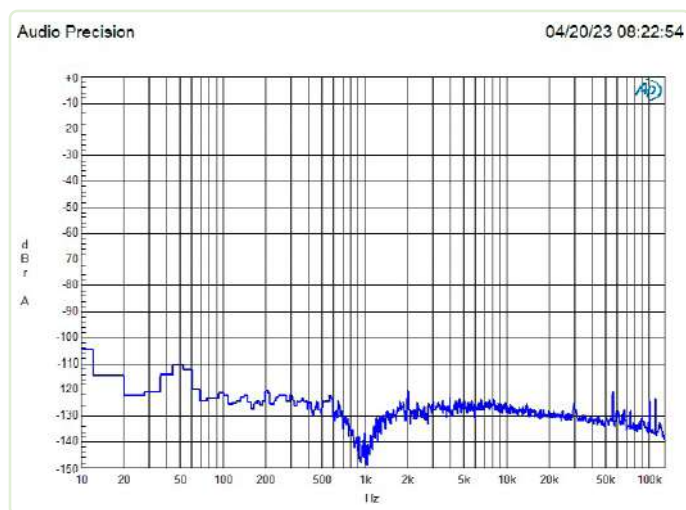


Figure 6: Plot C: The FFT of the output signal with P1 set to maximum and a sine signal of 1 kHz at 1 V at the input.

power of the circuit is 1.05 W, so a symmetrical 1 W DC/DC converter probably would be sufficient, but one with a slightly higher power output and regulated outputs is advisable. Most symmetrical DC/DC converter series have an output voltage of ± 12 V - this is why ± 12 V is chosen as the power supply voltage. However, power supply voltage range of the LME49720 is ± 2.5 V to ± 17 V.

The width of the PCB (**Figure 2**) is extended to almost 100 mm, so it can fit in the 1455 series of Hammond enclosures. The PCB can be shortened to the white lines. Four mounting holes can be used to fasten the PCB in any other enclosure. Enclosure 1455N1201 from Hammond would be a nice choice. However, the potentiometer is about 1 mm too high even if the PCB is placed in the lowest slots. Bending the wider part of the leads of the potentiometer slightly towards the body can make the potentiometer low enough to make it fit. Another option is placing the potentiometer with its thread through the front (of any enclosure) and use short thin flexible wires to connect it to the PCB. This way, any linear dual 10 k Ω potentiometer can be used. **Figure 3** shows the populated board of the prototype. The PCB layout files can be downloaded at the Elektor Labs webpage [1].

Measurements

To check whether the purely calculated goals were also achieved in practice, I made some measurements:

Plot A in Figure 4 shows the amplitude from 10 Hz to 100 kHz and gives a good impression of the characteristic of this adjustable treble boost. P1 is adjusted in 1 dB steps at 17 kHz. In the second lowest curve, P1 is adjusted to 0 dB gain at 17 kHz. Depending on the setting of P1, the operating point shifts from approximately 6 kHz to 3 kHz when P1 is adjusted from minimum to maximum setting.


Plot B in Figure 5 shows THD+N from 20 Hz to 20 kHz at an input signal of 1 V and a bandwidth of 80 kHz. The blue plot is measured with P1 set to minimum. THD+N varies from 0.0011 % to 0.0016 % at 20 kHz. The red plot is measured with P1 set to maximum. Above 3 kHz, THD+N decreases to 0.00048 % at 20 kHz. The relative noise level is lower due to the higher output level toward 20 kHz.

Plot C in Figure 6 shows a FFT of a 1 kHz signal with 1 V and P1 set to maximum. The 2nd harmonic and a few artifacts above 50 kHz are visible just above the noise floor. THD+N at a bandwidth of 22 kHz is 0.0012 %.

Conclusion

The measurements show impressively that the goals from the beginning have been more than achieved, don't they? If you build this, you get an electronic audio device with very good features. But, how do you achieve practical benefits with it?

As said at the beginning of this article, this device can aid the elderly with a loss in their ability to hear higher frequencies to hear better because this loss is compensated at least partially. So, you could simply connect this piece of electronics between the audio output of a TV and an amplifier (with speakers connected, of course). If the treble boost is then adjusted appropriately, the result is if not better movie enjoyment then at least better speech intelligibility for the elderly. If you are affected yourself, or if someone among your friends or family cannot hear high tones well, try it out!

Warning: As with all treble controls at high-volume settings and maximum treble boost, the power output of a power amplifier to a tweeter can be too much and damage it! Consider this: An increase of 4 times in amplitude means **16 times** an increase in power! 

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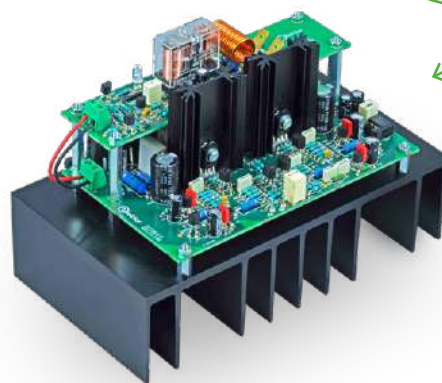
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Related Products

- > **B. Cordell, *Designing Audio Power Amplifiers (2nd Edition)*. New York: Routledge, 2019**
<https://elektor.com/19150>
- > **D. Self, *Small Signal Audio Design (2nd Edition)*. Burlington: Focal Press, 2010**
<https://elektor.com/18046>
- > **Elektor Fortissimo-100 Power Amplifier Kit**
<https://elektor.com/20273>



WEB LINK

[1] Project at Elektor Labs: <https://elektormagazine.com/labs/2nd-order-adjustable-treble-boost-230190>

35 Edwin Comes Home

A Look Back After 53 Years

By Jan Buiting (Elektor Retronics)

Nowadays, building your own high-spec audio gear is not nearly as popular as half a century ago. Back in 1970, good amplifiers were extremely expensive, so a bit of DIY-ing could save a lot of money and potentially achieve better results and greater power outputs than off-the-shelf gear. Elektor bit that bullet and released a top performer: Edwin.

This, and other reasons, must have prompted *Elektuur* to formulate and publish a high-spec amplifier for home construction, yet based on affordable transistors known over here. “Edwin” was born in January 1970 as a 10-watt or 20-watt mono amplifier and appeared again in later years as a youth with 40 watts out, and as an adult with 100 watts to deliver. Edwin was also the very first project in edition 1 of the German *Elektor* launched in May 1970. Readers raved, many PCBs were sold and even more were etched, drilled, and populated at home.

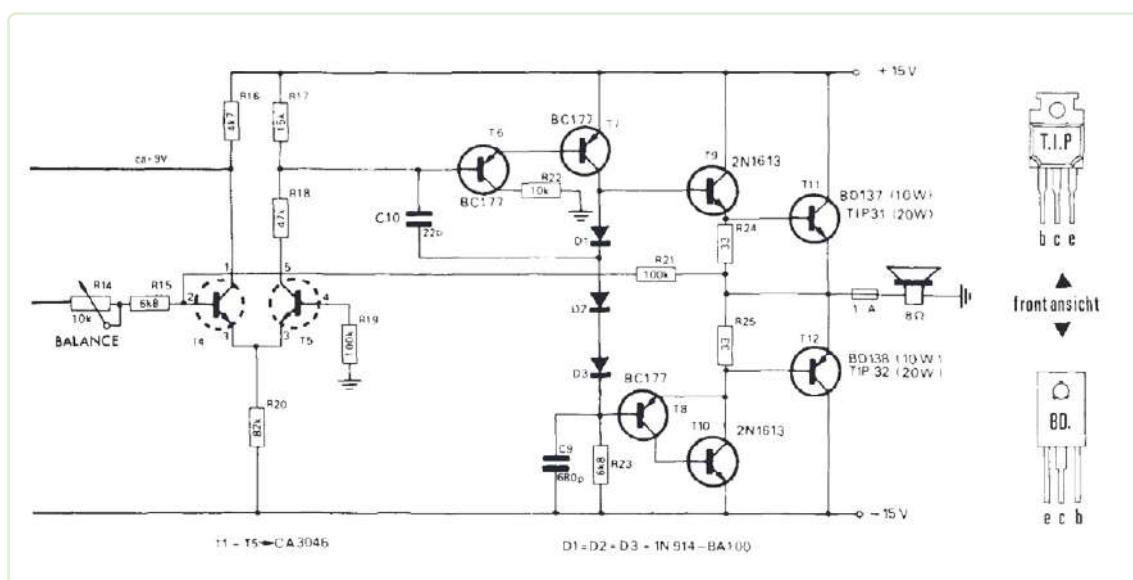
Worth a Patent?

The original Edwin was described as “a novel development in audio,” meaning it had some remarkable features for the time, such as

1. no quiescent current
2. no adjustments
3. very low cross-over distortion
4. one integrated circuit (IC) inside
5. no paired, complementary power transistors

Sure, even back in the 1960-70s when *Elektuur* Holland started out, there were popular amplifier “plans” that were widely imitated, but they were invariably of American or English origin and circulated among connoisseurs only. The problem back then on this side of the pond was the enormous cost and difficulty getting mainly American transistors, which were a rarity 50 years ago when *Elektor* was called *Elektuur* and fundamentally Dutch.

Figure 1: Output section of the Edwin audio power amplifier, published in *Elektuur* magazine in January 1970. The company applied for patent on the power stage drive and biasing circuitry, which “requires no adjustment yet affords low cross-over distortion at moderate cost.”



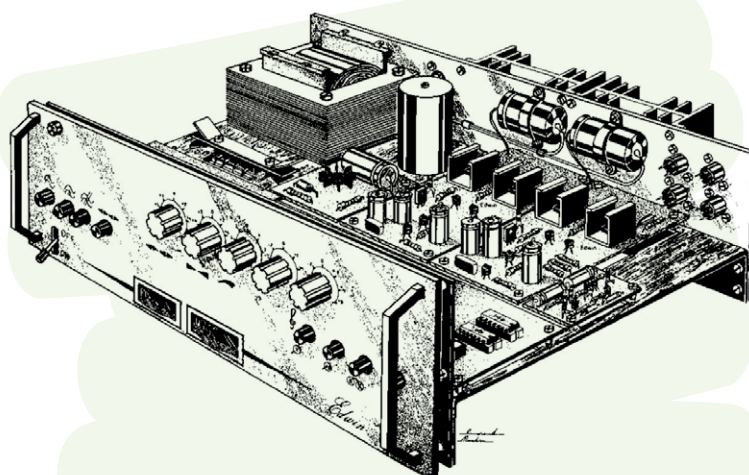
For this 2023 Circuit Special Flashback article, I was happy to have at least a worn paper copy of the “Edwin Amplifier” article. This copy came with an equipment donation, as I will tell further on. Let’s now look at the power amplifier section of the schematic reproduced in **Figure 1**. This part of the schematic actually highlights every single point mentioned above. The design principle applied to Edwin is a Class-B power output stage with a Class-A amplifier ahead of it to bridge the non-operative voltage range of the power transistors. This calls for excellent temperature stability and low drift in the biasing arrangements and the difference amplifier. That’s where the CA3046 IC enters — five closely matched n-p-n transistors on a common substrate, with two of them (T4...T5) having their emitters commoned. The CA3046 transistor array became an “Elektor darling” in later years. In the Dutch 1970 article, its HFL 7.50 price was described as “highly acceptable.” For fun and comparison, the PCB for the Edwin project cost HFL 3.50 from *Elektuur*.

Elektuur applied for a patent for the mixed Class-A / Class-B output amplifier drive and biasing method. I do not know if the patent was awarded, but readers at that time wouldn’t have cared much about it as long as they had a great sounding amp with (1) no adjustments and (2) no blown transistors or speakers due to thermal runaway!

While it’s true that the 2N1613 was a fairly common and not too expensive device in 1970, I believe its “2N” JEDEC type number identifies a US design, just as the CA3046 and the TIP31/TIP32 complementary transistors given as alternatives for a 20-watt version of Edwin. The BC and BD transistors you see in the schematic are of European origin, though, and wouldn’t have struck the 1970s *Elektuur* reader as odd or novel.

Since the input section of Edwin is not shown here due to poor originals on paper, suffice it to say that R16 provides around 9 V to the input transistor (CA3046-T1), R14 is capacitor-coupled to the amplified input signal (CA3046-T3) after the Baxandall tone control, and the -15 V line is dropped somewhat and decoupled by a 10 k Ω / 100 μ F RC network to feed the input transistor from the negative side.

The 1970 article also contains information on a suggested power supply for Edwin, a phono preamplifier, a PCB, and an input selector. In a second and final instalment in the February 1970 issue, *Elektuur* published the construction of Edwin.



The Homecoming, The Original

I am not an audio fan and would not have written this article if I had not stumbled upon an actual build of the original Edwin project from 1970. I have seen later, more powerful — and certainly slicker — versions of Edwin, such as the 40-watt variety [1] (**Figure 2**) and then the 100-watt amp with 2N3055s in its power stage. But I always wondered about the 10-watt Original.

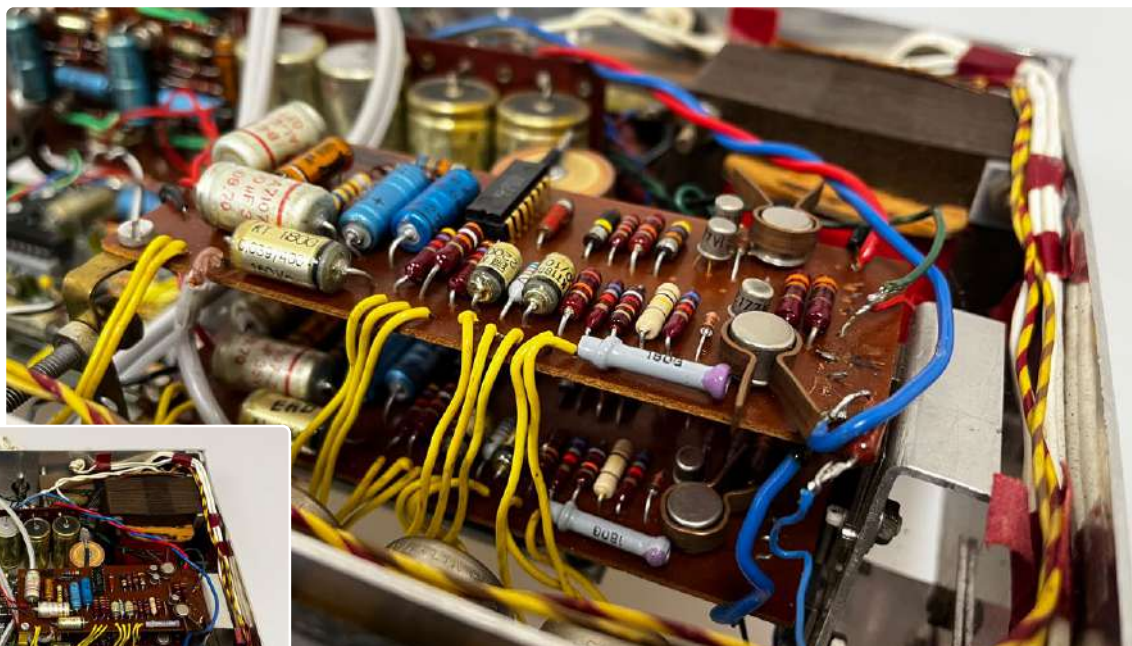
On a rare occasion, a DIY, stereo FM receiver containing the smallest and oldest Edwin amps was given to me by the wife of a deceased Elektor reader who worked at a famous research institution in the Netherlands. The FM receiver was contained in a green, hand painted, and homemade wooden box sized 31×9×20 cm and is shown here “as found” (**Figure 3**). It came together with a bunch of radio equipment, test gear, and a huge assortment of 1970s/1980s components of the “professional” class I have been drawing from occasionally. The kind benefactor, a lady in her eighties clearing her house, contacted me through Elektor by email and WhatsApp (!), specifically mentioning “this Elektor radio and amplifier thing he was mad about...”



Figure 2: Artist's impression of the 35-W Edwin stereo amplifier, published as a follow-up to the original 10- or 20-W version. To many readers, building audio amplifiers in a metal case needed much encouragement from Elektor, hence this drawing made by Laurent Martin.

Figure 3: The homemade, hand painted wooden box that turned out to contain two 20-watt Edwin amplifier boards and the 1974 Elektor “PLL Feedback FM tuner”.


Figure 4: Welcome Home, Ye 'Ole Edwins! It's taken a few years, and the pair of you are tucked in a stereo FM receiver, but now you're back at long last within the Elektor community.



The FM receiver being stereo, it had two Edwin amp boards inside, separated by PCB standoffs and with a common heatsink for the TIP31/TIP32 transistors to keep their cool, and fins on the TO-5 style 2N1613's (**Figure 4**). Clearly, this piece of audio gear was built by an advanced and apparently affluent engineer and *Elektuur* reader also keen on documenting his projects down to the last correction.

Play Us a Song

This pair of Edwins must have slumbered inside that green box for at least 30 years, so I gave them a calm run-in on a variac and a low-volume test on a 4 Ω loudspeaker, playing in some line-level audio and, later, a record. In both cases, I found the sound fresh

and bright, but lacking in dynamic range. During a later test in my lab, a spectrum analyzer, a dummy load, and a distortion meter revealed that the distortion was "in 1970 spec" at under 0.85% running 15 W out. The same approval was granted to Edwin's frequency response, bass, and treble boost. The FM tuner section of the receiver was silent. Remarkably, after 50 years, there was no smoke from the wooden box, just a faint aroma of epoxy, cigars, whiskey ... and vinyl? 

230194-01

Questions or Comments?

Do you have technical questions or comments on this article? Feel free to contact the author by email at jan.buiting@elektor.com or the editor at editor@elektor.com.



Related Product

- > **Jan Buiting, *Retronics* (PDF, Elektor)**
This e-book is a compilation of about 80 *Retronics* installments published in *Elektor* magazine between 2004 and 2012. The stories cover vintage test equipment, prehistoric computers, long forgotten components, and Elektor blockbuster projects.
<https://elektor.com/16885>



WEB LINK

- [1] Jan Buiting, "Edwin Audio Amplifier," *Elektor* 3/2005:
<https://elektormagazine.com/magazine/elektor-200503/17929>

36 One-Armed Bandit

A Simple, Fun, Nostalgic, and Educational Elektor Classic!

By H. J. Walter (Original Project) and
Ton Giesberts (PCB Design and Adaptations)

Here's another project selected from Elektor's long history of "idea-oriented" mini articles typically found in the erstwhile *Summer Circuits* magazines. Back in 1984, "One-Armed Bandit" was just one of around 100 schematics, each with a few words of clarification. Almost 40 years on, we're not just recycling this content, but actually enhancing and honoring it with a real PCB and a fancy kit from the Elektor Store. We do so all in good spirit and with feelings of light nostalgia after the glory days of 4000-series CMOS logic!



The populated circuit board inserted in the wooden desktop stand.

Like the "US-Style Siren" published exactly one year ago [1], the present plan complies with the following criteria set up for *Elektor Classic* projects:

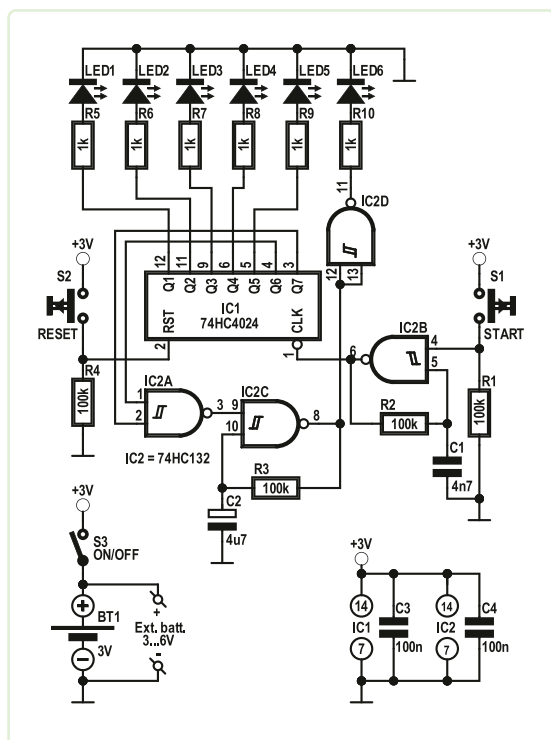
- > produces noise, light, movement, action, smell, havoc, "wow!" cries, irritation, or fun;
- > uses inexpensive TH parts from the "old school" bin or drawer;
- > is as true as possible to the original design;
- > has immediate appeal to beginners and e-outsiders;
- > is suitable for PCB-ing and placing on a desktop;
- > is available as a complete kit for home assembly;
- > is drawn in the inimitable Elektor style — meaning, stylish and e-ducational.

With all this in mind, and more, this Elektor Classic shows a playful application of (originally) CMOS 400x series logic ICs in combination with LEDs, a highly popular combination at that time [2]. The project only imitates the core of a spinning-digit type slot machine. As such, no attempt is made to implement all the bells, whistles, flashes, and sound effects of a real slot machine — these are best experienced in an arcade hall, at your personal risk and cost! Here, we're talking electronics and learning how things work.

The Game

To play the game, first agree on the number of rounds. Player 1 actuates the switch lever as long as desired and releases it. The LEDs then show the score, which

Figure 1: By the mid-1980s, 4000-series CMOS logic ICs and LEDs were cheap and offered great potential for hobbyists to design simple digital electronics. The circuit diagram for a “One-Armed Bandit” shown here (reworked from a 1984 original) is a good example of the zeitgeist.



is the sum of the 50-20-10-5 digits lit up. If the *Play Again!* LED lights, Player 1 has another, “free”, round. If not, it’s Player 2’s turn. The players keep tab of their scores, and the highest score wins.

Circuit Operation

The circuit diagram shown in **Figure 1** is based on a type 74HC4024 7-stage binary counter/divider, IC1. At the start of the game, it is reset by spring-loaded push-to-make switch S2, causing logic Low levels on counter outputs Q1...Q7, which in turn cause LED1...LED5 to remain off. Also, the output of NAND Schmitt trigger IC2A is logic High, switching on relaxation oscillator IC2C. The oscillator signal is inverted in IC2D and LED6 lights.

The game is started by closing switch S1 (i.e., pulling its lever downward). This turns on oscillator IC2B which starts clocking the counter. As soon as S1 is released, IC2B ceases to oscillate and the counter stops at a random output combination for Q1...Q7. One or several of LED1...LED5 will light at that time, indicating the number of points scored by the player.

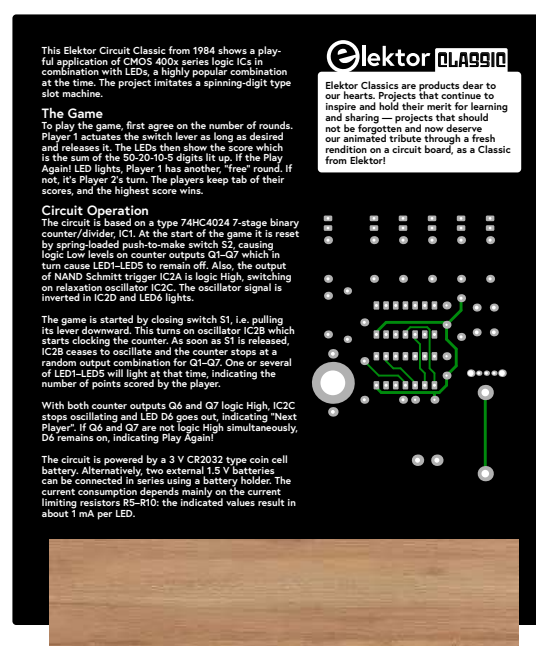
With both counter outputs Q6 and Q7 logic High, IC2C stops oscillating and LED D6 goes out, indicating “Next Player.” If Q6 and Q7 are not logic High simultaneously, D6 remains on, indicating *Play Again!*

The circuit is powered by a 3-volt CR2032 type coin cell battery. Alternatively, two external 1.5-volt batteries can be connected in series using a battery holder. The current consumption depends mainly on the current limiting resistors R5...R10: the indicated values result in about 1 mA per LED. This is actually the one significant difference between H.J. Walter’s 1984 design and the 2023 incarnation seen here: today we have far more efficient LEDs and no longer need buffer transistors between the CMOS counter outputs and the “score reel” LEDs consuming 20 mA each 40 years ago. Oh, and psst... we’ve used HCMOS ICs rather than vintage 4000 CMOS — but still in DIP cases!

Building the Bandit

In keeping with the *Elektor Classics* tradition, the circuit board designed for the One-Armed Bandit has the schematic printed on the front side, and the circuit operation on the back (**Figure 2**). Notice the use of the

Figure 2: PCB design for the One-Armed Bandit in lavish *Elektor Classics* style.



renowned Elektor-style component symbols and the axial-leaded electrolytic capacitor C2 in the component mounting plan. Okay, it takes up more PCB space than its radial counterpart mostly seen today (nor even mentioning SMDs) but gives a fine touch of 1980s authenticity to the project.

Assembling this project is plain sailing as only through-hole (TH) parts are used on a spaciouly designed board with a clear component overlay. Plus, all parts are contained in an attractively styled kit, so no need to rummage around for "ye ole" parts in dusty drawers.

The assembled board is placed in the wooden, engraved, desktop stand included in the Elektor kit. The stand is for showcasing, really, or showing off if you like. Don't pull that switch lever down too briskly, as the board may drop out of the stand. Use two hands, do not cheat, and be sure to limit your play time. ◀

230207-01

Classic Projects

Elektor Classics are products dear to our hearts. They are projects that continue to inspire and hold their merit for learning and sharing — projects that should not be forgotten and now deserve our animated tribute through a fresh rendition on a circuit board, as a Classic from Elektor!



Suggested through-board mounting method for the lever switch S1, which acts as the bandit's "arm."



Component List

Resistors

R1,R2,R3,R4 = 100 kΩ, 5%, 250 mW

R5,R6,R7,R8,R9,R10 = 1 kΩ, 5%, 250 mW

Capacitors

C1 = 4.7 nF, 10%, 50 V, lead spacing 5 mm

C2 = 4.7 μF, 10%, 63 V, axial

C3,C4, = 100 nF, 10%, 50 V, ceramic X7R, lead spacing 5 mm

Semiconductors

LED1...LED6 = LED, red, 5 mm diam. (T1 3/4)

IC1 = 74HC4024, DIP-14

IC2 = 74HC132, DIP-14

Miscellaneous

S1 = Switch, toggle, 21 mm lever actuator, SPDT, momentary action

S2 = Switch, tactile, 24 V, 50 mA, 6x6 mm

S3 = Switch, slide, SPDT (C&K OS102011MS2QN1)

IC socket, DIP14, for IC1, IC2

BT1* = CR2032 coin cell battery

PCB Mount CR2032 battery retainer clip

Desktop stand, wooden, engraved

PCB 230098-1

** May not be contained in Elektor-supplied kit due to transport restrictions.*

WEB LINKS

[1] L. Libertin and C. Valens, "US-Style Siren,"
Elektor Circuit Special 2022:
<https://elektormagazine.com/el-us-siren>



Related Product

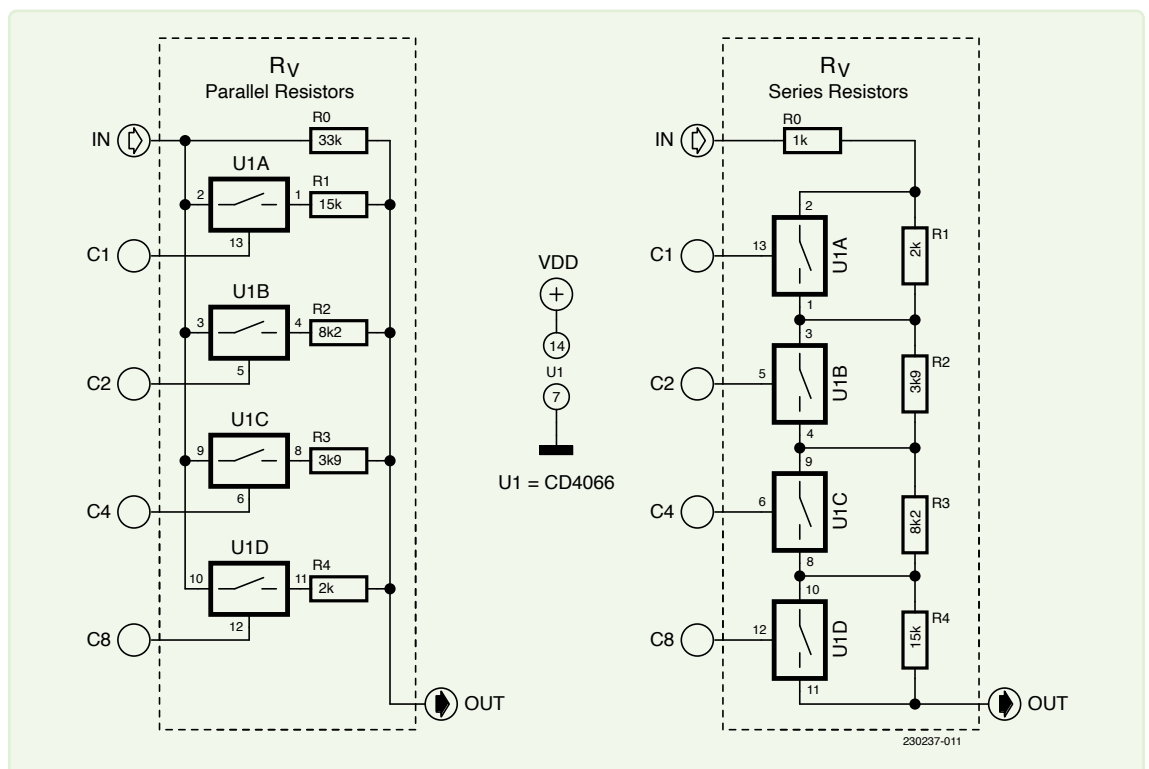
► Elektor One-Armed Bandit Kit Kit of parts including all parts, PCB and engraved, wooden desktop stand
<https://elektor.com/20516>



37 Simple Digitally Controlled Variable Resistor

By Walter Ribbert (Italy)

Sometimes it is useful to have a variable resistor that can be controlled via a microcontroller, even if the adjustment resolution is not very fine. Often, as few as 16 steps are adequate (e.g., for volume control or tone adjustment). For this, searching in the component drawer, we might find some unused 4016 or 4066 CMOS chips. Inside these are four analog switches that can be controlled with as many microcontroller outputs. Using just one chip and five resistors, you can construct a 16-step variable resistor.



The diagrams in **Figure 1** represent two examples of circuits using resistors — in parallel and in series, respectively. The results are two very different types of variable resistor (R_V).

R_0 , R_1 , R_2 , R_3 , and R_4 are standard resistors, whose values are chosen as binary multiples ($\times 1$, $\times 2$, $\times 4$, $\times 8$). Acting on the control inputs of the four switches with a binary sequence (on C1, C2, C4, and C8) produces the resistive curves visible in the respective diagrams shown in **Figure 2**. The circuit with the resistors in parallel gives us a logarithmic curve with 16 points on it, while the resistors in series create a linear curve.

By inserting these RV blocks into other circuits, it is possible to vary a voltage or current signal or to change the gain of an op-amp circuit, as shown in the circuits and diagrams in **Figure 3**.

Notes

The resistance of each of the 4016 (or 4066) in/out channels is about $400\ \Omega$ with a chip V_{DD} supply of 5 V, which is reduced to about $200\ \Omega$ at a V_{DD} of 10 V. The diagrams do not take these values into account, as they are ideal and deliberately stepped to highlight the poor control resolution.

Obviously, by adding switches and resistors, it is possible to increase this resolution to 32 or 64 steps, and so on, doubling it with each element added but also increasing the number of outputs required for control. Depending on what you want to do, you can also use a shift register (e.g., a 74HC595), but, beyond a certain limit, it is perhaps better to purchase an integrated serial-controlled digital potentiometer. ◀

230237-01

Questions or Comments?

Do you have technical questions or comments about his article? Email the author at w.ribbert@elettronicaemake.it or contact Elektor at editor@elektor.com.



Related Product

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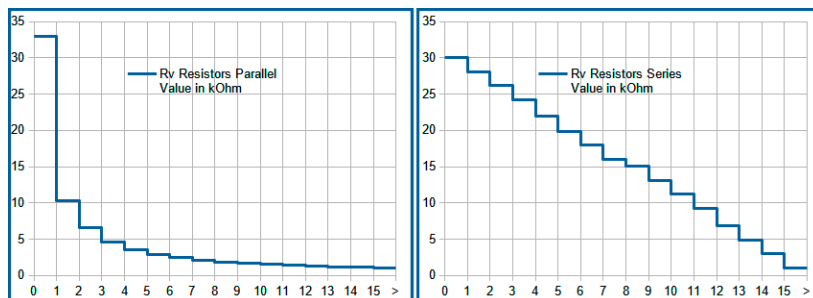


Figure 2: Logarithmic and linear curves obtained from different configurations.

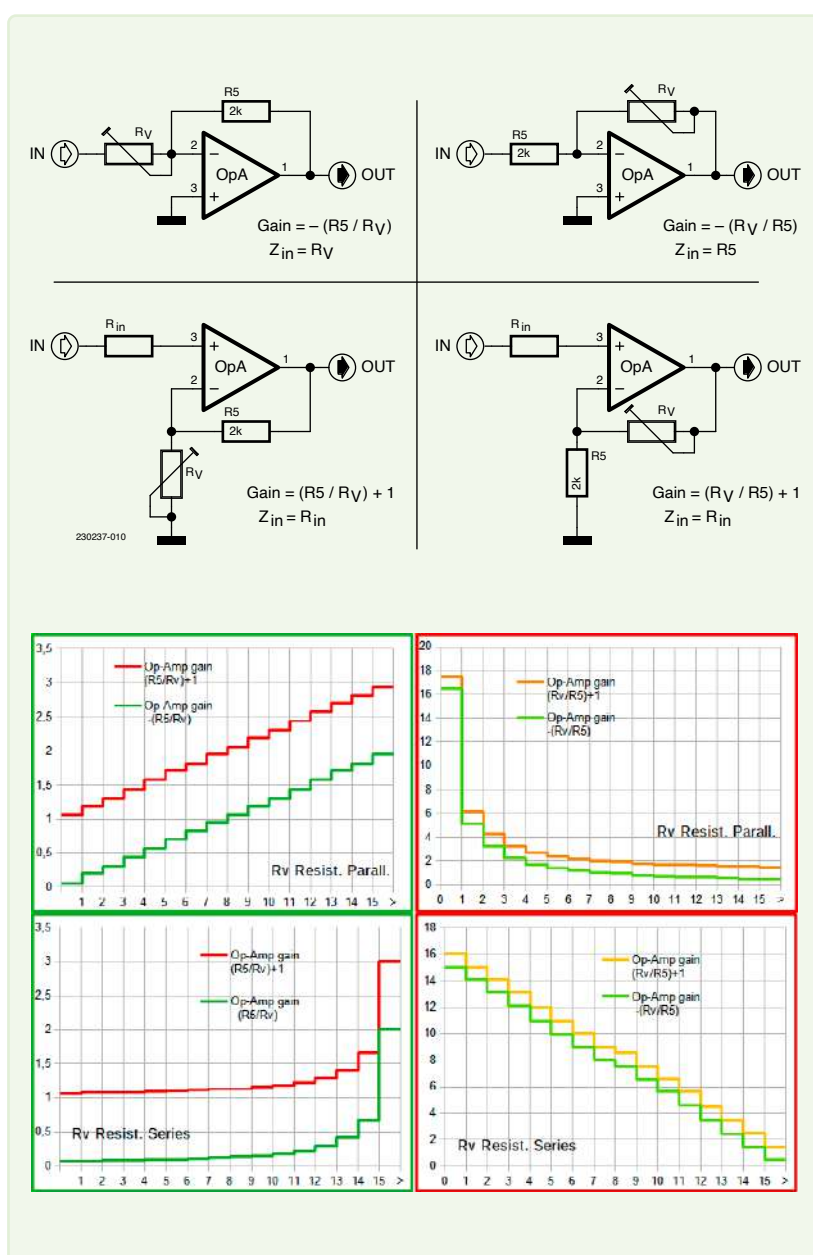


Figure 3: Examples of simple application circuits and the related charts.

Water Leak Protection

Safeguard and Alarm



By Giuseppe La Rosa (Italy)

This device was mainly designed for household appliances dealing with water. In the event of a leak — when a hydro-sensitive sensor is wet — the mains voltage is immediately cut off from the equipment, stopping the water flow and reducing the risk of electrocution.

Washing machines, dishwashers, and similar household appliances are potentially dangerous because they somehow bring water and electricity together. Leaks can occur, which can lead not only to expensive water damage but also electric shocks.

The circuit presented here gives off an alarm and can switch off connected devices when a moisture sensor is wet. The monitoring electronics are looped in between the socket and the mains plug or in the supply line of the appliance to be monitored. A suitable sensor can be installed on the floor or, in the case of the appliances listed, even better inside the appliance — e.g. directly under the water connections or near the water pump — because this is where there is the highest probability of a leak.



This circuit operates at 230 V and therefore care must be taken during its setup and testing with water, to avoid the risk of electrocution. If you do not have the necessary knowledge and experience to set it up and implement it safely, do not undertake this project.

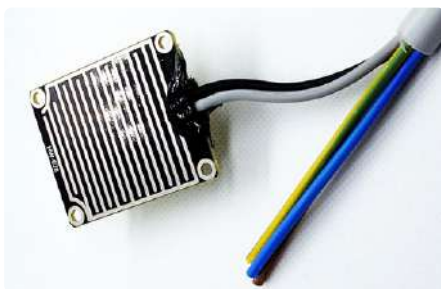


Figure 1: The MH-RD sensor used in this project.

Figure 1 shows a so-called raindrop sensor, which essentially consists of a small circuit board with a ground conductor and a sense conductor interlaced in a comb formation. When dry, it has a high resistance, and when wet, its resistance drops due to the water connecting the conductors.

Circuit Diagram

The circuit of **Figure 2** is quite simple. The humidity sensor is connected to X1-1 and X1-2. One electrode is then connected to earth and the other is connected via R2 to the input of NAND gate IC1A connected as an inverter. This input is brought to High (when the sensor is dry) via R1. As a result, the output of IC1A goes low and, thanks to the double inversion by IC1B and IC1C, 0 V is also present at R3. This leaves T1 and therefore Re1 off, which is why the load continues to be supplied with power via X1-3 and X1-4 through the normally closed contacts of Re1. If condensation or running water wets the connected sensor, the logic level of the input at IC1A tips, and LED1 lights up as an alarm indicator and the load is disconnected via Re1.

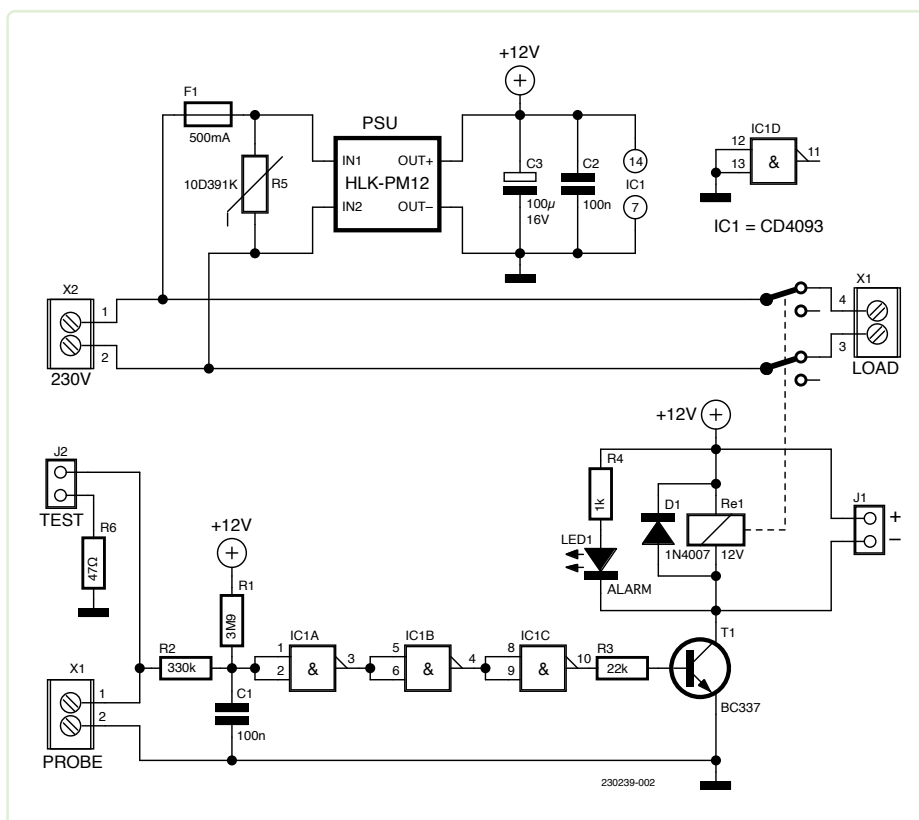


Figure 2: The relatively simple schematic diagram.

The circuit is powered by a small stabilized power supply for PCBs. Since the gate of IC1D is not used, its inputs are connected to ground to avoid undefined states.

The function of the circuit can be tested with a push button (normally open contact) at J2. Resistor R6 simulates the average resistance of a wet water drop sensor, which makes for a realistic simulation when tested by a pressed button.

A flashing 12 V LED, for example, can be connected to J1 to indicate a water leak remotely. A low-power acoustic signal generator suitable for 12 V could also be correctly connected here.

Varistor R5 protects the electronics from transient overvoltages. If it becomes active and its resistance gets low due to high voltage, fuse F1 blows and interrupts the power supply.

Figure 3 shows my finished prototype. If you want to rebuild the project and make a circuit board, you can follow **Figure 4**. The layouts are available for download on this article's webpage [1].

230239-01



Figure 3: The author's ready-built prototype.

Component List

Resistors

(SMD 1206 if not otherwise noted)

- R1 = 3M9
- R2 = 330 k
- R3 = 22 k
- R4 = 1 k
- R5 = varistor 10D391K
- R6 = 47 Ω

Capacitors

- C1, C2 = 100 n, SMD 1206
- C3 = 100 μ / 16 V, electrolytic, SMD, \varnothing 5 mm

Semiconductors

- D1 = 1N4007, DO213AB
- LED1 = LED, red, 3 mm
- T1 = BC337, SOT23
- IC1 = CD4093, SOP14

Miscellaneous

- Re1 = Relay 12 V, 2 \times 8 A, e.g. RT42412
- PSU = PCB power supply HLK-PM12
- J1, J2 = 2-pole pin header
- X1 = 4-pole screw terminal, 2/10"
- X2 = 2-pole screw terminal, 2/10"
- F1 = Fuse 500 mA
- Probe = MH-RD Sensor (see Figure 1)

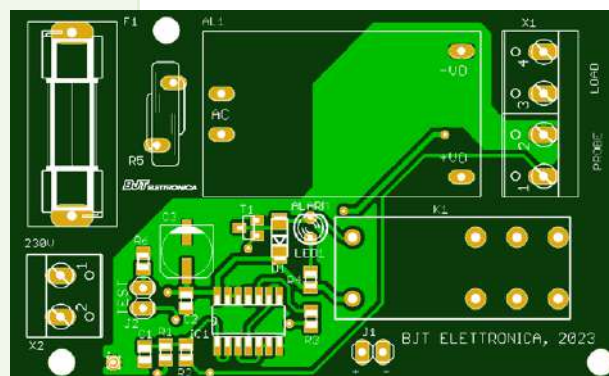


Figure 4: The electronic water leak protector PCB.

Questions or Comments

Do you have technical questions or comments about this article? Email Elektor at editor@elektor.com.



Related Products

- > **Elektor 37-in-1 Sensor Kit**
<https://elektor.com/16843>
- > **Dogan Ibrahim, "The Ultimate Compendium of Sensor Projects,"**
Elektor, 2019
<https://elektor.com/19103>

WEB LINK

[1] Layout download:
<https://elektormagazine.com/230239-01>



39 Eco-Timer with Auto-Shutdown

Needs 0.0 mW in Off Mode!

By Giovanni Carrera (Italy)

The main feature of this timer is that it disconnects not only the load but also itself from the mains when the time is up. This saves electricity, extends the service life and also complies with safety regulations. Just as with a start/stop relay circuit, in the event of a power failure, it is only reactivated when the Start button is pressed again.

As with ordinary start/stop circuits, a two-pole relay is used here: one for self-holding and the other for the load. In this case, however, the relay is supplied with 12 V DC. **Figure 1** shows the circuit of the timer.

The central circuit is certainly not new: To get relatively long timings, the CD4060 14-step binary counter is used; it has an integrated oscillator that works with a quartz or an RC element (like here). The Z-diode has a double function: It stabilizes the CD4060's voltage to get stable timings and it also prevents excessive voltage at the IC.

The counter is triggered by negative-going edges at its clock input. With Q14, for example, the level goes from High to Low after 2^{14} clock pulses. But, since it starts with Low after a reset, it takes 2^{13} clock pulses for it to go from

Low to High. At Low, however, the relay is energized due to the inversion of T1. It therefore drops out after 2^{13} clocks and de-energizes the load and the entire circuit.

To obtain a duration of 300 seconds at Q14, the RC oscillator must generate a clock pulse with a period of $300 / 2^{13} = 36.621$ ms (corre-

sponds to 27.3066 Hz). To measure the period duration, it is best to use output Q4 — because of the division by 16, the period duration there must be exactly 585.9375 ms if you want to get 300 s at Q14.

Operation

Pushbutton S1 is connected in parallel to the

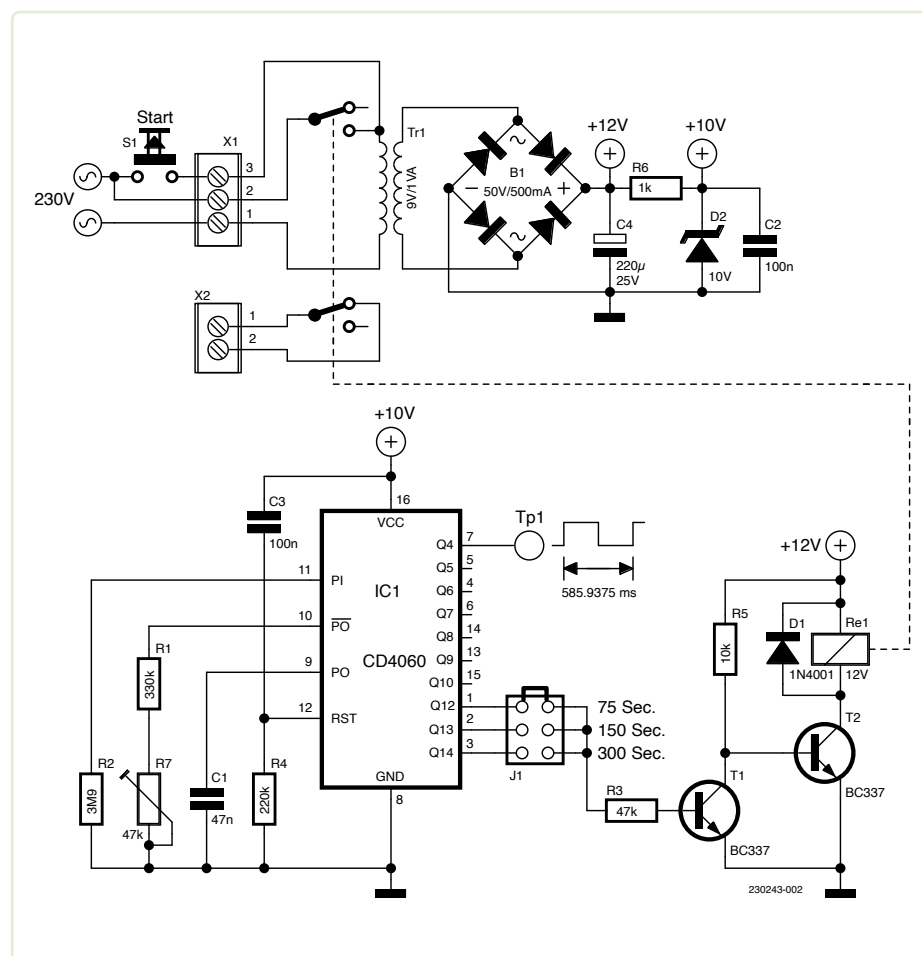


Figure 1: The schematic of this timer is so simple that it can easily be built on a breadboard.

Component List

Resistors

R1 = 330 k
R2 = 3M9
R3 = 47 k
R4 = 220 k
R5 = 10 k
R6 = 1 k
R7 = 47 k trimpot

Capacitors

C1 = 47 n
C2, C3 = 100 n
C4 = 220 μ / 25 V, electrolytic

Semiconductors

D1 = 1N4001
D2 = 10 V, Z diode
T1, T2 = BC337
IC1 = CD4060B

Miscellaneous

Tr1 = Transformer 12 V sec., 1 VA
Re1 = Relay 12 V, DPST 230 V / 5 A
S1 = Push button, 230 V / 5 A
J1 = 2 \times 3-pole pin header with jumper

self-holding contact of Re1. If it is pressed, an unstabilized 12 V DC appears very briefly at the output of the transformer after rectification by B1 and filtering by C4. Since the timer is reset by R4 and C3, the level at all outputs is initially Low. No matter what period is set with J1, T1 remains open at first, switching T2 through and making the relay pick up, whereby it holds itself via the contact connected in parallel to S1. After 2^{13} clock pulses, Q14 goes High and switches off the relay, which de-energizes the entire circuit and the relay remains switched off, together with the load. If you prefer Q13 with J1, this is the case after 2^{12} clock pulses = 150 s. With Q12, the switch-on time is 75 s.

A small drawback of the circuit should not be concealed: Closing pushbutton S1 must be designed to handle the load. Its contacts must therefore have the same current-carrying capacity as those of the relay. For my prototype (**Figure 2**) I chose a relay and a pushbutton with 5 A contacts.

Of course, you don't have to stick to the times listed here. In fact, you don't need to use trimmer R7 to adjust the period at Q4 to the absolute exact timings using a frequency counter; an oscilloscope is sufficient for the evaluation at TP1 or a simple stopwatch with which you record the time of Q12. If you want to have other durations, you can use other outputs. With Q10, for example, you get 18.75 s and, correspondingly, with Q9 just 9.375 s, and with Q8 only 4.6785 s. Longer times can be set, for example, with other values for the oscillator. The corresponding formula is:

$$F = 1 / (2.3 \times (R1 + R7) \times C1)$$

where the resistance of R2 should be about ten times the sum of R1 + R7. So, with 100 nF for C1, ten minutes can easily be set for Q14. \blacktriangleleft

230243-01

Questions or Comments?

Do you have technical questions or comments about this article? Email Elektor at editor@elektor.com.



Related Product

> Joy-IT JDS6600 Signal Generator & Frequency Counter
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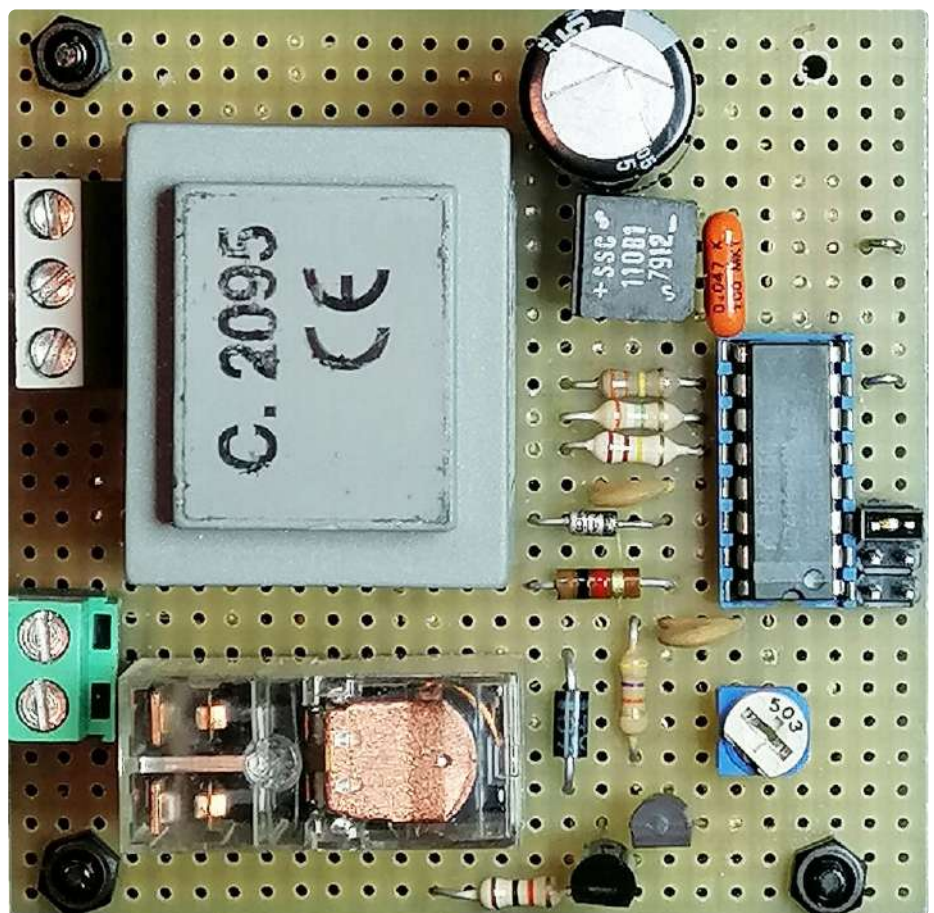
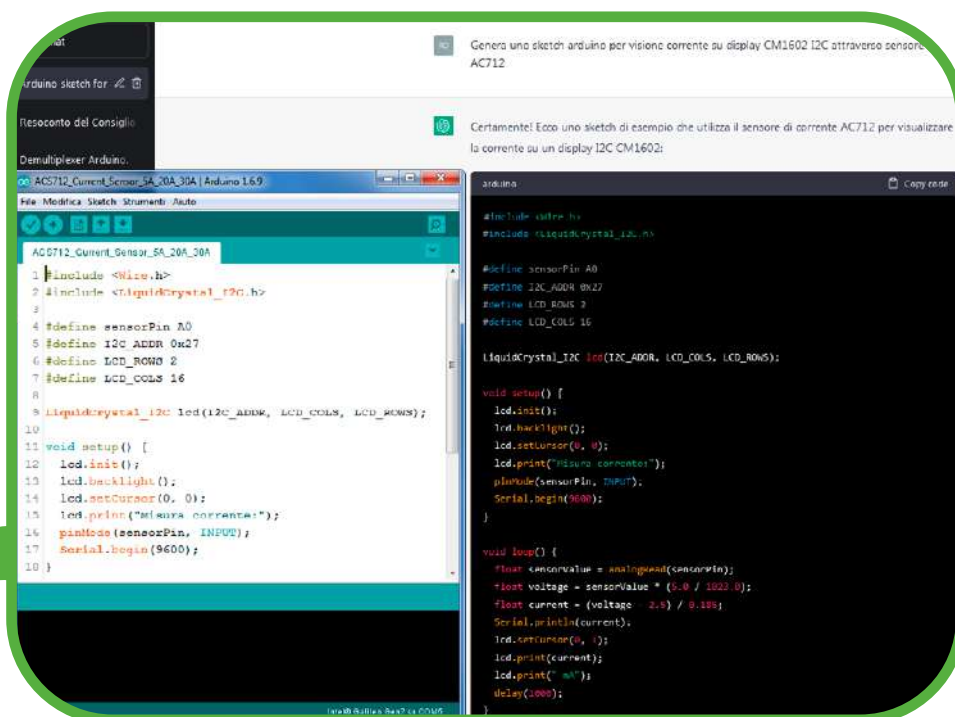


Figure 2: The prototype's component arrangement.

40 ChatGPT and Arduino

Figure 1: ChatGPT's answer to my request.



```

#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define sensorPin A0
#define I2C_ADDR 0x27
#define LCD_ROWS 2
#define LCD_COLS 16

LiquidCrystal_I2C lcd(I2C_ADDR, LCD_COLS, LCD_ROWS);

void setup() {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Misura corrente");
  pinMode(sensorPin, INPUT);
  Serial.begin(9600);
}

void loop() {
  float sensorValue = analogRead(sensorPin);
  float voltage = sensorValue * (5.0 / 1023.0);
  float current = (voltage - 2.0) / 0.185;
  Serial.println(current);
  lcd.setCursor(0, 0);
  lcd.print(current);
  lcd.print(" mA");
  delay(1000);
}

```



By Roberto Vallini (Italy)

ChatGPT and Arduino are two of the most exciting technologies of our time. Curious what happens when you use AI to program Arduino? Let's take a look.

ChatGPT is an artificial intelligence-based natural language model developed by OpenAI, an artificial intelligence research company founded in 2015 by Elon Musk, Sam Altman, and other investors. The model was first released in June 2020, and has caused a worldwide sensation due to its ability to generate highly coherent and plausible text. The basic ChatGPT model, known as GPT-1, was developed by OpenAI in 2018. It was trained on a large corpus of English-language text and proved to be able to generate high-quality text in a wide range of contexts. Since then, OpenAI has continued to further develop the GPT model, releasing several increasingly advanced versions, such as GPT-2 and GPT-3. These versions have continued to improve

the model's ability to generate high-quality text, ranging from simple sentences to whole articles, to code generation and high-quality responses on a wide range of topics. The use of ChatGPT and similar models has revolutionized the way people interact with technology, offering new possibilities in fields such as virtual assistance, content generation, translation, and more. As AI advances, it is possible that models such as ChatGPT will continue to improve and offer new and interesting applications in the near future.

In my project, I started the challenge with this AI to program Arduino, or rather to assess the ability for a neophyte to have a code or Sketch ready to use. Well, it all worked well, and I must say that it worries me a little. I wouldn't want novice makers to see it as a shortcut to their problems. Also, you should have knowledge of datasheets and general electronics-related principles. And the soldering iron must always be at-hand in your workshop, maybe with a nice self-built variable power supply. With that said, ChatGPT is a nice challenge.

Getting Started with ChatGPT

In the digital age in which we live, we increasingly turn to virtual assistants for answers to all our questions. One such assistant is ChatGPT, which can understand and answer users' questions using advanced natural language processing techniques. To ask ChatGPT a question, the first step is to access the website (<https://chat.openai.com>) or the platform where it is available. Typically, you will find a chat box

or a button dedicated to the 'Ask ChatGPT' function. Once found, you can write your question in the chat box and send it to ChatGPT for a response. It is important to be careful with the wording of your question, as ChatGPT relies solely on the text you enter to provide an answer. Therefore, it is advisable to ask clear and concise questions and avoid using language that is too technical or complex. Also, to get the most accurate and relevant answer possible, it is advisable to provide all details relevant to the question.

Once the question has been submitted, ChatGPT will process the text and provide an answer within a few seconds. The answer may be short or extended, depending on the complexity of the question and the information requested. In any case, it is important to read the answer provided carefully and, if necessary, ask additional questions or request clarification.

In summary, ChatGPT is an AI that is always available to provide quick and accurate answers to all users' questions. Thanks to its advanced natural language processing techniques, ChatGPT can understand the meaning of questions and provide relevant answers. However, for best results, it is important to ask clear and concise questions and to provide all details relevant to the question.

Listing 1: The code output from ChatGPT.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define sensorPin A0
#define I2C_ADDR 0x27
#define LCD_ROWS 2
#define LCD_COLS 16

LiquidCrystal_I2C lcd(I2C_ADDR, LCD_COLS,
LCD_ROWS);

void setup() {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Misura corrente:");
  pinMode(sensorPin, INPUT);
  Serial.begin(9600);
}

void loop() {
  float sensorValue = analogRead(sensorPin);
  float voltage = sensorValue * (5.0 / 1023.0);
  float current = (voltage - 2.5) / 0.185;
  Serial.println(current);
  lcd.setCursor(0, 1);
  lcd.print(current);
  lcd.print(" mA");
  delay(1000);
}
```

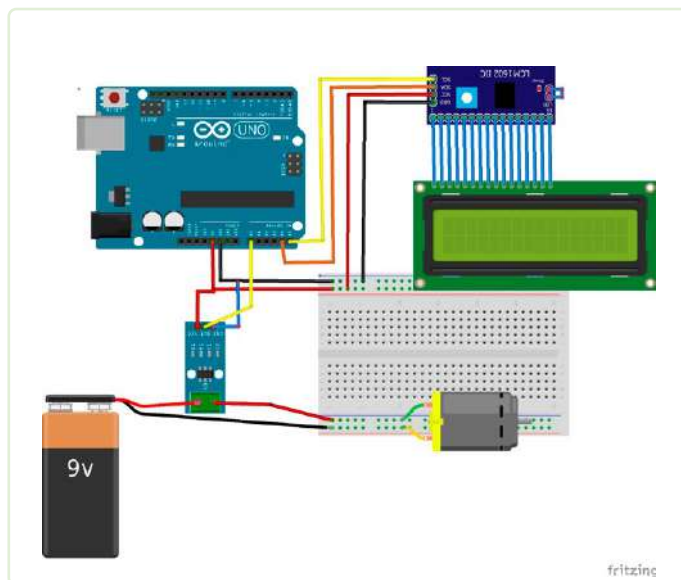


Figure 2: The project's wiring diagram.

Question and Answer

In **Figure 1**, you will see a screenshot showing its answer to the question regarding the generation of an Arduino code for current measurement with ACS712 and display on LCM1602 display with I²C communication. In this sketch, the ACS712 current sensor is connected to pin A0 of the Arduino. The sensor measures the current flowing through it and converts this current into a voltage using the scaling factor of 0.185 V/mA. The current value (proportional to this voltage) is then visualized on the I²C LCM1602 display in milliamperes (mA). The display is initialized in the `setup()` function, while in the `loop()` function, the voltage is read from the sensor and converted to a current before being shown on the display. The current is also printed in Serial Monitor for diagnostics. The code copied and pasted from ChatGPT is shown in **Listing 1**. ◀

230253-01

About the Author

Roberto Vallini is an electronics engineer. After graduating from high school, he worked for almost 20 years in a multinational process electronics company, where he reached the position of area manager. He then founded his own company in the electromechanical sector. Currently, Vallini is involved in information and technical publishing, writing for many electronics news magazines. When he discovered the world of Arduino, it was "love at first sight."



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ZD Meter

Measuring Z Voltages of Z Diodes $\leq 100\text{ V}$

By Giovanni Carrera (Italy)

Every electronics engineer collects old components in some drawer, because they “can be used again sometimes.” However, with time, illegible or incomprehensible inscriptions, it is not always clear what these components can do. With Zener diodes, there is also the question: “Are they still okay?” With the help of this ZD Meter, these ambiguities can be eliminated.

For material for my prototypes, I often obtain many components from boards that I have salvaged from old devices. I’ve been using the measuring device described here for years to measure the reverse voltage of Z diodes. It is also suitable for testing normal or Schottky diodes. It delivers a measurement voltage of up to 100 V with a switchable constant current of 5 or 10 mA. It can therefore also be used to test glow lamps or neon bulbs. However, it is not recommended for testing LEDs, as their reverse voltage is usually only specified up to 5 V and they therefore quickly become defective when connected in reverse direction.

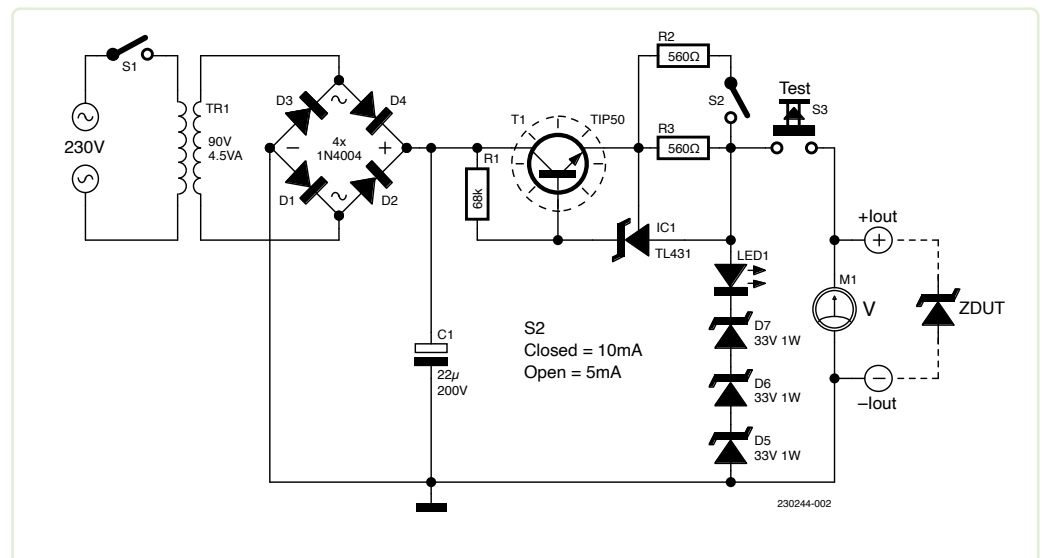


Figure 1: Schematic of the simple ZD Meter.

Circuit Diagram

Figure 1 shows the ZD Meter’s circuit diagram. The basis is IC1, a TL431 shunt regulator, whose voltage range has been massively extended with the help of T1. In this circuit, this combination results in a stabilized current source with a voltage range of between 0 V and over 200 V. This behavior results from the fact that IC1 tries to adjust the voltage dropping across it so that a voltage of $V_{ref} = 2.5\text{ V}$ always drops across R3 (and R2). At $560\ \Omega$ for R3, this leads to a current of about 4.5 mA. With S2 closed, the current doubles to 9 mA. Added to this is the current flowing through R1. In the TL431 datasheet [1], this current is referred to as I_{KA} .

Since the voltage of small mains transformers is usually a good 20% above the nominal value at low load, a DC voltage of about 150 V is present at C1. At rest, i.e. without ZDUT (**Z** Diode **U**nder **T**est) connected or with S3 open, the voltage at the output of the current source (or at the anode of LED1) rises to the sum of the Z voltages of all the three Z diodes, D5...D7, plus the forward voltage

of LED1. M1 can thus measure a voltage of about 100 V when S3 is pressed without a ZDUT connected. Back to I_{KA} : The difference of 150 V and 100 V must therefore drop across R1, resulting in an I_{KA} of 0.5 mA. If the output is short-circuited and S3 is closed, nearly 150 V is present at R1, and, as a result, this value increases to $I_{KA} = 1.5\text{ mA}$. The flowing and only “relatively constant” current at the output terminals of the circuit is therefore between 5 and 6 mA, depending on the voltage, and about 9.5 to 10.5 mA when S2 is closed.

To avoid the output sockets being live all the time, I have provided pushbutton S3. If S2 is closed, the current doubles from 5 mA to about 10 mA. LED1 lights up when S3 is not pressed, or when no ZDUT is connected while S3 is pressed. If S3 is pressed and e.g. an 82 V Z diode is connected to the output the correct way around, the voltage at M1 and at the anode of LED1 will be limited to 82 V. As a result, no more current flows through D5 to D7 and the LED remains dark. If a Z diode or a normal diode is connected in the

Zener and Z Diodes

The two terms stem from the fact that there are at least two general types of diodes used to generate stable voltages. For Z diodes with voltages below 5 V, the so-called Zener effect (based on the tunnel effect of electrons) dominates with its negative temperature coefficient. Above 5 V, the avalanche effect with its positive temperature coefficient becomes more and more effective. At voltages between 5 and 6 V, there are currents at which both temperature coefficients compensate each other to about 0 mV/K. Strictly speaking, there is even a third type: diodes with voltages below 1.8 V. A diode with 1.5 V is not a “real” Zener diode, but just two serial normal diodes in one package, not reverse-biased, but forward-biased. The same applies to typical 0.7 V Zener diodes — they only have one p-n junction like normal diodes, which are also used in the forward direction.

forward direction, the voltage drops to 0.7 V and LED1 does not light up, either. But, be careful: Not all “normal” diodes can handle 100 V in the reverse direction.

Some Notes

Perhaps the most difficult thing is to find a small transformer for Tr1 with 90 V on the secondary side. You might be able to find a transformer with 2×48 V secondary windings. Its secondary windings in series lead to a combined secondary voltage of 96 V, which is no problem. You may also use two smaller transformers of about 2.5 VA and a secondary voltage of 48 V. Their primary windings will then be connected in parallel and their secondary windings in series — in the correct phase, of course.

Why these relatively high voltages? Z diodes are available with voltages from 1.5 to over 100 V. With a maximum test voltage of 100 V, the vast majority of Z diodes should be covered. By the way: Reading this far, have you thought about why the term “Z diode” is used? Why not Zener diode? The **Zener & Z Diodes** frame explains the terminology.

For T1, a high voltage, medium-power NPN transistor is used. Its V_{CE} should be above 200 V. Because 10 mA multiplied by 150 V leads to a power of about 1.5 W, T1 must be equipped with a small heat sink.

The circuit is so simple that you can easily build it on a breadboard. However, because of the voltages of 100 V and more, you should be cautious and maintain safe distances between components on the board. I built the electronics into a plastic housing and used a three-digit DVM module with a voltage range of 0...99 V for M1 (**Figure 2**). The red LED is an On indicator and the yellow LED labelled O.C. is LED1. It goes without saying that, after successful assembly, care should be taken when testing Z diodes due to the “tingling” voltage. ◀

230244-01

About the Author

Giovanni Carrera holds a degree in electronic engineering. As a university professor in the Faculty of Naval Engineering in Genoa, Italy, he taught numerous courses, such as naval automation and the simulation of ship propulsion systems. Carrera started working in the late 1970s with the 6502 CPU and then moved on to other processors. Today, he enjoys the design and development of analog and digital electronic circuits, many of which he has written about on his blogs (ArduPicLab and GnssRtkLab) and in various magazines.



Figure 2: My prototype has served me well for many years.

Questions or Comments?

Do you have technical questions or comments about this article? Email Elektor at editor@elektor.com.



Component List

Resistors:

R1 = 68 k, 2 W
R2, R3 = 560 Ω

Capacitor:

C1 = 22 μ / 200 V, electrolytic

Semiconductors:

D1..D4 = 1N4004
D5..D7 = 33 V Z diode, 1.3 W
LED1 = LED, yellow, 5 mm
T1 = NPN transistor, $V_{CE} \geq 200$ V, e.g. TIP50
IC1 = TL431

Miscellaneous:

S1, S2 = 1 A / 230 VAC SP switch
S3 = 1 A / 230 VAC push button
M1 = DVM module 3 or 2.5 digits, range 100 V
Tr1 = 90 V sec. transformer (see text)
Heat sink for T1
2 sockets, 4 mm



Related Product

► Joy-IT VAX-1030 Wireless Multifunction Meter
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WEB LINKS

[1] Datasheet TL431: <https://ti.com/lit/gpn/tl431>

42 Servo Tester

By Stefano Purchiaroni (Italy)

Here comes a practical and inexpensive circuit to test any type of servo motor, with up to 1 A maximum absorption.

The circuit diagram of this project (see **Figure 1**) is minimalistic — most of the work is done in software. The circuit employs a Microchip PIC16LF1554 microcontroller operating with an internal clock of 16 MHz, and a 7805 voltage regulator. To avoid overheating, do not supply it with too high a voltage. Adjustment of the axis positions of four servo motors is possible by operating four 10 kΩ potentiometers (RV1...RV4).

Software

The control logic is handled by a program written in mikroC PRO for PIC (must be Version v5.6 or higher). You can see the code in **Listing 1**; it is also provided for download [1]. The code is easily portable under other compilers, but the value I found experimentally for the `delay_us()` function may require some revision.

The potentiometer values, measured by the ADC, are mapped to internal values 0...99, determining the servo position. The `img` array holds the duration of the pulses to be sent to the servos. It is populated by a chain of "1" values, with a length from 0 to 99. In fact, there are four individual chains encoded at different bit positions — each one stands for one pin/channel/servo.

We first send a fixed pulse of about 0.5 ms to the servo, then we continue with a variable pulse length in 100 steps, determined by the "1" values in the `img` array:

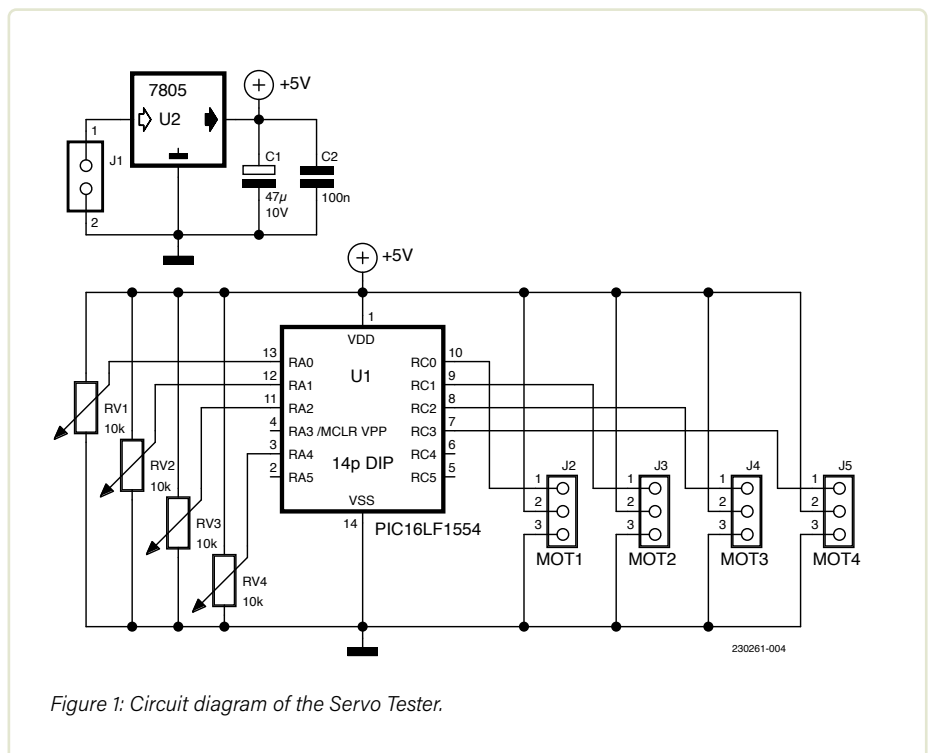


Figure 1: Circuit diagram of the Servo Tester.

```
// Set all outputs to High
PORTC = 0b11111111;

// Fixed first pulse at High
delay_us(500);

// Playback of prepared sequence
for (i = 0; i < 100; i++) {

    PORTC = img[i];

    // Value from experimentation
    delay_us(14);
}

// Turn off all motor pulses
// after playback
PORTC = 0;
```

The maximum of the pulse length is about 2.5 ms. True, the servo datasheets report a different interval to cover all servo positions: 1 to 2 ms. But, practice shows that the maximum servo extension is achieved by widening this operating window. It is always possible, however, to operate the potentiometers in a more limited range where necessary.

I put a demonstration video on YouTube [2]





Some Notes

The code is adaptable for other microcontrollers with more pins, to handle more servo motors.

The wiring diagram in Figure 1 can be unraveled by using a PCB that you can find in the downloads. Adapt the PCB to the measurements given in **Figure 2** before etching. ◀

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Related Products

- **FeeTech FS90 Micro Servo with Accessories**
<https://elektor.com/19788>

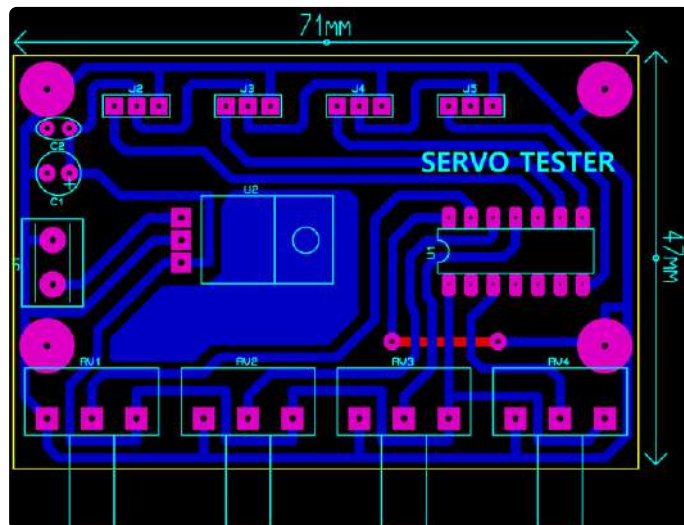


Figure 2: Scale the PCB copper layout ([1]) to the dimensions shown here.

WEB LINKS

- [1] Downloads for this article: <https://elektormagazine.com/230261-01>
- [2] Demonstration video: <https://youtu.be/LFJw72H-8GI>



Listing 1.

```
//=====
//
// Servo Tester: drive up to 4 Servo Motors          SPU 12.2022
//
// It generates a 50 Hz pulse sized 0.5-2.5 ms by manual trimpot
// on four independent channels.
//
// By SPU (info@purchiaroni.com) - Rome (IT)
//
// MCU Model:      PIC 16LF1554
// Oscillator:     Internal 20 MHz
// Compiler:       MikroC Pro 5.61 or higer
//
// Email me for schematic and documents: info@purchiaroni.com
// Homepage: www.purchiaroni.com
//
// Changes log
// 14.12.2022 - Code creation
//=====
// Timer1 preload value calculated for interrupt each 20ms (50 Hz pulses)
#define TMR1H_INI    0x63
#define TMR1L_INI    0xC0
// Various
#define OFF          0
#define ON           1
#define FALSE        0
#define TRUE         1
unsigned short img[100]; // Data for channels playback (max 8 channels)
int t1, t2, t3, t4;     // Times for pulses width
```



```
void TrimPots_Read() {
    // Map 0..1023 to 0..100 steps
    // (101, 102 values truncated by "for" cycles during playback)
    t1 = ADC1_Read(0) / 10;
    t2 = ADC1_Read(1) / 10;
    t3 = ADC1_Read(2) / 10;
    t4 = ADC1_Read(10) / 10;
}

//*****
// Interrupt management procedure
//*****
void interrupt() {
    // Interrupt Service Routine. Called on any interrupt
    int i;          // Generic local variable
    // ---TMR1---: Manage Timer1 overflow (each 0.1s)
    // to update remaining time
    if (PIR1.TMR1IF == TRUE) {
        // Keep Timer1 running
        TMR1H = TMR1H_INI;    // Reload counter high byte
        TMR1L = TMR1L_INI;    // Reload counter low byte
        PIR1.TMR1IF = FALSE;  // Clear TMR1 Interrupt flag

        PORTC = 0b11111111;    // Set all outputs to High
        delay_us(500);          // Fixed initial pulse at High level
        for (i = 0; i < 100; i++) { // Play back the prepared sequence
            PORTC = img[i];
            delay_us(14);        // Value derived by experimentation...
        }

        PORTC = 0;            // Turn off all motor pulses after playback
        TrimPots_Read();      // Update the potentiometers' readings
        // Prepare a new sequence on the basis of last readings
        for (i = 0; i < 100; i++) {
            img[i] = 0;
            if (i <= t1) img[i] |= 0b0001;
            if (i <= t2) img[i] |= 0b0010;
            if (i <= t3) img[i] |= 0b0100;
            if (i <= t4) img[i] |= 0b1000;
        }
    }
}

void StartTimer() {
    // Timer1 Registers: Prescaler=1:2; TMR1 Preset=25536;
    // Freq=50,00Hz; Period=20,00 ms
    T1CON = 0b00010101;
    T1GCON = 0;
    // Settings for interrupt management
    INTCON.GIE = TRUE;          // Global Interrupt Enable
    INTCON.PEIE = TRUE;         // Peripheral Interrupt Enable
    // Start the Timer1 and then the Countdown
    TMR1L = TMR1L_INI;          // preset for timer1 LSB register
    TMR1H = TMR1H_INI;          // preset for timer1 MSB register
    PIE1.TMR1IE = TRUE;         // Timer1 Interrupt enable
    PIR1.TMR1IF = FALSE;        // Clear TMR1 Interrupt flag
}

//*****
// MAIN
//*****
void main() {
    int i;                      // Generic local variable
    // Oscillator and ports settings
    OSCCON = 0b01111000;        // Internal clock 16 MHz
    ANSELA = 0b11111111;        // PORTA analog
    TRISA = 0b11111111;         // PORTA input
    TRISC = 0b00000000;         // PORTC output
    ADC1_Init();                // Initialize ADC #1
    StartTimer();               // Start TMR1
    for (i = 0; i < 100; i++) img[i] = 0; // Clear the data image
    do { delay_ms(1000); } while (1);   // Idle. Operations managed by ISR
}
```


43 ESP32 Windows Controller with Free Software

Contributed by Matrix

Here is a little project that you can put together if you have a spare ESP32 in your drawer: It's a customisable general-purpose motor controller, input-output device and input voltage monitor. The project is based on an ESP32 device, communicating via Wi-Fi with a user interface on your PC.

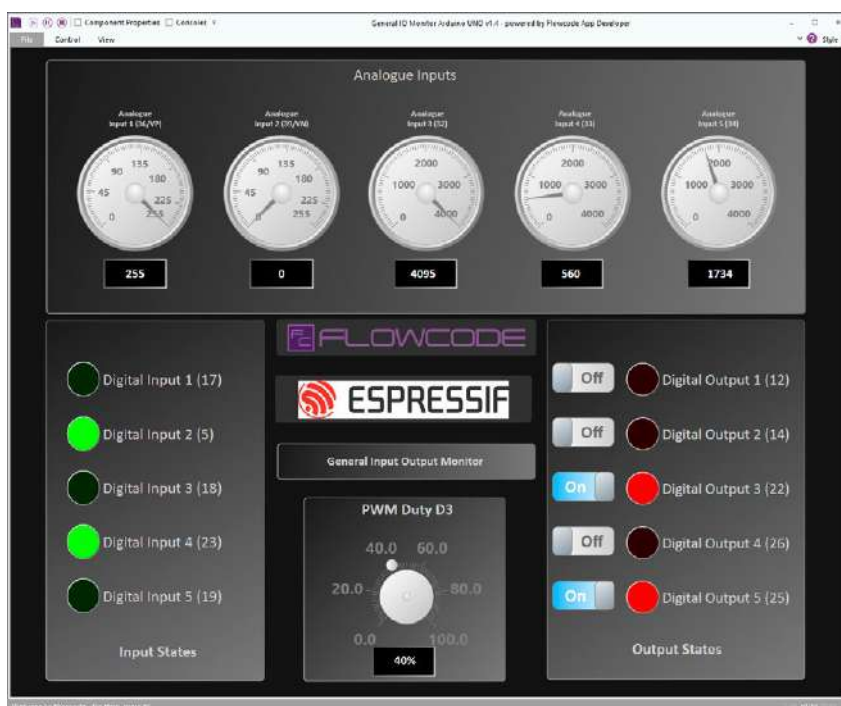
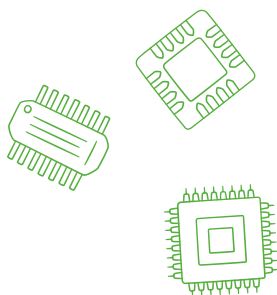


Figure 1: General IO Monitor Arduino UNO.

Flowcode App Developer is a piece of free software that enables you to build human-machine interfaces (HMIs) on Windows PCs, for low-cost controllers such as ESP32, Arduino, and Raspberry Pi as well as for microcontrollers with a USB interface, such as the PIC. Flowcode App Developer allows you to construct Windows HMIs using flowcharts, blocks, or pseudo code, which means it is very easy for beginners to produce quite complex systems.

As an example, here is an ESP32 I/O monitor that has 5 digital inputs, 5 digital outputs, 5 analog inputs and 1 PWM control output

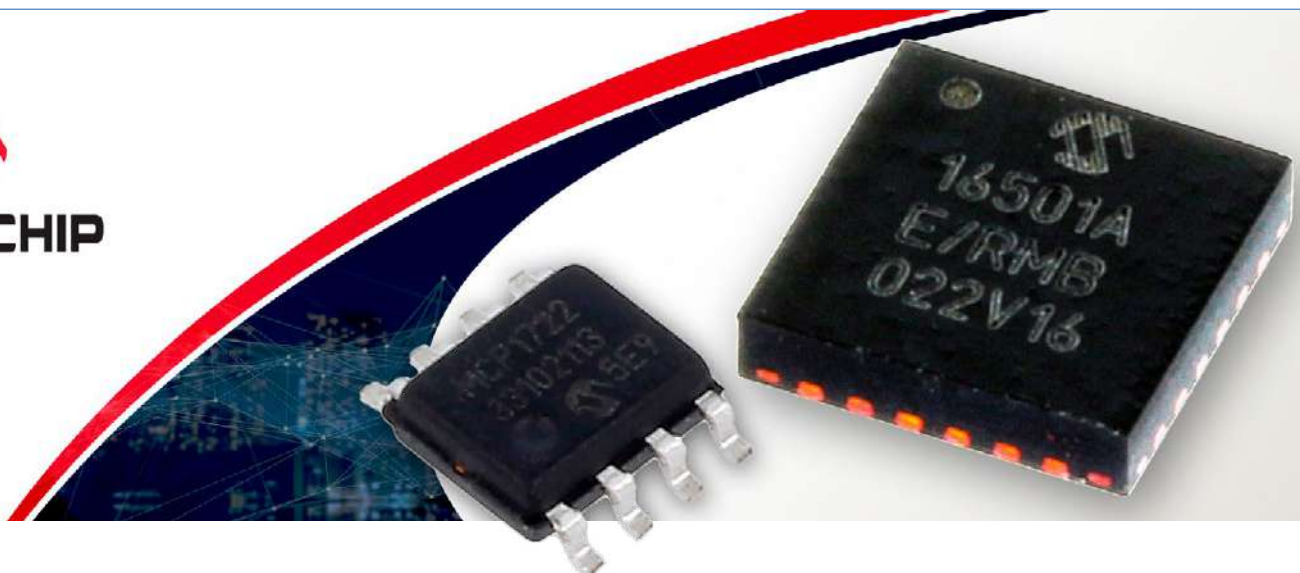
(see **Figure 1**). This can be expanded further to up to 30 digital inputs, 30 digital outputs, 6 analog inputs, 7 PWM outputs, 6 servo controllers, a 1 Wire, I²C, and SPI interfaces.

You can find out how to put this together from the Flowcode website [1]. Flowcode itself and the project's source code are available as a free download. ◀

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WEB LINKS

[1] Flowcode: <https://flowcode.co.uk/>



Analog and Mixed-Signal ICs by Microchip

Low-Consumption Power Management and Signal Processing

Contributed by Transfer Multisort Elektronik Sp. z o.o.

Microchip is primarily known as a manufacturer of microcontrollers, microprocessors, memory, and other integrated circuits. However, this supplier also offers a wide range of innovatively designed analog and mixed-signal circuits that can be used in modern applications. These products are manufactured for consumer and industrial solutions, mobile devices, computers, precision electronics, as well as automotive applications.

Below, we present three series of Microchip [1] products intended for power management, voltage regulation, and analog signal processing. We invite you to go to our online catalog and learn more about the full range of Microchip products.

PMIC Solutions by Microchip

We have already described the power-management IC (PMIC) solutions offered by Microchip in a separate article [2]. Here, we will focus only on general informa-

tion about these products. These DC-DC converters combine small size with high functionality. Their main area of application is supplying power to circuits containing microcontrollers and more complex microprocessor systems. PMICs can be powered by typical lithium-ion and lithium-polymer battery voltages (that ranges from 2.7 V to 5.5 V DC). The capabilities of these products suit the challenges faced by professionals who develop electronic circuits intended for mass production (see **Table 1**).

The MCP16502 ICs support dynamic voltage scaling (DVS) power saving technology. This series features four independent channels of DC/DC regulators and enables sequencing of peripherals. The circuits are available in a 32-pin, 5×5 mm VQFN package. These products' functionality may be used in many applications in order to manage the power supply of all components in the circuit. What is more, the MCP16502 can be managed externally through the Inter-Integrated Circuit (I²C) bus.

Microchip offers DT100105 evaluation boards [3], with which you can conduct comprehensive tests of PMICs' operation to simplify their implementation in your prototype project.

Table 1: Needs and challenges

Needs	Challenges
Providing different values of input voltage and enabling sequential switching in order to ensure that the device works in a stable manner.	<ul style="list-style-type: none"> ➤ an increased number of components ➤ a larger PCB area for the power supply section ➤ higher cost of the circuit
Taking into account current capacities utilized by different types of memory.	<ul style="list-style-type: none"> ➤ the power supply circuit depends on the type of memory used ➤ it takes longer to develop a universal solution
Making the current capacity of the power supply system dependent on the microcontroller's operating mode.	<ul style="list-style-type: none"> ➤ virtually impossible to use in applications that are solely based on discrete components ➤ inefficient energy consumption

MCP1722 LDO Linear Voltage Regulator

Nowadays, devices designed for consumer use (though not exclusively) are battery-powered. Rechargeable batteries are characterized by high amperage and a relatively long work cycle. However, their major disadvantage is that the voltage produced by these batteries can drop by as much as 20% as the discharge progresses. Although a number of circuits, DC/DC converters, and other components that help stabilize voltage are available on the market, using them in your project may cause some undesired consequences, such as significant power loss and interference. Low-dropout (LDO) linear voltage regulators are a solution to this problem. They are marked by the lack of switching noise (due to the absence of the keying circuit), smaller device size, simplicity of design, and high power capacity. Moreover, the way these LDO regulators are constructed enables miniaturization and lowers the manufacturing cost (and, consequentially, the application cost).

The MCP1722 circuits deserve recognition not only in the context of Microchip products, but also among other low-dropout regulators available on the market. They are characterized by a wide input voltage range (from 4.5 V to 55 V DC) with UVLO (undervoltage-lockout) at 2.7 V. These products feature dual outputs: one is 3.3 V DC (max. current 50 mA) and the other one is 10 V or 12 V DC with a max. current of 100 mA (depending on the model). These circuits offer an extended operating temperature range (from -40°C to 150°C). Due to their small size, they can be produced in SO8 and VDFN8 SMD packages. Moreover, the MCP1722 features thermal shutdown protection and current foldback limiting to protect the circuit itself and the system in which it is installed. *Power Good* open-drain leads are used to monitor the regulator's operation by indicating that the power supplied to its outputs has the correct parameters. A crucial feature of this product is that it has a very

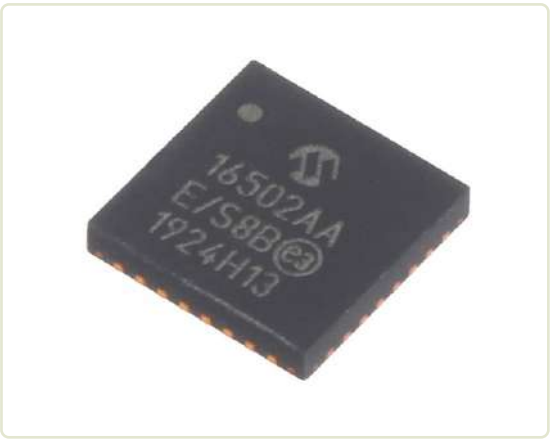


Figure 1: The VQFN32 package makes it possible to fit the circuit into a 5×5 mm case.

low quiescent supply current of 50 µA when inactive. If the project makes use of the *shutdown* feature (the IC has a dedicated SHDN pin), the supply current will be typically lowered to 4 µA when the regulator operates in Sleep mode.

A very low dropout voltage, a low voltage ripple, and a precise output voltage (±2%) makes the MCP1722 an ideal solution for a wide range of applications. In addition,

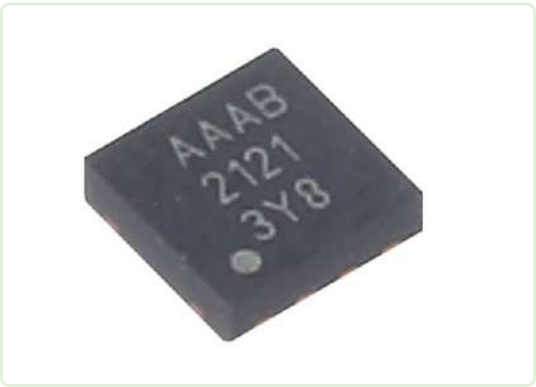


Figure 2: MCP1722 regulators are available in SO8 and VDFN8 packages.

Figure 3: All MCP648X amplifiers are suitable for surface-mounting.



the product is AEC-Q100 qualified, so it can be used in a wider range of systems, e.g. in onboard equipment in the automotive industry (for example in window control modules and audiovisual head units). The Microchip regulators can also be used in wireless control modules in electrical tools (such as drill drivers and chainsaws), home equipment, and home appliances (electric toothbrushes and hairdryers), and in drones and RC models, where a light weight and compact construction is of key importance. A single MCP1722 regulator has the ability to power a microcontroller and supply the right voltage to a *gate driver* (which takes part in controlling the H-bridge and the electric motor). Therefore, it is possible to lower the size and weight of the PCB.

MCP6486/7/9 Operational Amplifiers

Operational amplifiers are another noteworthy group of analog integrated circuits produced by Microchip. This family is offered in single (MCP6486), dual (MCP6487), and quad (MCP6489) packages. All of these products operate at voltages ranging from 1.8 V to 5.5 V and at frequencies of up to 10 MHz.

Operational amplifiers are an inseparable part of analog and mixed-signal applications. They are most frequently implemented in circuits that contain analog (pressure, temperature, humidity, etc.) sensors, for output signal processing to adapt the signal to the parameters demanded by receivers, actuators, and A/C converters.

Additionally, op-amps are very often used for amplifying the output signal supplied by digital-to-analog converters (DAC). What's more, they simplify the process of signal polarity inversion and facilitate noise filtering, which can be incredibly useful.

The MCP6486/7/9 amplifiers combine the most desired features, namely low quiescent current (720 μ A maximum per amplifier), high noise resistance and low power consumption in the standard operating mode. These products have electromagnetic interference (EMI) protection with a common mode rejection ratio of 61 dB at 1.8 GHz. They also offer a low max. input offset voltage of ± 1.6 mV, which is relevant in the case of low-value signals. Additionally, the amplifiers are characterized by a fast start-up time of 2.3 μ s and an extended operating temperature range (from -40°C to 125°C).

Microchip amplifiers come in several package types (in different lead variants): MSOP8, SC70-5, SO8, SO14, SOT23-5, and TSSOP14. Like the regulators described above, these products are AEC-Q100 qualified, which means that they can be used in the automotive industry (in fuel pump controllers, lighting systems, or even power mirrors). Their technical parameters allow them to be used in industrial solutions (in power supplies, pressure detectors, and optoelectronic gas and liquid flow meters), as well as in the medical field (for example in patient-monitoring systems or biochemical sensors used for blood testing) and in consumer solutions (in humidity, temperature, and movement monitoring systems, gas and smoke detectors, GPS trackers, and many more).

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WEB LINKS

- [1] Microchip Technology linecard: https://tme.eu/en/linecard/p,microchip-technology_632
- [2] PMIC solutions by Microchip: <https://tme.eu/en/news/library-articles/page/43320/pmic-solutions-by-microchip>
- [3] DT100105 evaluation boards: <https://tme.eu/en/details/dt100105/microchip-development-kits/microchip-technology>

Interface Standards

Filter and Surge Protection for the I²C Bus

By Andreas Nadler (Würth Elektronik)

The communication of microcontrollers with their peripheral devices often takes place via the I²C bus. The longer the transmission distance, the more susceptible to interference the communication becomes. With a suitable filter and protection circuit, interference immunity can be significantly increased.

The I²C bus (Inter-Integrated Circuit) is a popular serial communication interface used mainly to connect microcontrollers to peripheral ICs (for example, sensors or memory). The bus uses one bidirectional data line (SDA) and one clock line (SCL). The bus is used not only within circuit boards, but, in many applications is also extended to other areas with the aid of various connectors and cables. This makes the I²C bus potentially more susceptible to external interference such as ESD, burst, and radiated RF noise. The aim of this article is to suggest a suitable filtering and protection circuit that increases the noise immunity of the I²C bus without sacrificing the signal quality of the data and clock lines. For this purpose, simulation models were created in LTspice and a real application was measured to verify the simulation results.

I²C Bus Topology

The I²C bus works according to the "master-slave" principle, where the master always initiates the data transfer. Due to its low complexity, the bus has achieved wide distribution, but its protocol is designed very simply and the

physical topology is only single-ended. In practice, both of these aspects mean that the bus can be very susceptible to external interference (for example, during EMC tests).

Table 1 provides an overview of the I²C specifications.

All ICs that participate on the bus have open-collector outputs (**Figure 1 left**). These can switch the pull-up resistors reference ground, and thus generate logical states 1 (V_{CC}) and 0 (GND). As can be seen in Table 1, the maximum permissible edge rise times decrease as the data rate increases. The mathematical relationship of the min./max. values for the pull-up resistors is given by **Equations 1 and 2**.

$$R_{\text{Pullup_min}} = \frac{(V_{CC} - V_L)}{I_{\text{Pullup}}} \quad (1)$$

$$R_{\text{Pullup_max}} = \frac{t_r}{(0,8473 \cdot C_{\text{BUS}})} \quad (2)$$

V_{CC} = I²C bus reference voltage level (volts)

V_L = Max. logic 0 threshold (e.g., 0.4 V with $V_{CC} > 2$ V)

C_{BUS} = Application's max. parasitic bus capacitance (farads)

t_r = Max. permissible rise time, depending on data rate (seconds)

$I_{\text{Pull-up}}$ = Max. possible current through the open collector pins (amperes).

The pull-up resistors [1] in combination with the parasitic bus capacitance form an RC element. This leads to a delay of the edge rise time of the square wave signal. In many applications, this RC element is often the limiting factor in terms of the maximum possible data rate and cable length. As can be seen in Table 1, the I²C specification therefore results in a maximum bus capacitance of 400 pF at 3 mA current for the most commonly used data rates (100 kbit/s and 400 kbit/s). The smaller the pull-up values selected, the shorter the edge rise time can be. As can be seen in Equation 1, the lower limit determines the maximum logic low threshold, the reference voltage level, and the maximum possible current.

Table 1: I²C bus specifications at a glance.

Mode	CLK	Max. data rate	Max. rise time 0.3 – 0.7 V _{CC}	Max. bus capacitance	Max. current
Standard	100 kHz	100 kbit/s	1000 ns	400 pF	3 mA
Fast	400 kHz	400 kbit/s	300 ns	400 pF	3 mA
Fast+	1 MHz	1 Mbit/s	120 ns	550 pF	20 mA
High Speed	3,4 MHz	3.4 Mbit/s	10 ns	100 pF	3 mA

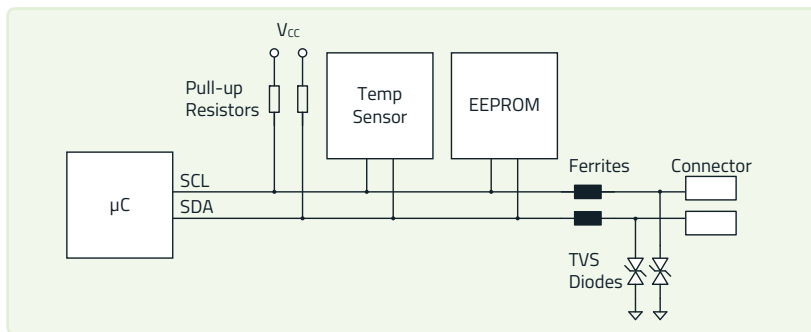


Figure 1: Simplified block diagram of an I²C bus with pull-up resistors (left) and ferrites and TVS diodes (right) as interface protection for improved noise immunity and reduced interference emission.

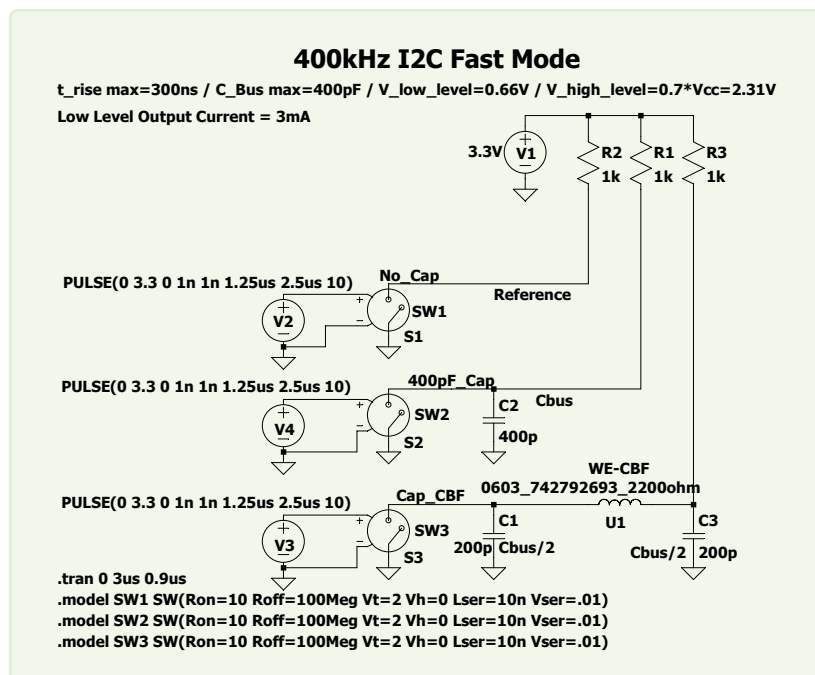


Figure 2: Schematic of LTspice simulation with 3 channels 0 pF, 400 pF, and 400 pF + multilayer SMT ferrite.

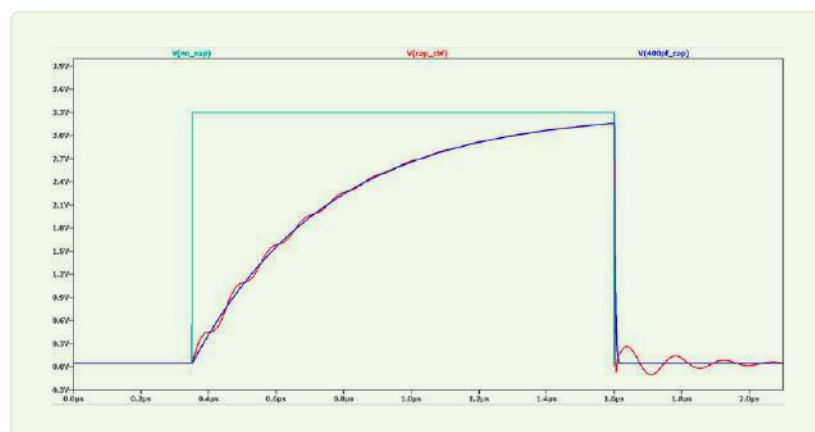


Figure 3: LTspice simulation result time domain 0 pF (turquoise), 400 pF (blue), and 400 pF+ multilayer SMT ferrite (red).

The parasitic bus capacitance depends on, among other things:

- component capacitances
- length and width of the traces (approx. 0.5 pF/cm)
- length and type of cables & connectors
- PCB layer structure and dielectric constant

Selection of Filter and Surge Protection Components

In order to increase immunity to ESD, burst, and radiated RF signals, a combination of SMT ferrites plus TVS diodes is recommended (Figure 1 right). Wideband SMT ferrites (e.g., 742792693) continuously build up impedance above 10 MHz and are therefore able to protect the bus against radio-frequency interference. Overvoltages can also be effectively diverted to reference ground by the TVS diodes.

Since the values of the pull-up resistors are often in the kΩ range, the RDC and the impedance of SMT ferrites below 10 MHz play only a minor role here. Thus, in a first consideration, it can be assumed that the edge rise time of the useful signal is hardly influenced. If suitable TVS diodes with low capacitances (e.g., the 824012823 @ 0.18 pF) are selected, their component capacitance also has no relevant influence on the signal quality. During an ESD test, for example, a current of more than 10 A can flow briefly, which then causes the application of a voltage of approximately 10 V to this diode.

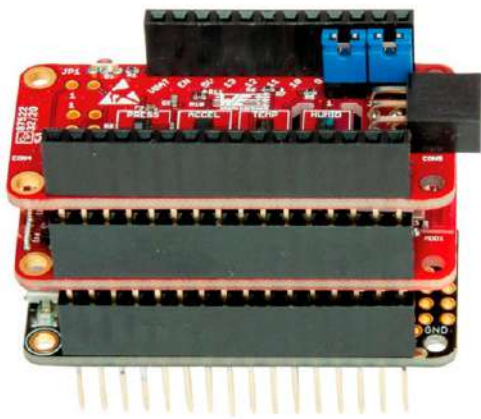
All other ICs on the I²C bus must thus be able to withstand this voltage. This only works if you provide a low-impedance ground (e.g., large copper area in an inner layer) to avoid a further voltage drop.

LTspice Simulation with 400 kHz Clock Frequency

Using the free simulation program, LTspice, it is relatively easy to investigate the influence of the parasitic bus capacitance in combination with the selected pull-up resistors. For a voltage-controlled switch, one selects the *Pulse* function and determines the desired bandwidth based on the desired I²C specification. For the widely used 400 kbps variant, a period of 2.5 µs is selected. For a 50 % duty cycle, the "high" time is set to 1.25 µs. To take advantage of the maximum 400 pF parasitic bus capacitance allowed, the pull-ups have been set to 1 kΩ. Three channels (each may represent SCL or SDA in practice) are simulated (Figure 2):

- without parasitic bus capacitance
- with 400 pF parasitic bus capacitance
- with 400 pF + wideband multilayer SMT ferrite (742792693).

The simulation result in Figure 3 shows that practically no influence on the rise time of the signal can be expected from the multilayer SMT ferrite. Because each multilayer SMT ferrite also has an inductance component, minor oscillations are visible in combination with the bus capacitance. However, these are not critical, since their amplitudes are less than 10% of the actual useful signal.



Measurement at Application with 400 kHz Clock Frequency

To verify the relatively simple LTspice simulation, additional measurements were performed on a SensorBLE FeatherWing kit [2] from Würth Elektronik. This kit consists of a master board with a microcontroller. The other two boards include a WE Bluetooth module and various WE sensors (3-axis acceleration, temperature, humidity, pressure — **Figure 4**). The master board communicates with the other two via I²C bus at a maximum data rate of 400 kBit/s (**Figure 5**). The sensor data can then be visualized using a suitable smartphone app, such as WE-SensorBLE. MLCCs are used to emulate a parasitic capacitance of 400 pF with respect to GND. The multilayer SMT ferrite (742792693) modeled in the simulation was also installed, plus a TVS diode array (824012823). A cable with a length of 20 cm connects the sensor board to the rest of the I²C bus. Such an arrangement can be observed in many applications in practice.

The voltage curve on the SCL line was always measured. The measurements [3] show practically identical results to the simulation (**Figure 6**). Neither the rise time nor the signal quality are negatively influenced by the multilayer SMT ferrite in combination with the TVS diode. The rise time of the high signal, which is critical for the timing, depends only on the bus capacitance in combination with the selected pull-up resistors. With the help of the WE-SensorBLE smartphone app, error-free operation could be verified in all three tested scenarios.

Simulation and Measurement in Harmony

Both simulation and measurement show that SMT ferrites in combination with ESD protection diodes influence neither the I²C bus's data (SDA) nor clock (SCL) signals. The signals' edge steepness is largely influenced by the pull-up resistors in combination with the parasitic bus

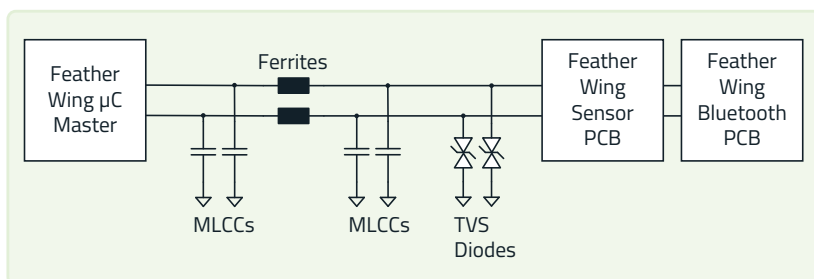


Figure 4: SensorBLE FeatherWing kit from Würth Elektronik, consisting of microcontroller, Bluetooth, and sensor board.

Figure 5: Schematic of the test setup with the SensorBLE-FeatherWing kit from Würth Elektronik.

capacitance. In return, this component combination of ESD protection diode and broadband SMT ferrite increases the bus's noise immunity. In practice, this means, in particular, higher immunity to ESD, burst, and radiated RF signals. ◀

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About the Author

Andreas Nadler graduated from the Kempten Technical School as a state-certified electrical engineer. He then worked for several years as a hardware engineer in the field of switched-mode power supplies and analog circuit technology. Since 2015, Nadler has been a Field Application Engineer at Würth Elektronik eiSos in the business unit for passive and active components. There, he specializes in the design of EMC-compliant power supplies and interfaces, as well as overall interference suppression in electronic assemblies.



Figure 6: Reference measurement with 1 kΩ pull-ups, multilayer SMT ferrite, TVS diode array, 20 cm cable strands, and 400 pF MLCCs (= 344 ns rise time).

WEB LINKS

- [1] R. Arora, "I²C Bus Pullup Resistor Calculation," Application Report SLVA689, Texas Instruments: <https://ti.com/lit/an/slva689/slva689.pdf>
- [2] SensorBLE Featherwing kit: https://we-online.com/en/components/products/SENSOR_BLE_FEATHERWING_KIT
- [3] A. Nadler, "Filter and surge protection for the I²C bus," Application Note ANP121: <https://we-online.com/en/support/knowledge/application-notes?d=anp121-filter-and-surge-protection>

44 Li-Ion Battery Monitor

Residual Charge Indicator Provides Visual Feedback

By Antonello Della Pia (Italy)

A residual charge indicator provides a useful visual indication of battery charge status. Here, you can build one using just a simple “tiny” microcontroller, LEDs, and a few passive components.

Li-ion batteries are steadily becoming more widely used by DIY enthusiasts, but the usefulness of a residual charge indicator is not always taken into account. If you do not want to rely on commercial solutions, this simple design can provide a quick visual indication of battery charge using a Microchip Technology ATtiny45 microcontroller, six LEDs, and a handful of other components.

The basic premise of this project is that the remaining capacity of a single Li-ion cell is proportional to the battery voltage, to a good approximation, and the battery voltage is equal to the microcontroller supply voltage, in this case.

Figure 1: Li-ion monitor schematic.

Monitoring Using Software

Taking a look at the schematic in **Figure 1**, we see that all the magic is done in software. Six LEDs visualize the

battery voltage. You can see that R2 and R3 limit the LEDs' current, C1 and C2 are the usual bypass capacitors, and F1 is a resettable fuse to protect the battery from any circuit faults.

The source code [1] is quite straightforward: Using a well-known trick, the `readVccVoltage()` function measures the supply voltage through direct register manipulation, using Vcc as a reference against the microcontroller's internal reference of 1.1 V, which is used as the ADC input instead.

The accuracy of the measurement depends on the exact value of the reference voltage, which can vary considerably from chip to chip. The ATtiny25 /45 /85 datasheet states that the 1.1 V reference can vary between 1.0 and 1.2 V.

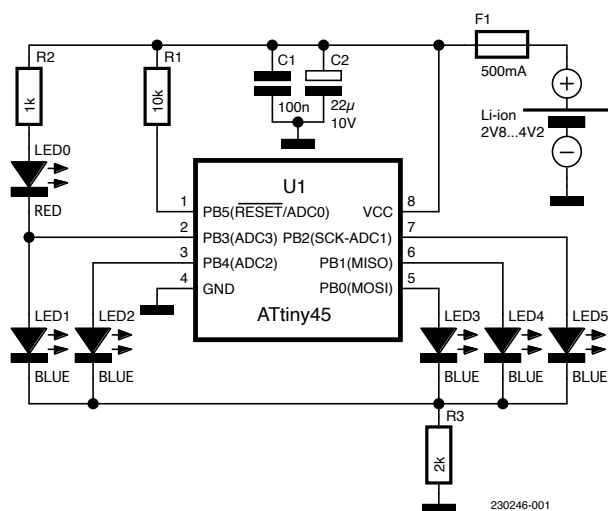
There are special routines to determine the exact value of Vref, but a simple workaround is to experimentally vary the value of Vref until a measurement comparable to that of a digital reference multimeter is obtained. I have included the constant `const float vRef` for this purpose in the sketch.

Next, still in the loop, we find some conditional expressions, which define six small voltage windows that determine whether the corresponding LEDs are switched on or off.

In detail, LED0 (red) lights up at voltages below 3.00 V, LED1 above 3.20 V, LED2 above 3.40 V, LED3 above 3.60 V, LED4 above 3.80 V and LED5 at over 4.00 V. Furthermore, between 3.00 V and 3.20 V, LED0 and LED1 flash alternately.

The alternating blinking of LED0 and LED1 is achieved by changing the state of pin PB3 and adding a certain delay, as in the classic Arduino *Blink* sketch. In our case, when PB3 is high, it drives LED1, and when it's low, it drives LED0.

The voltage ranges can, of course, be modified by code. Bearing in mind that a Li-ion cell is typically considered fully discharged at 3.00 V and fully charged at 4.20 V, reference percentages can easily be defined.

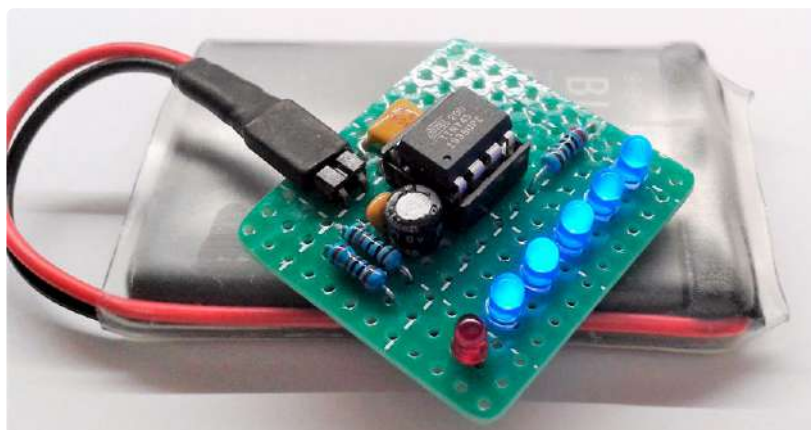


The source code was written and compiled using Arduino IDE 1.8.19 with *ATTtinyCore 1.5.2* by Spence Konde installed. I used a USBasp programmer to flash the MCU. The provided sketch file, *Li-ion_Battery_Monitor.ino*, which includes further comments and information, can be modified and recompiled easily. The Hex file is also available.

Some Notes

Blue LEDs must be high brightness and have a forward voltage (Vf) not exceeding 2.70 V. The total current consumption when the five blue LEDs are switched on (Vcc higher than 4.00 V) is about 2 mA. ◀

230246-01



Related Products

- ▶ W. A. Smith, "Explore ATtiny Microcontrollers using C and Assembly Language," Elektor, 2021
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Figure 2: Li-ion battery monitor construction on perfboard.

Questions or Comments?

If you have any questions or comments regarding this article, you can contact the author at a.dellapia@elettronicaemake.it or Elektor's team at editor@elektor.com.

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- [1] Software at this article's web page:
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Quiz: Circuits from the Past #01

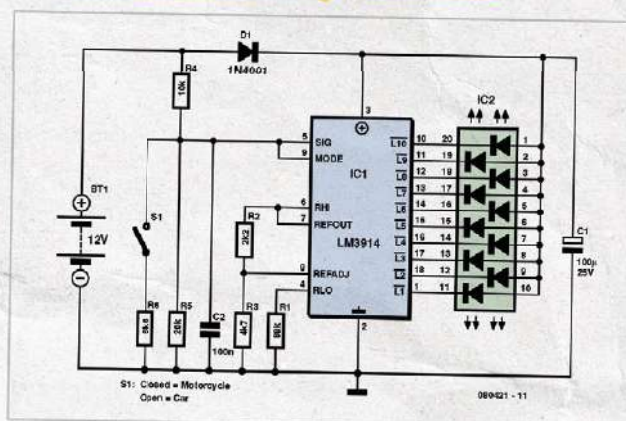
Car & Motorcycle Battery Tester

Joseph Zamnit

Going camping nowadays involves taking lots of electronic equipment whether for day to day running or for fun and entertainment. Most of the time a charged lead-acid battery and a power inverter would be used to ensure a smoothly organised holiday where ideally the missus and the children cheerfully use their electric and electronic gear!

With rechargeable lead-acid batteries it's invariably useful — if not essential — to determine whether the power source you're hauling along on your travels is losing capacity and needs to be topped up. The same circuit would also come in handy when going on a car or motorbike trip as it can check the status of a 12 V (car) or a 6 V (motorcycle) battery. Although the circuit draws so little power that it will not noticeably load the battery under test, it should not be left connected permanently.

The circuit employs the familiar LM3914 (IC1) to display the voltage level. The LED readout creates a battery status readout: when the top LED lights, the battery is fully



charged. When the bottom LED lights, the battery needs imminent charging! Switch S1 selects between 12 V and 6 V operation. A series diode, D1, protects the bargraph driver from reverse supply voltage. A colour-coded display with individual

LEDs could be used instead of the common-anode bargraph display for better indication of the state of the battery.

(030421-6)

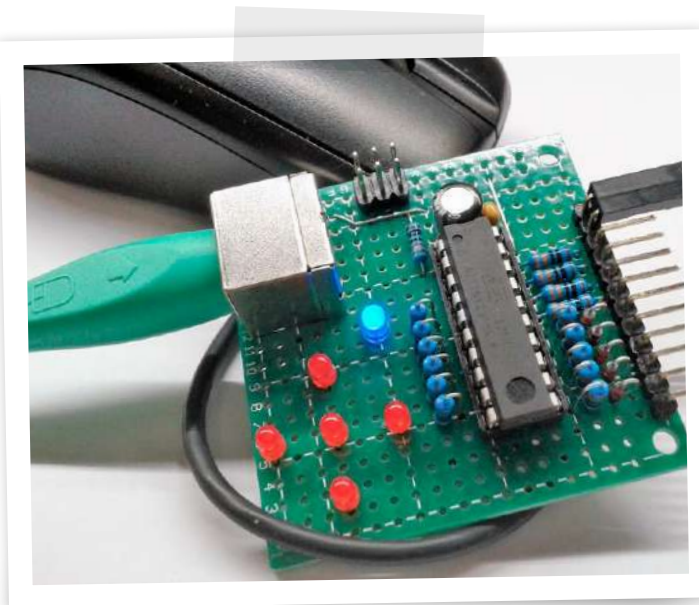


45 PS/2 Mouse as Rotary Encoder (and More...)

By Antonello Della Pia (Italy)

The goal of this project was not simply to connect a mouse to an MCU, but to create a sort of generic interface that could directly replace a rotary encoder and its switch.

A small adapter circuit was built based on an ATtiny. It converts the signals from a PS/2 mouse to control nine outputs; two of them are used to encode the direction of the moving scroll wheel.



The idea for this project came from working on another project which involved the use of a rotary encoder.

I normally use a mouse with a scroll wheel, and I was wondering whether such a device could replace the type of quadrature encoder usually connected to a microcontroller. The goal was not simply to connect a mouse to an MCU (a design often seen on the internet), but to create a sort of generic interface that could directly replace a rotary encoder and its switch. So, I focused my attention on an old PS/2 mouse that I had lying around, and, after finding a good library on the internet that could also handle the scroll wheel, the challenge began. The result, achieved with the help of a humble Microchip ATtiny2313A microcontroller and a few readily available components, is an old mouse turned into a rotary encoder with switch, two additional buttons, and four "directional" outputs (up, down, left, right), and possibly an "idle" output (*IDLE_LED* output).

Circuit Diagram

Looking at the schematic in **Figure 1**, you can see that the PS/2 protocol uses only two connections besides the power supply: *Data* and *Clock*. From the data received, it was possible to address nine outputs, each with a different function and all referenced to circuit ground. Outputs *EN_A* and *EN_B* provide the quadrature signal that simulates the action of the encoder's mechanical contacts, the output *EN_SWITCH* corresponds to the encoder switch, while *L_CLICK* and *R_CLICK* represent

the left and right mouse button contacts. The remaining four outputs are normally at Low level and switch to High when the mouse makes the corresponding movements (left, up, right, down), behaving similar to a joystick.

These outputs have a high level of 5 V. Diodes D1–D5 allow the respective outputs to appear as open-collector, thus as normally open contacts. These five outputs can also be connected without problems to circuits with a logic High level of 3.3 V. The 330 Ω resistors protect all the outputs from overcurrents. The blue LED lights up when the mouse is idle, while the five red LEDs provide immediate visual feedback of the actions performed. The resistors, R2–R7 limit the LEDs' current. Capacitors C1 and C2 are the usual power supply bypasses, while connector JP1 allows the connection of a USBasp programmer to flash the MCU. The circuit works with a 5 V power supply, but, if the mouse allows it, it also operates perfectly with 3.3 V.

Software

The source code [1], which is quite straightforward, was written and compiled using Arduino IDE 1.8.19 with *ATtiny Core 1.5.2* by Spence Konde installed. In the sketch, I used the `#define` directive to create macros to set the pin state at runtime instead of the usual Arduino `digitalWrite()` function. Similarly, I used direct port manipulation to set the pins as input/output and their initial state in the `setup()` routine instead of the usual Arduino `pinMode()` and `digitalWrite()` functions.

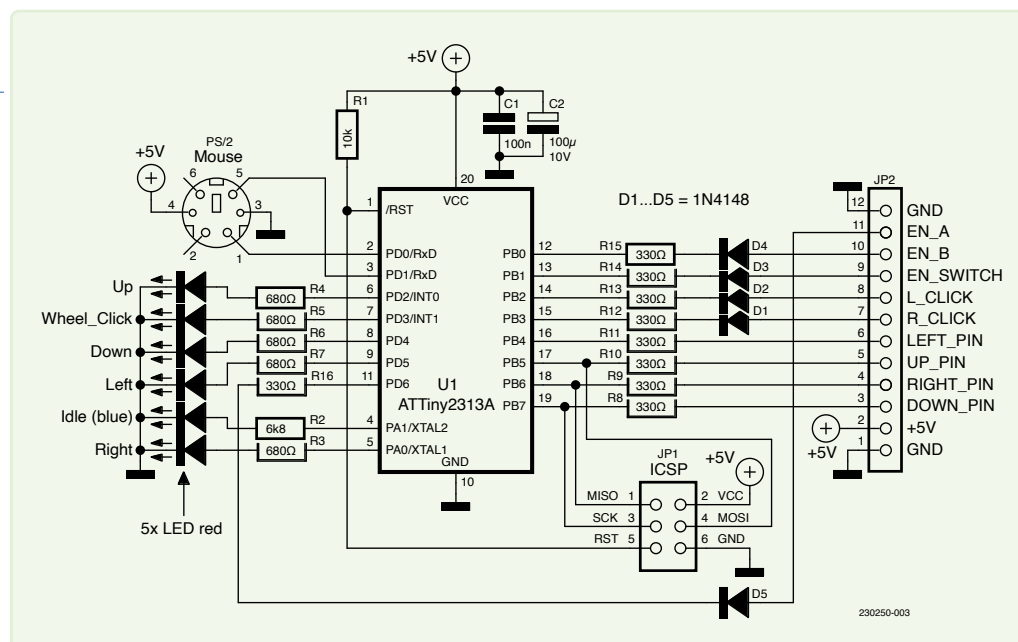


Figure 1: The circuit diagram based on an ATtiny.

This way, the size of the compiled sketch is only 1830 bytes, so the code fits into the ATtiny2313A's small flash memory (2048 bytes). For the same reason, it is necessary to set *LTO* to "Enabled" and set the use of `millis()`/`micros()` to "Disabled" in the Arduino IDE Tools menu.

In the `loop()` function, the data processed by the *arduino-ps2-mouse* library is evaluated by conditional expressions that call the three main functions appropriately. So, the `generateQuadratureSignal()` function produces the signal for outputs *EN_A* and *EN_B* when the scroll wheel is operated (see **Figure 2**). I obtained the quadrature signal in a simple but effective way by toggling pins PD6 and PB0 High/Low at fixed intervals and with a 90-degree phase shift. The `mouseButtonHandling()` function handles the buttons by routing the signal to their respective outputs, using a `switch` statement. And, finally, the slightly more complex `mouseShiftHandling()` function detects mouse movements along the main axes (X, Y, -X, -Y), and activates the appropriate outputs. All of these functions also provide for the LED event notifications.

It may also be useful to experiment with different values for the `delay()` functions and the coordinates that define the mouse position to adapt the behavior of the program to different mouse models.

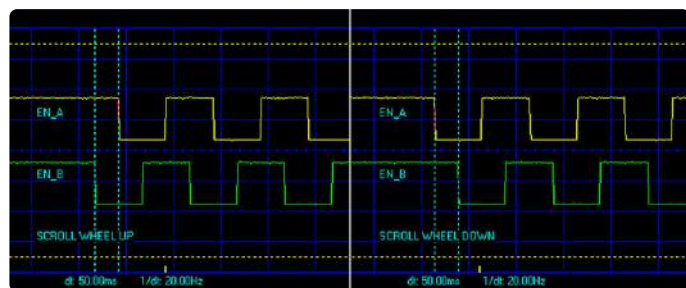


Figure 2: The software produces the signal for outputs *EN_A* and *EN_B* when the scroll wheel is operated.

The necessary library files, *PS2Mouse.cpp* and *PS2Mouse.h*, are already included in the sketch folder, so there is no need to download them separately.

The provided sketch file, *PS2_Mouse_As_Rotary_Encoder.ino*, which includes further comments and information, can be easily modified and recompiled. The HEX file is also available [1].

230250-01

About the Author

Since childhood, Antonello Della Pia was attracted to electricity and electronic devices. He holds an Electrical Engineering Technician high school diploma. Antonello has always cultivated and developed his passion for analog and digital electronics. Currently, he plays around with microcontrollers and programming, trying to improve his computer skills. Antonello likes to develop and propose projects that are as original as possible and — as he hopes — interesting, as well.

Questions and Comments

If you have any questions or comments regarding this article, you can contact the author at a.dellapia@elettronicaemaker.it or the Elektor team at editor@elektor.com.



Related Product

> W. A. Smith, *Explore ATtiny Microcontrollers using C and Assembly Language*, Elektor, 2021
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WEB LINKS

[1] Software download on this article's webpage: <https://elektormagazine.com/230250-01>

A twilight switch is a useful device that turns a lamp on at dusk and off at dawn. Some lamps have this included, but, if not, you can build your own twilight switch!



Figure 1: A simple LDR. Almost any LDR will work in this circuit.

mechanical parts apart from the relay; even today, relays are in common use. The basic element of the twilight switch is still a common photoresistor, also known as an LDR (**L**ight-**D**ependent **R**esistor; see **Figure 1**).

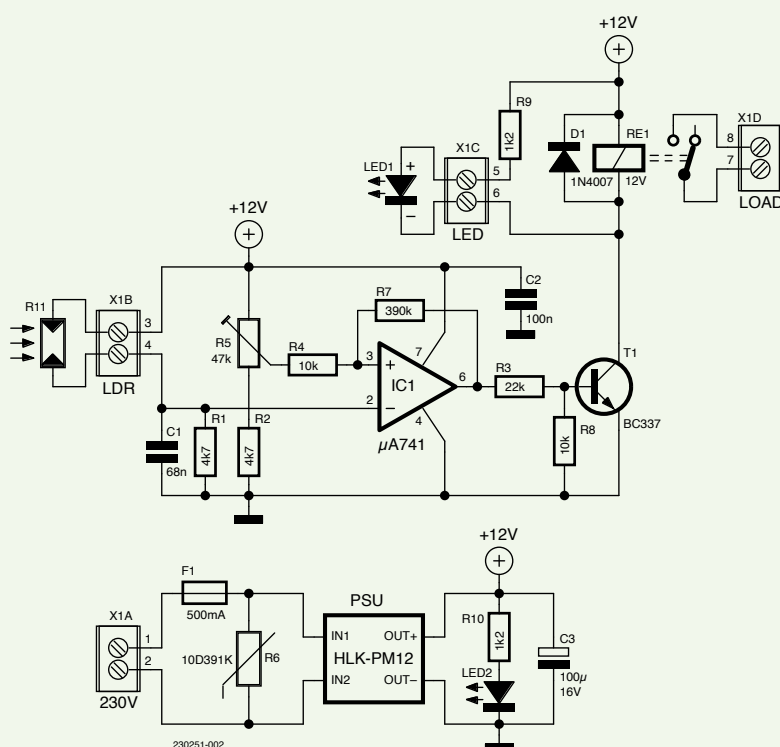
An LDR is a variable resistor, i.e. its resistance varies and does not have a fixed value. The variation is proportionate to the illumination: In complete darkness, the resistance between the terminals of a standard LDR is usually several M Ω , while under direct, intense lighting, it can drop below 1 k Ω . With these characteristics, it is straightforward to build an automatic light-dependent switch that can turn a lamp on at dusk and off again at dawn. All you need to do is add a comparator and a relay (or triac controlled by it) as a power switch. In this way, it is easy to implement a circuit to turn the garden lighting on when the evening hours arrive.

Circuit Diagram

Figure 2 proves that the twilight switch's circuit can actually be elementary. The central component, next to the LDR, is opamp IC1, which is connected as a comparator. It checks if the voltage at pin 2, which depends on the LDR, is lower than the voltage at pin 3 (this voltage is set with R5 and determines the brightness threshold). If it is lower, the output of the opamp goes High and T1 is switched through via R3, which causes the relay to respond and LED1 to light up. R7 is used to implement a hysteresis so that the dimmer switch does not rattle the relay in the chaotic transition area.

If you switch a relay with a transistor, a precaution is needed, because a relay has a coil and this coil behaves inductively. Diode D1 prevents a voltage spike, which would occur when switching off an inductance, and

Figure 2: Twilight switch complete schematic.



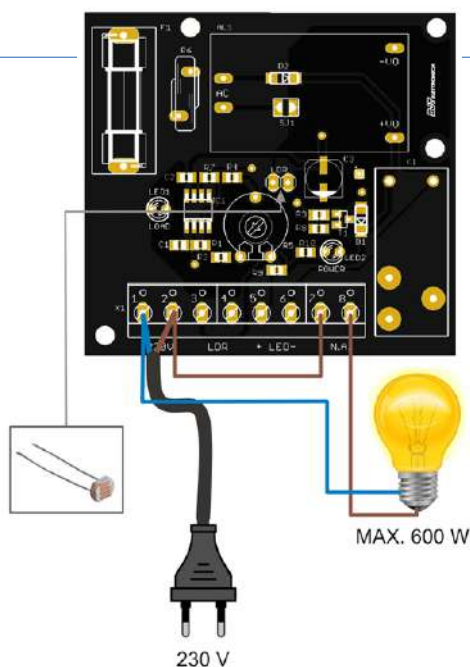


Figure 3: Assembly of the board and external connections.

possibly destroy the transistor. LED1 serves as a control indicator, so to speak, telling us whether the electronics have actually switched the output load on in the twilight.

Some Notes

The circuit is powered by the PSU power supply module, which is intended for board assembly. You don't have to use this, necessarily — any other small (stabilized) 12 V power supply with at least a 100 mA rating will do.

I developed a small circuit board for this circuit, which simplifies the reconstruction. **Figure 3** shows the assembly with (relatively large) SMDs and the external wiring. **Figure 4** shows the board's top and bottom layouts. These are available as a download from this article's webpage [1].

230251-01



Component List

Resistors

(SMD 1206 if not otherwise noted)

- R1, R2 = 4k7
- R3 = 22 k
- R4, R8 = 10 k
- R5 = 47 k Trimpot
- R6 = Varistor 10D391K
- R7 = 390 k
- R9, R10 = 1k2
- R11= LDR

Capacitors

(SMD 1206 if not otherwise noted)

- C1 = 68 n
- C2 = 100 n
- C3 = 100 μ / 16 V, electrolytic, \varnothing 5 mm

Semiconductors

- D1 = 1N4007, DO-213AB
- LED1 = LED, red, 3 mm
- LED2 = LED, green, 3 mm
- T1 = BC547, SOT23
- IC1 = LM741, SOP8

Miscellaneous

- RE1 = Relay 12V / 10 A, type 40.515
- X1 = 8 poles screw terminal, 2/10"
- F1 = Fuse 500 mA
- PSU = PCB power supply 12 V / 3 W, HLK-PM12

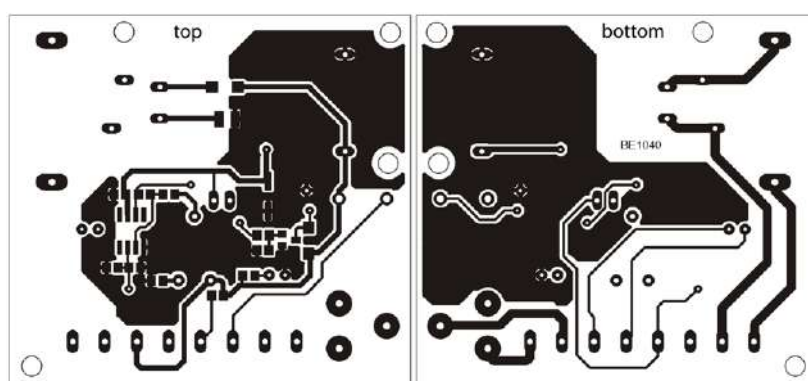


Figure 4: PCB layout, top and bottom side.

Questions or Comments?

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47

Water Pump Controller

Prepare Yourself Against Rising Water Levels

By Stefano Purchiaroni (Italy)

Due to climate change, water levels are going up and some areas get more rain, increasing the risk of floods. Keep your basement or garage dry with this automatic water pump controller circuit!



Figure 1: This is how I installed the pump in my garage.



Figure 2: Inside the water level sensor is a reed relay; the ring is a potted magnet.

After a dark and stormy night, with torrential rains having gone on for days, water entered my garage from the saturated drainage systems. To avoid such disasters in the future, besides structural interventions such as drain plugs and overflow vents, I installed a flat-bottomed draining pump, equipped with a filter for particles larger than 3 mm, and a float switch to activate it. I placed it in a 15-cm-deep hole drilled in the floor, as shown in **Figure 1**.

The float switch that came with the pump required a minimum excursion of 20–25 cm to activate the pump, which exceeded the depth of the hole. I needed a circuit that would activate the pump once the presence of 5–6 cm of water in the hole was detected. The result is the circuit presented here. It requires only a few components, which you probably have in one of the drawers of your lab.

Oscillatory Phenomena

An early naive version of the circuit triggered a curious oscillatory phenomenon — delightful to observe, but detrimental to the health of the device's motor. The pump would power on as soon as the water rose to the trigger level, quickly sucking up about a liter and a half. This made the water level drop, opening the sensor contact and switching off the pump. This abrupt starting and stopping of the pump caused a wave that retriggered the sensor. The system soon oscillated with a period of about 1 to 2 seconds. I had to prevent this!

The Solution

These pumps cannot remain switched on for more than half an hour without water because the liquid is also used for cooling the motor. Without it, the pump will overheat. Even though it has a thermal protection, you should not let it run all day, just in case. I needed the pump to stay on for a few tens of seconds only, just enough time to empty the hole of residual water.

The water level sensor I used (**Figure 2**) can easily be found and purchased online. It consists of a reed relay potted in a watertight tube. A ring magnet potted in polyurethane foam slides up and down the tube. It is more robust than it appears, and it works perfectly.

The schematic is shown in **Figure 3**. When the water level rises above the sensor's activation position, the reed relay closes. Q1 switches on and, with it, relay RL1, and the pump starts pumping. When the water level drops below the sensor's activation position, the reed relay opens. However, the charge on C3 keeps Q1 in conduction for about half a minute, allowing the pump to evacuate the remaining water. With this type of pump, only a couple of millimeters of water is left, which will dry up easily.



Warning!

This circuit operates directly from the AC mains voltage; there is no isolating transformer. Therefore, take proper precautions when building, testing and installing it. Do this project only if you have the required knowledge to ensure full safety.



elektor Circuit Special 2023 111

48 Solar-Powered Christmas FM Radio Ball

All You Want for Christmas Is This

By Stefano Purchiaroni (Italy)

Tired of listening to *Jingle Bells* the whole day long during Christmas? Then, build this decorative FM radio ball and tune in to a station that also plays Mariah Carey.

bled... unless it were rechargeable, perhaps by sunlight. Thus, the idea of a transparent ball with a radio and a solar panel inside saw the light.

Circuit Diagram

The schematic is shown in **Figure 1**. The main component is the TDA7021 (IC1), an FM receiver that only needs a few external capacitors and a tuning circuit. For this, I used a variable capacitor found in the scrap box, and an air coil with a diameter of 6 mm consisting of eight turns of 0.8 mm wire. By expanding or compressing the coil, the frequency band of interest can be set.

The audio amplifier is limited to Q1, a single Darlington transistor. It works well, even though the audio quality is not perfect. I have done some experimenting with a three-transistor circuit that performs better, but I plan to use a stereo amplifier IC in a future version (TDA2822D).

The radio is powered by two AAA rechargeable 700 mAh Ni-MH batteries. Two solar cells charge them when the ambient light allows it.

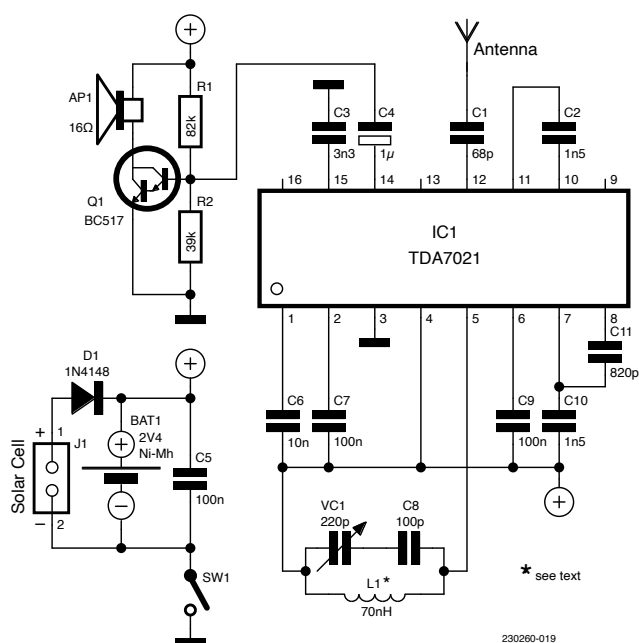


Figure 1: The TDA7021 together with a few capacitors is all that is needed to build an FM radio.

The cute gadget proposed here combines several interesting features. The idea was born during Christmas while we were decorating the tree. How about adding a ball with an FM radio inside? But one that doesn't need battery replacement; otherwise it would have to be disassembled...

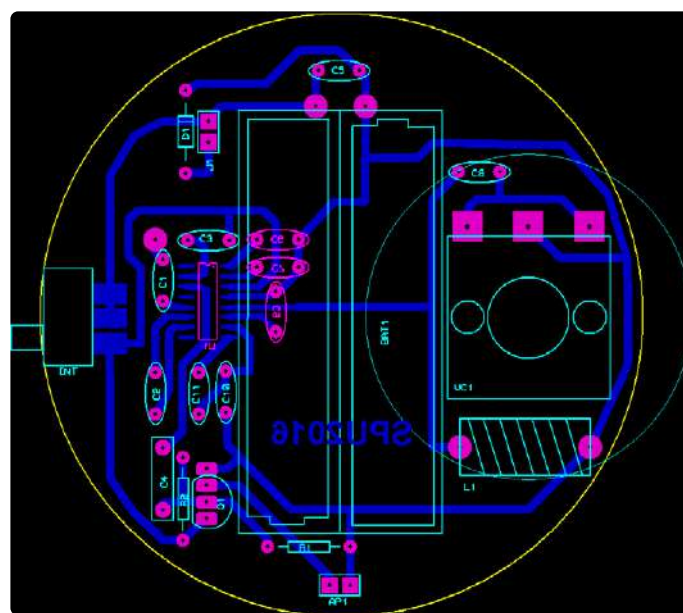


Figure 2: This single-sided PCB has components on two sides.

PCB and Assembly

I designed a single-sided PCB for the circuit (**Figure 2**), available at [1]. IC1's SMD package is mounted on the copper side, together with a few other components that didn't fit on the top side due to the battery holder's bulk. The latter is easily attached with double-sided adhesive tape.

To facilitate connecting a better sound module in place of Q1, I added a fourth pad next to its footprint. If you use it, do not mount R1 and R2.

Assembling the radio ball (**Figure 3**) requires milling openings in the two shells that make up the 8 cm transparent ball. The slide switch sticks through one shell, while the variable capacitor wheel sticks through the other. The loudspeaker is hot-glued to the shell on the slide switch side. The two solar panels, salvaged from exhausted garden LED spotlights, are hot-glued too.

Given the Christmas theme, I used a Christmas garland as an antenna. This has a metal core, which I connected with a wire to IC1's antenna input. ◀

230260-01

Questions or Comments?

Do you have technical questions or comments about his article? Email the author at s.purchiaroni@elettronicaemaker.it or contact Elektor at editor@elektor.com.



Figure 3: The Christmas radio ball assembled and ready to decorate the room.

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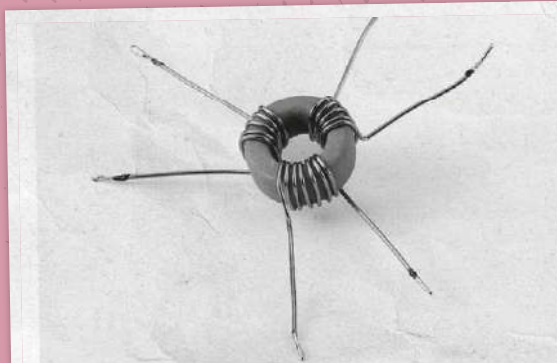
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Quiz: Circuits from the Past #02



T. Giesberts

The circuit in the diagram enables the digital audio output of, say, a compact-disc (CD) player to be linked to two different appliances simultaneously. It is, of course, considerably less expensive than the proprietary active splitters on the market.

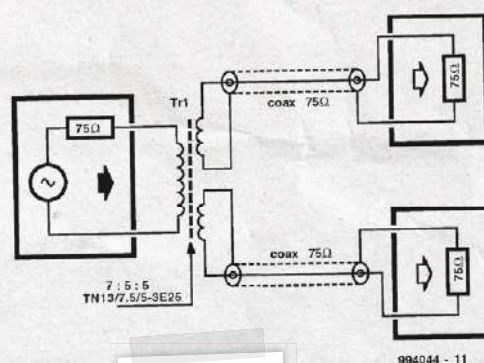
The circuit is in effect a small transformer that can be wound easily on a Philips' type TN13/7.5/5-3E25 toroidal core. The wire should be 0.5 mm dia. enamelled copper wire. The primary winding is seven turns and there are two secondary windings, each of five turns. The bandwidth of the transformer is 40 kHz to 16 MHz. When both outputs are loaded, there is a voltage of 0.33 V_{pp} at each output. When one of the outputs is open circuited, the volt-

the signal source.

A drawback of the splitter is that the output voltage is 34% below the internationally specified level. However, most S/PDIF (Sony/Philips Digital Interface Format) inputs can cope with this perfectly well.

Place the transformer directly at the output of the signal source. The reason for this is that the input and output impedances of the transformer are not exactly 75 Ω. With the transformer directly at the source and provided the coaxial cable at the computer end is terminated correctly into 75 Ω, all will be well.

[994044]



994044 - 11



Tap or Shake to Switch On

Figure 1: The good-old 555 timer IC — this time triggered by an SW-18010 vibration sensor.

output drives, with the help of Q2, relay RL1. RV1 controls the length of the output pulse between 0.1 s and 10 s. The pulse duration can be doubled by increasing the value of C4 to 100 μ F.

The coil of RL1 is rated for 12 V, which determines the required power supply voltage. Lower supply voltages are possible by replacing the relay with a 6 V or 9 V type.

A PCB for the circuit (**Figure 2**) is available at [1]. The assembled vibration detector is shown in **Figure 3**. ◀

230262-01

Questions or Comments?

Need more info about this project? Contact the Elektor team at editor@elektor.com.

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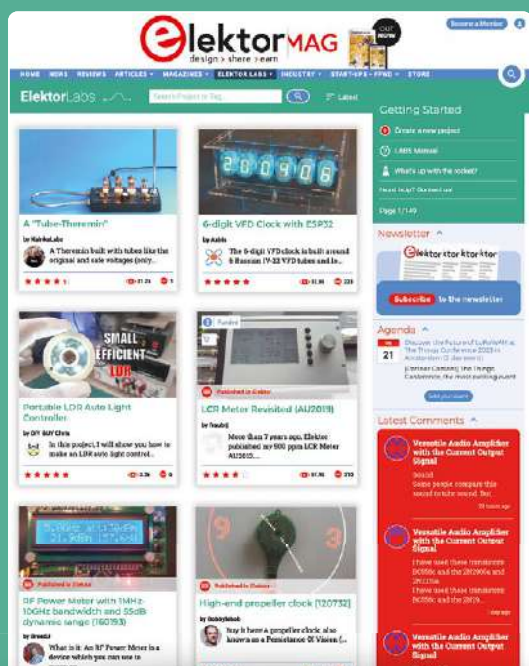


Figure 3: This is what the circuit looks like when assembled on the PCB.



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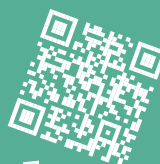
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50 Continuity Tester

Sensitive and Unintrusive

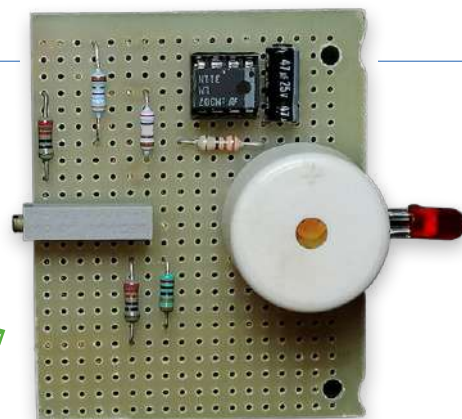


Figure 2: The prototype assembled on a piece of perfboard, ready to be mounted in a suitable enclosure.

By Giovanni Carrera (Italy)

This simple yet sensitive and unintrusive tester will help you locate broken PCB traces or find short circuits in no time!

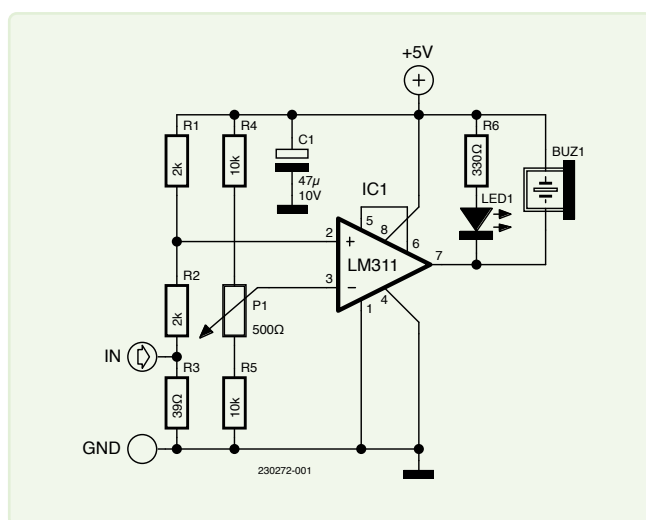


Figure 1: A short circuit or a very low resistance in parallel to R3 will make the buzzer beep and light the LED.

Almost all multimeters have a continuity or diode test function with beeper. However, often, they have open-circuit voltages of 2 V to 3 V, which may interact with semiconductors present in the circuit under test. Many designs of varying complexity for continuity testers can be found on the net, some of which may also cause permanent damage to the circuit under test.

The project presented here has an open-circuit voltage of about 48 mV and a short-circuit current of about 1.25 mA. The beeper will sound for low resistance values; the threshold value can be adjusted with a multi-turn trimmer.

Obviously, this tester does not measure the semiconductor junction voltage because it was designed for continuity measurements only.

The power supply voltage should be around 5 V to 6 V, obtained from a phone charger, for instance, but four AA or AAA batteries will do too.

Circuit Diagram

The schematic is shown in **Figure 1**. Voltage comparator IC1 compares the voltage on node R1/R2 to the voltage on the wiper of P1. R1 and R2 limit the test current to a safe but not too small value of 1.25 mA.

P1 is adjusted in such a way that, when the tester is idle, the voltage on the inverting input of IC1 is lower than the voltage on the non-inverting input. Therefore, the buzzer does not sound, and the LED is off. A short circuit or low-enough resistance on the input will pull the voltage on the non-inverting input below the voltage on the inverting input. Now the output of IC1 will go low, making the buzzer sound and turning on the LED.

Make sure to use a so-called active piezo buzzer (i.e. with built-in oscillator), seen on the construction in **Figure 2**, as it can be driven directly from the comparator output. ◀

230272-01



Component List

R1, R2 = 2 kΩ, 1%
 R3 = 39 Ω, 5%
 R4, R5 = 10 kΩ, 1%
 R6 = 330 Ω, 5%
 P1 = 500 Ω, multi-turn trimmer
 C1 = 47 µF, 16 V
 IC1 = LM311
 LED1 = LED
 BUZ1 = piezo buzzer with oscillator



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51 Power On/Off with a Push Button

By Tam Hanna (Hungary)

Sometimes a simple push button is better than a switch. There are many circuits that convert a pushbutton into an On/Off button. Here we present a version using an NE555 timer IC.

Power switches are expensive, no matter how you approach the issue. The costs extend to more than just the actual bill of materials. You should bear in mind that in many cases, elaborate designs are required in order to access circuit boards fitted in enclosures and the actuators located on these boards. Transferring the forces necessary for the required motion can be a considerable challenge for mechanical design. In this sort of situation, push buttons can easily be integrated thanks to their unidirectional actuation.

There are many circuits that convert a push button into an On/Off button. Here I present a circuit based on an NE555 timer IC. For the sake of convenience, I used the original version of this IC for experimenting with the circuit described below. In practice, it is recommended to instead use a CMOS version due to its significantly lower current consumption. With the CMOS version, you can sometimes achieve a standby current of less than 100 μA .

The Circuit

For the description of the circuit concerned (see **Figure 1**), let's start with the Reset pin (pin 4) of the timer IC. The R/C network used here ensures that the NE555 remains reset for a while after the supply voltage is applied and only becomes active after a certain time. In my tests, this ensured that the circuit did not unintentionally switch on by itself.

Next, let's look at the voltage divider R1/R2. It holds pins 2 and 6 of the IC at very close to half the supply voltage ($V_{CC}/2$). This ensures that the output is normally in the Low state (switched off).

Now we're ready for the first test. Connect a supply voltage to the circuit and tie pins 2 and 6 to either Ground or to V_{CC} . Keep in mind that the supply voltage should only be applied after the connection is made, because a "floating" cable acts as an antenna and can sometimes collect enough energy to change the state of the timer IC input. In this test, you should confirm that, when these pins are pulled Low the circuit switches on, and when the pins are pulled High the circuit switches off.

Now, let's also consider resistor R4 and capacitor C2. Via the connection to the timer IC output, the voltage on the capacitor will always correspond to the current state (Low = switched off; High = switched on). Pressing the push button applies the voltage on capacitor C2 to timer IC pins 2 and 6, causing the output state to change as previously described.

At this point, we're basically done. Instead of the LED that I connected to pin 3 of the IC for test purposes, you can connect just about any other circuit to the output. With a relatively large circuit, you could, for example,

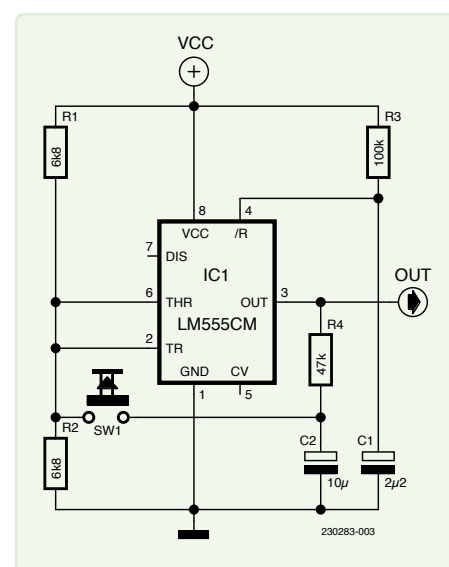


Figure 1: The circuit is built around an NE555 timer IC.

use a transistor to convert the NE555 output signal into a signal that can drive a larger load.

I hope you have a lot of fun with your own further experiments!

Translated by Kenneth Cox — 230283-01

Questions or Comments?

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Related Products

> **The 555SE Discrete 555 Timer**
<https://elektor.com/19732>

52 Mini-Drill Power Control 2023

A Revision of a Design from 1980

By Walter Ribbert (Italy)

Making your own PCBs can imply a lot of drilling. To obtain the best results, besides using sharp drill bits, a constant drill speed is recommended. This controller helps you to achieve exactly that.

As the title states, this is a revision of a circuit published in an Elektor article from 1980 [1]. It is an adjustable power supply for low-voltage mini drills, 12 V to 18 V, 1.5 A to 2 A, with compensation for the motor's internal resistive losses. The operating principle is practically the same as its predecessor, the upgrade being the use of a more modern switching regulator instead of a linear one.

The previous version featured a Fairchild 79GU 4-terminal adjustable negative linear voltage regulator with a control voltage of -2.23 V. The version presented here is equipped with an LM2576-ADJ, a switching regulator with a lower control voltage of 1.25 V, higher efficiency and lower heat dissipation (a small 60 × 60 × 1.5 mm aluminum heat

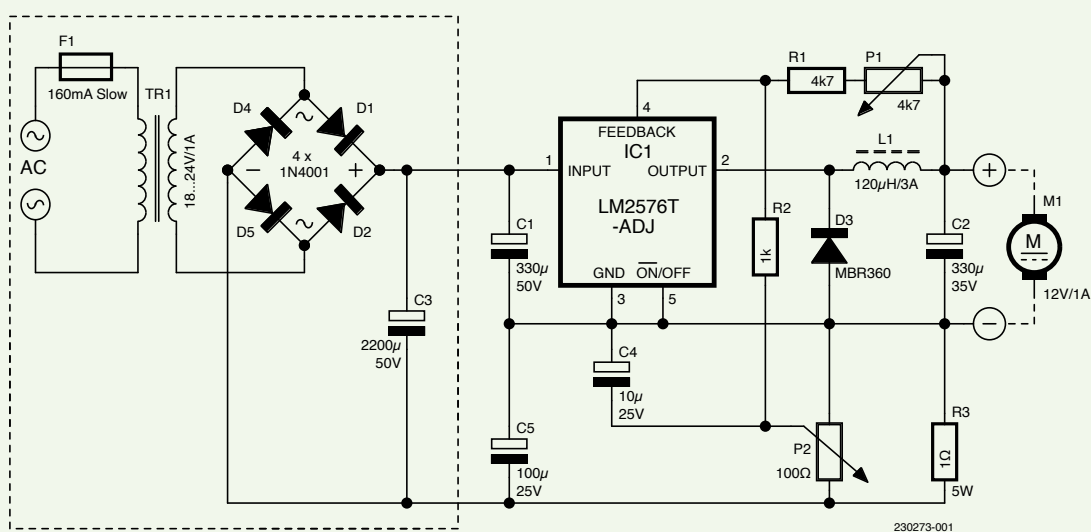


Figure 1: Schematic of the revised mini-drill controller, based on a switching voltage regulator.

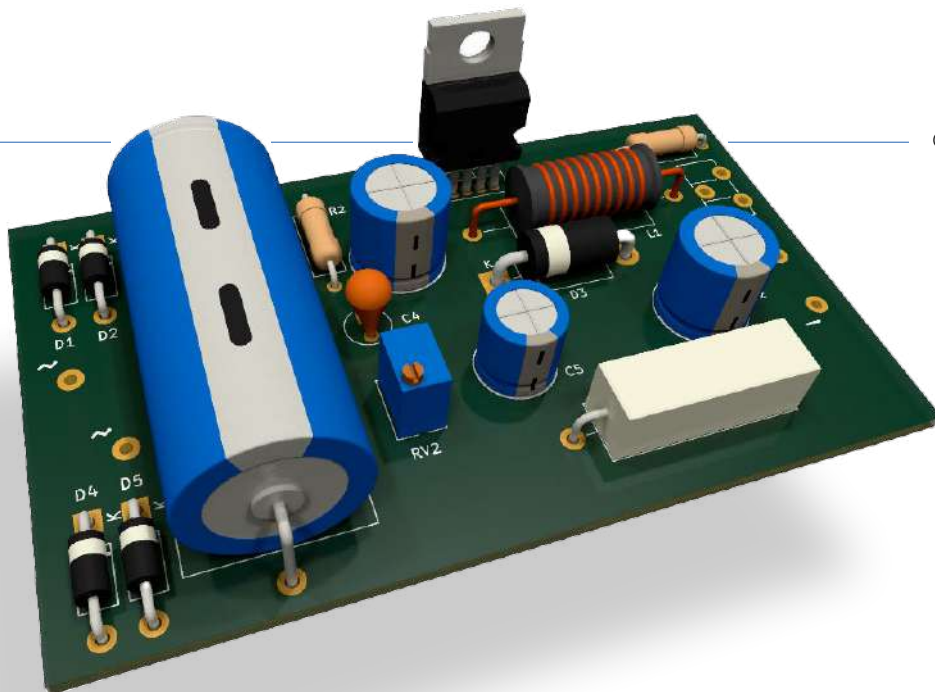


Figure 2: A 3D rendering of the prototype. The PCB design files are available for download at [2].

sink is sufficient). The lower control voltage allows the value of the current-sensing resistor to be reduced to $1\ \Omega$ while maintaining excellent regulation/speed compensation.

Circuit Diagram

From the schematic in **Figure 1**, it can be seen that the voltage drop over R3 due to the current circulating in the motor is negative relative to IC1's reference ground (GND), lowering the control voltage feedback at pin FB. This positive feedback forces IC1 to increase the output voltage to compensate for the drop.

Calibration of the circuit is simple. Start by turning trimmer P2's wiper fully towards GND (zero compensation). Using P1, set the output voltage to the motor's nominal value. Slowly load the motor and adjust P2 to increase the output voltage. Monitor the voltage and current parameters by measuring the output voltage and the voltage drop over R3 ($1\ \text{V} = 1\ \text{A}$). Adjust P2 so that the voltage measured on the motor contacts (at the rated current) does not exceed the rated value by more than 25%.

R1 and P1 are calculated for an output voltage adjustment range of approximately 7 V to 13 V with no load. My mini drill has a rated voltage of 12 V. There is no point in reducing the output voltage any further, as the motor loses power and stops easily when the speed drops below 60%. Also, small drill bits or sanding tools need high speeds to work properly.

The circuit design assumes the use of an external transformer, diode rectifier bridge, and filter capacitor (shown within the dotted lines in the circuit diagram). The circuit can be supplied with a smoothed DC voltage of up to about 36 V. If you have a suitable power supply, you can omit these components from the PCB [2]. **Figure 2** shows a 3D rendering of the assembled board. ◀

230273-01

About the Author

Born in Turin in 1957, Walter Ribbert studied electromechanics and industrial electronics and started working at the age of 17 as an apprentice. Today, he is retired after a 43-year career as an electrical and electronic designer for a large industrial automation and robotics company, where he worked, never ceasing to learn. Now, with more free time, he has resumed studying a little mathematics and physics (without too much effort) and continues to "play" with electromechanical and electronic devices like a kid. True passions never die!

Questions or Comments?

Do you have technical questions or comments about his article? Email the author at w.ribbert@elettronicaemaker.it or contact Elektor at editor@elektor.com.



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WEB LINKS

- [1] Mini Drill Speed Control, Elektor 1/1980: <https://elektormagazine.com/magazine/elektor-198001/44358>
- [2] PCB design files: <https://elektormagazine.com/230273-01>



Digital Vibration Sensor

Turn Vibrations into Precisely Timed Pulses

By Stefano Purchiaroni (Italy)

Vibrations are often detected with tiny MEMS accelerometers, but mechanical sensors exist as well. Even though they won't fit in your phone, they can be useful in other applications.

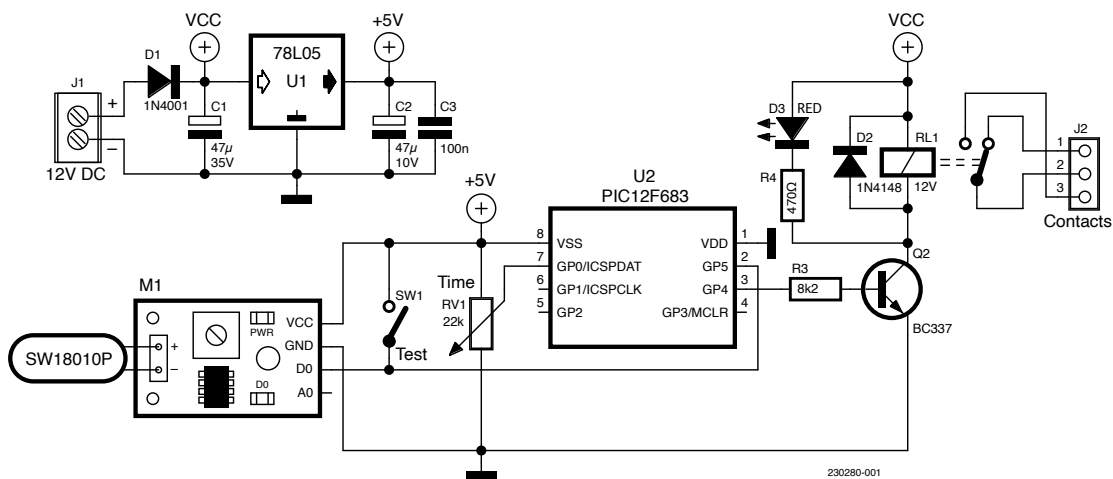


Figure 1: The digital vibration sensor. The supply voltage is determined by the voltage rating of relay RL1's coil.

This circuit is a digital vibration sensor based on the SW-18010(P) sensor module. The sensor on this module consists of a flexible metal spring placed around a metal rod. When it vibrates or shakes, the spring touches the rod, creating short pulses. A comparator at its output turns these into a usable High-Low signal.

Circuit

Here, the output signal is read by a Microchip PIC12F683 microcontroller (Figure 1). When a High level is detected, it turns on the relay for a certain duration (adjustable with RV1). When the delay timer elapses, the relay is switched off. After returning to its idle state, the circuit ignores vibrations (produced by the relay mounted on the circuit board) for one second. This considerably increases the sensitivity of the circuit, without introducing any inconveniences.

The trimmer lets you adjust the relay "on" duration to between one and sixty seconds.

The power supply voltage required by the circuit is determined by the relay coil. It is 12 V in our case, but it is possible to replace it with a 6 V or 9 V model, adjusting the input voltage accordingly.

The PCB design, together with the program and HEX files, can be downloaded from [1]. Scale the copper layout to obtain the dimensions as shown in Figure 2. The assembled circuit is shown in Figure 3. ▶

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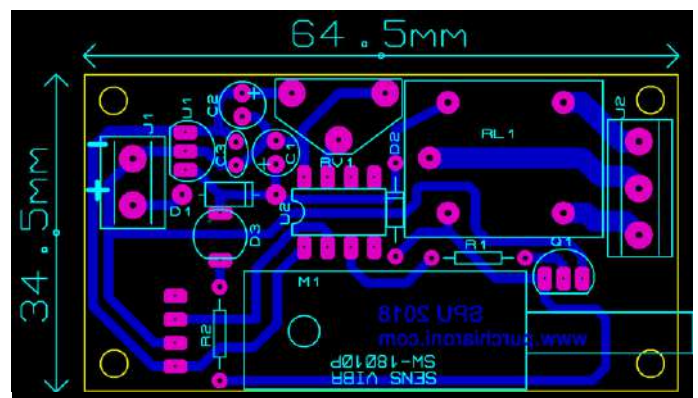


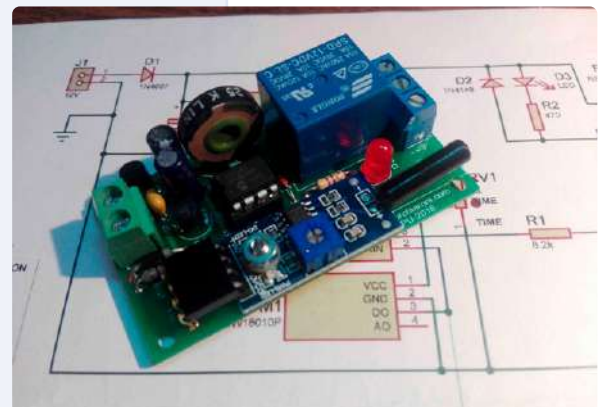
Figure 2: Scale the PCB copper layout [1] to the dimensions shown here.



Listing 1

```
/******  
Vibration sensor  
Max ON state time (Ton) adjustable via trimmer. Input changes make  
output On. Further signals are ignored during a stabilization period  
after Turn-Off  
  
MCU:          PIC12F683  
Oscillator:    internal, 4.000 MHz  
Compiler:      mikroC v8.2.0.0  
  
Author: info@purchiaroni.com  
  
Changelog:  
- 19.02.2018 : Creation of the program  
  
*****/  
  
// Constants  
#define TonMax 60 // Max ON state time (s)  
#define Toff 1 // Post-activation sleep timer prevents relay feedback  
  
// Pin usage  
#define OutPin F4 // Output to the transistor base, to drive a relay  
#define AdjPin F0 // Trimmer analog input  
#define SnsPin F5 // Vibration sensor input  
  
// Variables  
int i, t;  
  
void main() {  
  
    ANSEL = 0; // Configure AN pins as digital  
    CMCON0 = 7; // Turn off the comparators  
  
    // Configure pins' direction  
    TRISIO = 0; // All output  
    TRISIO.SnsPin = 1; // Sensor input  
    TRISIO.AdjPin = 1; // Trimmer input  
  
    OPTION_REG.F7 = 1; // Disable pull-up internal resistors  
  
    // Init the output pins value  
    GPIO.OutPin = 0;  
  
    // Endless loop  
    do {  
        if (GPIO.SnsPin == 1) { // If sensor goes on...  
            GPIO.OutPin = 1; // turn output on  
            // Translate trimmer voltage to t  
            t = 1+((long)Adc_Read(0) * TonMax) / 1024;  
            // Stay On for t seconds  
            for (i = 0; i <= t; i++) Delay_ms(1000);  
            // Turn output off  
            GPIO.OutPin = 0;  
            // Ignore input for Toff seconds  
            for (i = 0; i <= Toff; i++) Delay_ms(1000);  
        }  
    }  
    while(1);  
}
```

Figure 3: The circuit can be assembled on a compact circuit board.



Related Products

- > **Elektor 37-in-1 Sensor Kit**
<https://elektor.com/16843>
- > **Seeed Studio Grove Piezo Vibration Sensor**
<https://elektor.com/20029>

WEB LINKS

- [1] Downloads for this article:
<https://elektormagazine.com/230280-01>

54 Reverse-Polarity Protection with Low Voltage Drop

By Tam Hanna (Hungary)

When developing an application, in particular an automotive application, you should always include reverse-polarity protection for the supply voltage. The circuit described here reduces the power loss of this reverse-polarity protection.

You may find it hard to imagine as an electronic designer sitting in the lab, but some automotive mechanics tend to connect the battery the wrong way round. The author can confirm this from personal experience in a German transportation company.

Reverse-polarity protection is often implemented with a diode. This is simpler and more economical than the solution described here, but the simplicity comes at the cost of a constant power dissipation that can be calculated using the formula $P = U_D \times I$. Especially with automotive systems, which often draw relatively high currents, that approach leaves something to be desired.

Eliminating Diode Voltage Drops with MOSFETs

Field-effect transistors are superior to their bipolar counterparts because the field effect can be used to emulate a diode without the diode voltage drop. This makes the schematic diagram in **Figure 1** easy to explain.

When power is switched on, the intrinsic body diode in the MOSFET conducts to produce a voltage between the gate and the source. This voltage acts a starter to drive the drain-source channel of the MOSFET into conduction via the Zener diode. This condition is met as long as the supply polarity is correct.

If the polarity is reversed, the Zener diode circuit cannot perform this task, so the MOSFET remains cut off and the load is not connected to the reverse-polarity supply voltage. It should be noted that the Zener diode and resistor values shown here are only examples.

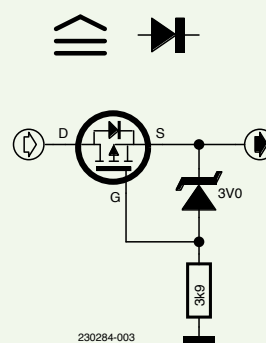


Figure 1: MOSFET reverse-polarity protection with low voltage drop.

Lab Experiments

For quite a while, the author of this article has been using this circuit operationally in an automotive application: a school bus tracker. So far, it has worked perfectly, creating opportunities for practical experiments.

Along with the MOSFET circuit, a normal diode (1N4007) and a Schottky diode (1N5819) were measured. The voltage drops measured at different current levels are listed in **Table 1**. The current was measured with an HP 6624A, with a Kikusui PLZ 150W serving as the load. The voltage was measured with a Keithley 177.

Further Considerations

The circuit described here is based on a P-channel MOSFET. An advantage of this circuit topology is that the ground is not affected by the voltage drop. This is helpful because it makes interfacing to external signals or circuits easier.

However, in practice, N-channel MOSFETs have higher performance and are less expensive. If your system is completely galvanically isolated, it can be a good idea to use an N-channel version.

Summary

If you use MOSFETs for reverse-polarity protection in your automotive applications, you can save energy and — in many cases — reduce

Table 1. Voltage drop comparison.

8 V	1N5819	1N4007	IPD80P03P4L
100 mA	0.3428	0.7964	0.0009
250 mA	0.3744	0.8287	0.0021
500 mA	0.4062	0.8490	0.0043
1000 mA	0.4562	0.8685	0.0086

12 V	1N5819	1N4007	IPD80P03P4L
100 mA	0.3377	0.7970	0.0009
250 mA	0.3690	0.8275	0.0019
500 mA	0.3994	0.8506	0.0041
1000 mA	0.4530	0.8648	0.0079

dissipated power, which is hard to get rid of in closed spaces. In most cases, the relatively small additional cost compared to a diode is acceptable. This approach is especially important when you consider that the lower voltage drop in extreme situations (cold crank) leaves a significantly higher voltage available for the load concerned. ◀

Translated by Kenneth Cox — 230284-01

Questions or Comments?

If you have technical questions or comments about this article, feel free to contact the Elektor editorial team by email at editor@elektor.com.

About the Author

As an engineer, Tam Hanna has been working with electronics, computers and software for more than 20 years. He is a self-employed designer, book author and journalist (@tam.hanna on Instagram). Tam spends his spare time on a variety of activities, including 3D printing and selling cigars.



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Quiz: Circuits from the Past #03

12 V stroboscope

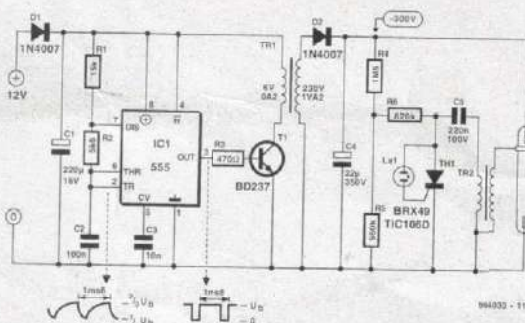
There are inexpensive stroboscopes on the market that can be screwed directly into an E27 socket. Such devices already have the circuit to the right of mains transformer Tr_1 in the diagram. To enable the stroboscope to be operated from 12 V, a 12-240 V converter needs to be fitted inside the housing.

The circuit of the converter is simplicity itself. Diode D_1 is a polarity protection device that may be omitted. A 555 is used as an astable with a frequency of about 0.7 Hz. When T_1 is on, a current flows through the 6 V winding of Tr_1 . The voltage across the 240 V winding must be such that D_2 does not conduct. This may be ensured with the aid of an oscilloscope. When the collector voltage of T_1 is nearly 0, the potential at the anode of D_2 must be negative; When T_1 becomes reverse-biased, its collector voltage rises to about 12 V and the potential

at the anode of D_2 must then be positive, so that C_4 can be charged. Check these voltages, but carefully—they may be lethal!

about 300 V. This causes a potential at junction R_6-C_5 of about 100 V. The neon lamp then comes on, so that a gate current flows into the thyris-

sand valve. This is sufficient for the xenon tube to strike and at the same time discharge C_4 . From then, the operation can start again.



Never operate the converter without a load. It is, perhaps, advisable to shunt C_4 with a 100 k Ω , 1 W resistor. The converter charges C_4 to

tor. This comes on and clears the way for C_5 to discharge through Tr_2 . This starting transformer produces a secondary voltage of a few thou-

The circuit draws a current of about 250 mA, but this depends on the flashing rate and the type of xenon tube.

[J. & W. Wüstermann-Rüch - 664133]

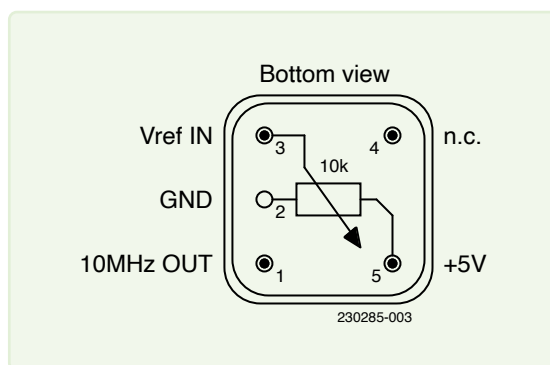


SS A Low-Cost Frequency Standard

By Tam Hanna (Hungary)

If you're looking for a frequency standard, an oven-controlled crystal oscillator (OCXO) is a low-cost option. Here, we report briefly on practical experience.

Figure 1: Typical OCXO pin assignment.
(Source: Tony Albus,
<https://youtu.be/pVmBU0xSt78>)



There is a broad range of measuring instruments, including oscilloscopes, spectrum analyzers and counters, that can benefit from a 10 MHz reference standard signal to improve their accuracy. It goes without question that a GPS disciplined oscillator is the best you can get. However, in practice this comes with some annoying conditions, such as the need for a sky-facing antenna. An OCXO is a good deal more economical and can achieve similar stability. One of the welcome side effects of the announced shutdown of 3G mobile networks is that low-cost reference oscillators made by CTI are flooding the market.

What Is an OCXO?

The abbreviation OCXO stands for "oven-controlled crystal oscillator", which pretty much says it all. As is generally known, temperature changes make stable values difficult to achieve. An OCXO uses a brute-force approach to combat this problem: It encloses the frequency-determining component in an oven whose temperature is stabilized as well as it possibly can be, by a heater and a temperature controller.

Basic Structure of an OCXO

Most low-cost, readily available OCXOs have the same pin assignments, as shown schematically in **Figure 1**. Here, the most important pin is Vref IN, to which an external voltage can be applied to adjust the frequency of the oscillator signal. Logically enough, the components used to generate this reference voltage should be as stable as possible.

The supply voltage should be 5 V. A current of up to 600 mA is required to heat the OCXO oven. In the author's tests, after about 5 minutes, normal operation was reached, at which the current consumption was typically somewhere around 250 mA.

Another thing to question in this regard is what type of output signal an OCXO provides. For the OC5SC25 from CTI, there is a data sheet that mentions a TTL signal (**Figure 2**). By contrast, another OCXO with type number OSC5A2B02 generates a sine wave signal. This can, of course, be checked by connecting an oscilloscope to the output.

Ready-Made Boards

If you want to save the trouble of doing your own circuit design, you can buy the board shown in **Figure 3** for around € 15 from AliExpress or other providers. The author bought this module, fitted with an OSC5A2B02, from [1].

The poorly finished board contains a linear voltage regulator that reduces the input voltage (7–12 V) to 5 V. On the board, there is also a (half-baked) adjustment circuit and



Figure 3: Vendor "HUNDI500" offers fast and economical service.

	Specification	Value	Test conditions
Frequency stability			
1	Nominal frequency	10.00 MHz	
2	Initial frequency accuracy	±200 ppb	Vc = +2.0V; @ +25°C, after
working for 15 minutes			
3	Power stability	≤±2 ppb	Vs ±5%
4	Load stability	≤±2 ppb	Load ±5%
5	Ageing	≤±0.5 ppb/day ≤±100 ppb/first year ≤±0.4 ppm/10 years	@25°C after 30 days of power-on work
6	Temperature stability	≤± 10PPB	-0°C~+75°C, ref to +25°C
7	Short-term stability	≤ 0.05 ppb/s	1 hour after power-on
8	Boot time	≤5 min.	≤±100 ppb; power-on for 5 minutes; Vc = center voltage; 25°C vs. 1 hour frequency; Vc =+2.0V; @ +25°C
Supply voltage/current			
9	Voltage	+5.0 V ±5%	
10	Working current	≤600 mA initial ≤250 mA steady state	
Output characteristics			
11	Output waveform	HCMOS	
12	Output load	15 pF	
13	Output level	VOH: ≥4.5 V VOL: ≤0.5 V	
14	Rise/fall time	≤6 ns	
15	Duty cycle	45/55 %	
16	Clutter suppression	-	
Voltage control characteristics			
17	Voltage control range	2.0 ±2.0 V	
18	Frequency range	-2.0~ -1.0 ppm	Vc = 0 V
		-0.2~ +0.2 ppm	Vc = 2.0 V
		+1.0~ +2.0 ppm	Vc = 4.0 V
19	Voltage control slope	Positive slope	
20	Voltage-controlled linearity	<±10%	
21	Input resistance	≥100 kΩ	
22	Modulation bandwidth	>10 kHz	
Phase noise			
23	Phase noise	-80 dBc/Hz @ 1 Hz -120 dBc/Hz @ 10 Hz -140 dBc/Hz @ 100 Hz -145 dBc/Hz @ 1 kHz -150 dBc/Hz @ 10 kHz	
Temperature range			
24	Working	0~75°C	
25	Operating	-40~85°C	
26	Storage	-55~105°C	
Package			
27	Dimensions	25.4 mm × 25.4 mm × 12.5 mm	
28	Lead plating	Nickel plating with tin immersion	
29	ROHS	ROHS network exemption	

Figure 2: Excerpt from the data sheet for OCXOs from CTI's OC25 series. (Source: CTI datasheet)

a low-pass filter to convert the square wave signal into a sinusoidal signal. In practical use, the adjustment range of the trimpot is often not adequate, so it could be helpful to solder in a resistor. The quality of the generated sine wave can be assessed from the spectrum analysis result shown in **Figure 4**.

In the author's tests, the board generally worked as well as might be expected. A "stability" comparison also yielded interesting results. In **Figure 5**, the lower trace shows the signal at the sine wave output of the module and the upper trace shows the signal from the TTL output, both after passing through some SMA adapters. There is no significant jitter to be seen.

Summary

No matter whether you acquire a bare OSC5A2B02 or one mounted on a finished board, there is presently no lower-cost way to get your hands on a frequency standard.

Figure 4: Analyzing the sine wave signal with the author's HP 4195A.

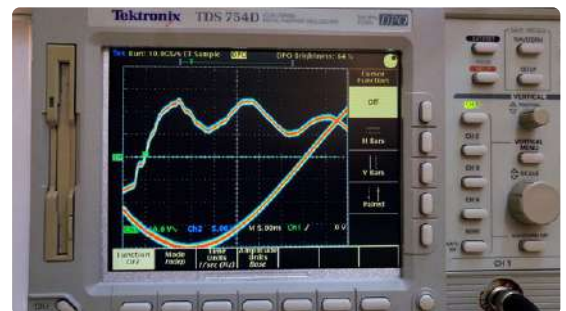



Figure 5: The lower trace shows the signal at the sine wave output of the module and the upper trace shows the signal from the TTL output, both after passing through some SMA adapters. No significant jitter is visible.

You can carry out a lot of fascinating experiments with OCXOs, especially if you have two of them, so the boards are ideal as a present for that individual known to already have everything. 

Translated by Kenneth Cox — 230285-01

Questions or Comments?

If you have technical questions or comments about this article, feel free to contact the Elektor editorial team by email at editor@elektor.com.



Related Products

- Joy-IT JDS6600 Signal Generator & Frequency Counter
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WEB LINK

[1] OCXO 10 MHz Frequency Reference Module: <https://aliexpress.com/item/1005004874160549.html>

56 Tiny DCF77 Simulator

An Accurate Fake-Time Standard

By Stefano Purchiaroni (Italy)

Simulators and reliable signal sources simplify testing during circuit and software development. Here is a small, easy-to-build module that simulates demodulated DCF77 time signal pulses.

Building a clock that uses the 77.5 kHz DCF time signal transmitted from Frankfurt, Germany, is a challenge to the designer who, like me, desires to write from scratch his own algorithm for decoding the bit stream. Even with a commercial receiver module, which can be purchased for about fifteen euro, it is difficult to obtain a clean reception during the daytime. Furthermore, if the goal is to use Nixie tubes for displaying the time, precautions must be taken to avoid receiving the interference caused by the switching boost converter used to power the tubes. Therefore, I decided to build a DCF77 simulator.

Specifications and Features

The device described here is a convenient and inexpensive simulator, which can replace the DCF77

receiver module during software development. The output is a bit sequence in form of pulses, identical to one received and demodulated by the receiver module itself. It sends a formally correct time to the clock, even though it does not correspond to the current time. It always starts at 17:43 and is then incremented and transmitted every minute, as if it were a real DCF77 receiver.

A switch allows adding some interference to the signal to make it more realistic, but also to check the robustness of the decoding algorithm. This simulator allowed me to validate the program running on the microcontroller of my Nixie clock.

The DCF77 Standard

The DCF77 time is obtained from a cesium atomic clock and transmitted on a 77.5 kHz carrier from a location near Frankfurt, Germany. The range is up to 2,000 km. Reception is better during the night thanks to the reflection in the stratosphere that thickens in the absence of solar radiation.

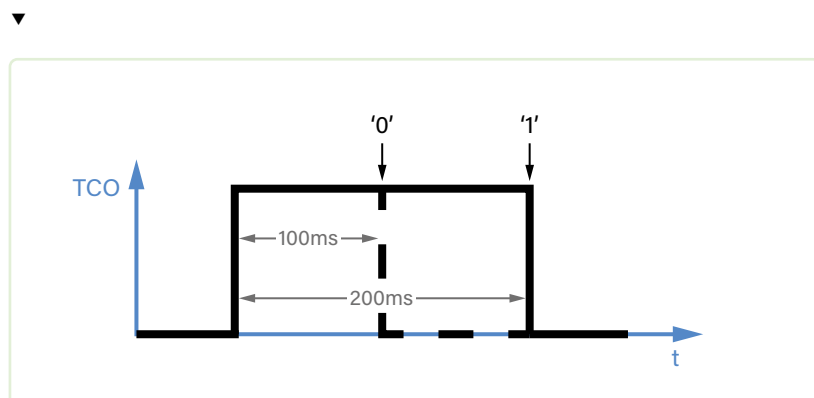
The carrier's amplitude is modulated every second for either 100 ms or 200 ms. These pulses represent the bits '0' and '1', respectively. The 59th bit is followed by a full second without modulation (i.e., no pulse), which allows synchronization to the bit stream. Besides the current hour and minute, the date and some other useful information is transmitted too. The exact format of the bit stream (and much more) can be found at [1].

Simulator Output

Like the real receiver, the DCF77 simulator supplies the data in the form of a pulse train that corresponds to the demodulated DCF77 signal. A pulse duration of 100 ms is equivalent to a logic '0', whilst a 200-ms pulse stands for a logic '1' (see **Figure 1**).

The simulator outputs fixed date information up to bit 19. Bits 20 to 35 contain an incrementing time. The two checksums calculated from the transmitted bits

Figure 1: Coding of a bit in the DCF77 time signal.



are updated too, of course, as they are indispensable for validating the received data.

Short 6-ms pulses (glitches) of polarity opposite to the expected polarity can be added to the bit stream to exercise the decoding algorithm and check its robustness.

The Circuit

The DCF77 simulator is very simple as it consists of only a few components, see **Figure 2**. It is easily assembled on a piece of prototyping board (**Figure 3**).

The Microchip PIC12F683 microcontroller U1 is used in full digital mode; its comparators and analog outputs are disabled. The I/O pins are mapped so that placing the components on a prototyping board is as easy as possible. VDD must be in the range from 2 V to 5.5 V.

Connector J1 is wired the same way as the real receiver (**Figure 4**). The PON pin controls the data output TCO. When set to high (i.e., VDD, shutdown mode), the bit stream is suspended. LED D1 imitates the receiver's on-board LED and flashes when a pulse is being sent. Switch SW1 enables or disables adding random glitches to the output signal. The source code of the DCF77 simulator together with its mikroC project and a precompiled Hex-file can be downloaded from [2].

230307-01

Questions or Comments?

Do you have technical questions or comments about his article? Email the author at s.purchiaroni@elettronicaemaker.it or contact Elektor at editor@elektor.com.



Related Products

- > **Diamex LED Tube Clock ESP Kit**
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- > **C. Valens, Mastering Microcontrollers Helped by Arduino (3rd Edition)**
<https://elektor.com/17967>

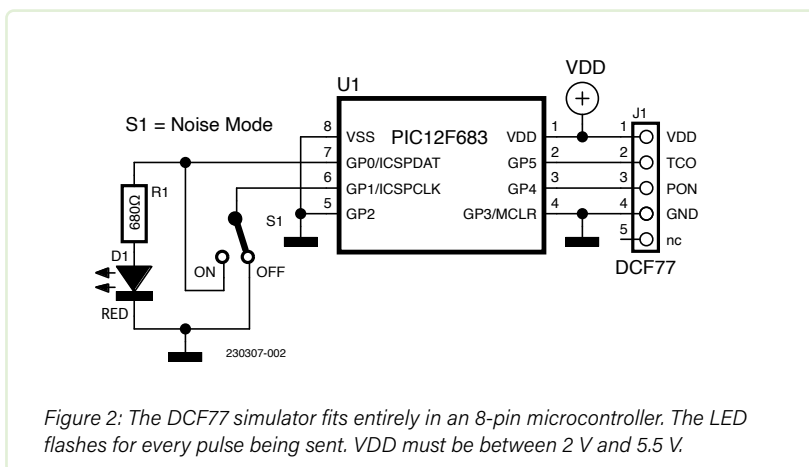


Figure 2: The DCF77 simulator fits entirely in an 8-pin microcontroller. The LED flashes for every pulse being sent. VDD must be between 2 V and 5.5 V.

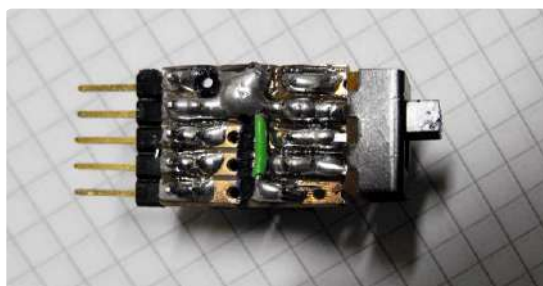


Figure 3: When building the simulator on stripboard, only four tracks need to be cut.

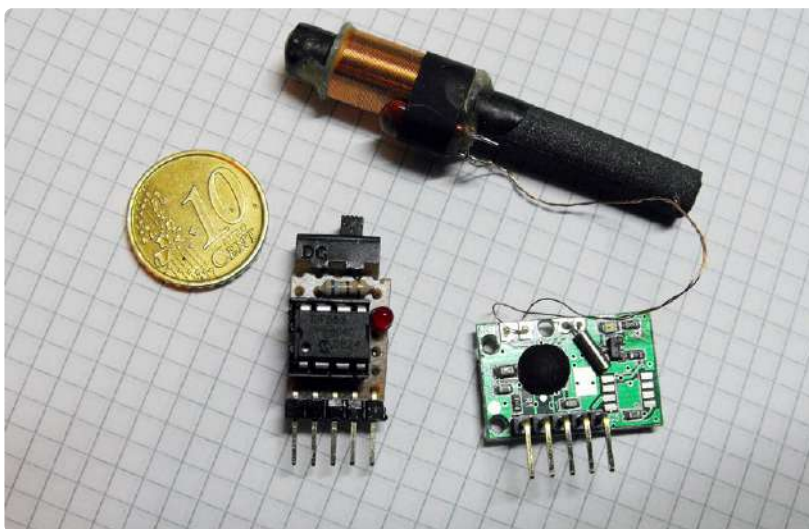


Figure 4: The DCF77 simulator and commercial DCF77 receiver module side by side. The simulator, of course, does not need an antenna. The connector on the simulator board has the same pinout as the connector on the receiver module.

WEB LINKS

- [1] DCF77 format and details: <https://en.wikipedia.org/wiki/DCF77>
 [2] Downloads for this article: <https://elektormagazine.com/230307-01>

57 The Lilygo T-PicoC3

Combines RP2040 and ESP32-C3 with Full-Color TFT Display



By Clemens Valens (Elektor)

The Lilygo T-PicoC3 module is a compact development board that features Wi-Fi and Bluetooth in addition to its full-color IPS TFT display. Let's take a closer look.

The Lilygo T-PicoC3 module's full-color IPS TFT display is a 1.14", 240×135-pixel type. The module combines a Raspberry Pi RP2040 [1] with an ESP32-C3 microcontroller, plus Wi-Fi and Bluetooth, USB-C, two pushbuttons, and a battery connector with an integrated Li-ion charger. The kit includes a little cable to connect a battery to the tiny battery connector, together with pin headers for the extension ports. The Lilygo T-PicoC3 is Raspberry Pi Pico-compatible. Even though the module sports two powerful MCUs, you should think of it as an RP2040 board with

Wi-Fi and Bluetooth extension that happens to be an ESP32-C3. The RP2040 drives the SPI display, as well as the two pushbuttons and most of the pins of the extension connectors. The RP2040 talks to the ESP32-C3 over a serial port; the ESP32-C3 functions as a kind of AT modem.

The bottom side of the board contains the RP2040 microcontroller and its memory. The ESP32-C3 and its supporting components are on the top side, hidden by the display. This makes the board look a bit like two MCU boards rolled into one. The USB-C connector that does some magic further accentuates this.

Neat USB-C Trick

The USB-C cable plugged in one way, the board is identified (by Windows 10) as a USB/JTAG/serial debug unit and as a USB Serial Device (COM12 in my case). A green LED lights up on the bottom side. This is ESP32-C3 mode.

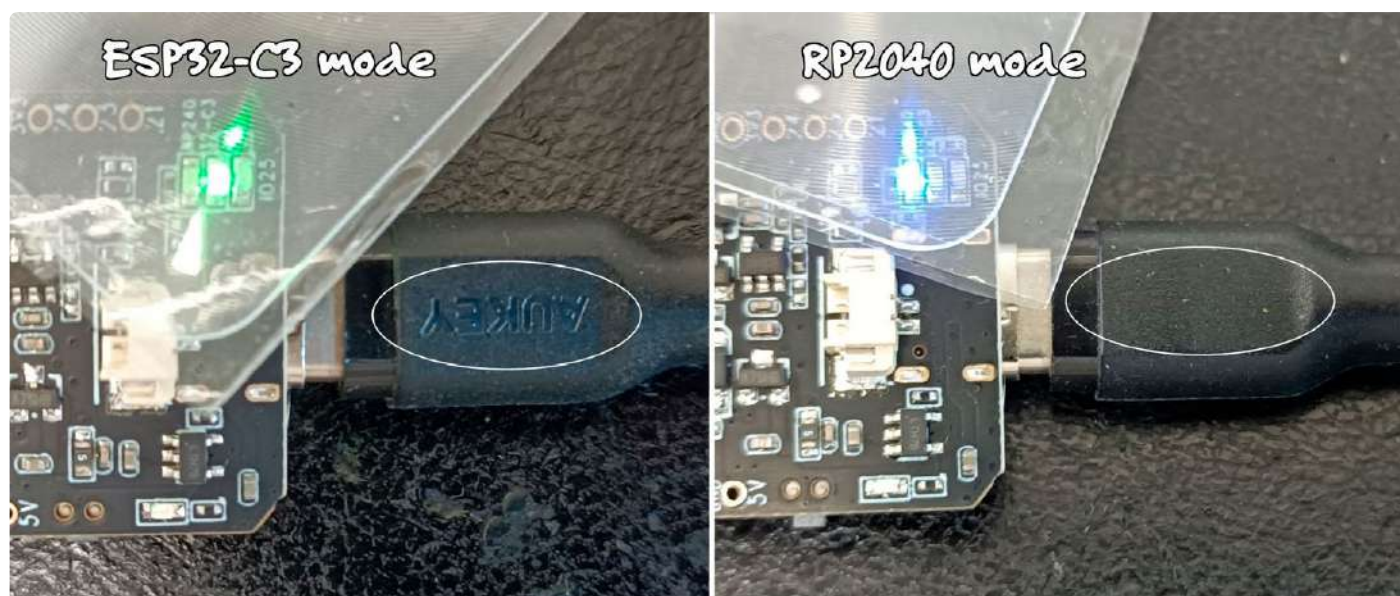


Figure 1: The T-PicoC3 board's operating mode depends on how you plug in the USB-C cable.

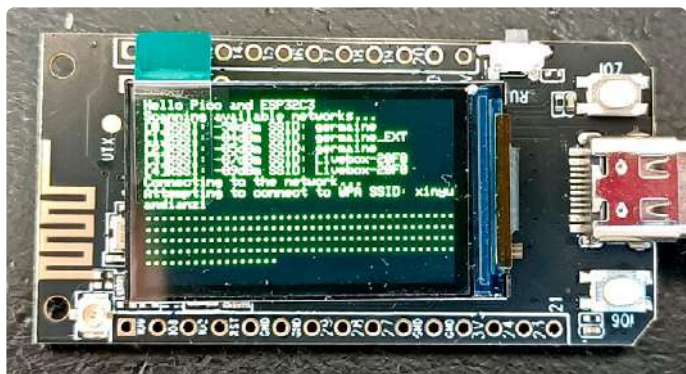


Figure 2: Out of the box, the Lilygo T-PicoC3 tries to connect to a Wi-Fi network that's probably not available near you.

Plugging in the USB-C cable rotated 180 degrees, the LED at the bottom turns blue. Windows 10 detects a USB Serial Device (COM13 in my case). This is RP2040 mode. This is quite surprising, as USB-C is supposed to be symmetrical.

In both cases, the display shows the splash screen and then starts looking for a Wi-Fi connection.

Software Development

Writing applications for the board can be done in a variety of ways. For the RP2040, the one I am most familiar with is using the Arduino IDE with Earl Philhower's *rp2040* boards package. If you don't have it yet, instructions on how to install it are given on the T-PicoC3 module GitHub page [2]. (And, even if you already have it, you must visit that page anyway to download the TFT display libraries.) The board to select in the IDE is simply the Raspberry Pi Pico.

If you prefer, you can use PlatformIO, too.

MicroPython

As the T-PicoC3 is compatible with the Raspberry Pi Pico, you can also program it in MicroPython, and they suggest using Thonny [3] for that. Refer to the official Raspberry Pi Pico documentation for more information.

The ESP32-C3 can be used as an independent MCU. Writing applications for it is similar to the Arduino way for the RP2040. You must first install the official Espressif ESP32 Boards Package. As board, you must select the ESP32C3 Dev Module. The way to upload an executable to the ESP32-C3 depends on how the USB-C cable is plugged in. Again, all the details are available on the T-PicoC3 module GitHub page [2].

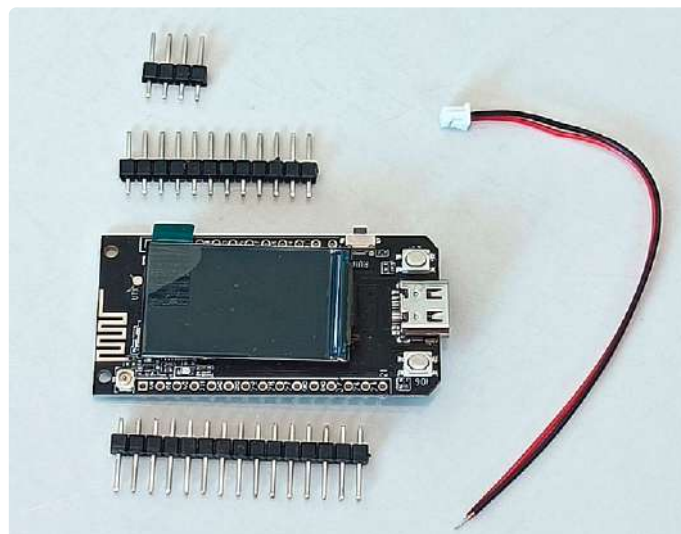


Figure 3: Lilygo T-PicoC3 kit contents.

A Powerful Tool

Overall, the Lilygo T-PicoC3 module is a nice, compact RP2040 development board with full-color TFT display and wireless capabilities that can run from a battery. It is great for IoT and smart home applications, while its two MCUs make it a versatile and powerful tool for a wide range of other projects. Additionally, its ease of use and comprehensive documentation make it a great choice for both novice and experienced users alike. ◀

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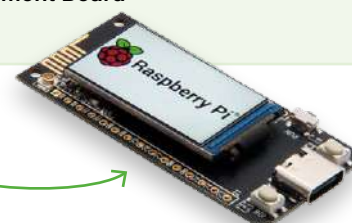
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Related Product

> **LilyGO T-PicoC3 Development Board**
<https://elektor.com/20221>



WEB LINKS

[1] Mathias Claussen, "Get to Know the Raspberry Pi Pico Board and RP2040," [Elektormagazine.com](https://elektormagazine.com/articles/pico-power-raspberry-pi-pico-rp2040):

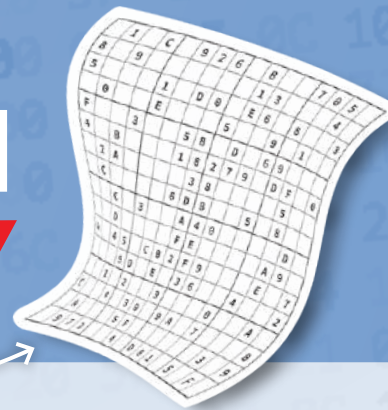
<https://elektormagazine.com/articles/pico-power-raspberry-pi-pico-rp2040>

[2] T-PicoC3 module GitHub page: <https://github.com/Xinyuan-LilyGO/T-PicoC3>

[3] Download Thonny: <https://github.com/thonny/thonny/releases/download/v3.3.5/thonny-3.3.5.exe>

Hexadoku

Puzzles with an Electronic Touch



Traditionally, the last page of *Elektor Magazine* is reserved for our puzzle with an electronics slant: Welcome to Hexadoku! Find the solution in the gray boxes, submit it to us by email, and you automatically enter the prize draw for one of five Elektor Store vouchers.

The Hexadoku puzzle employs digits in the hexadecimal range 0 through F. In the diagram composed of 16×16 boxes, enter digits such that **all** hexadecimal digits (that's 0–9 and A–F) occur once only in each row, once in each column, and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle, and these determine the starting situation.

Correct entries received enter a prize draw. All you need to do is send us **the digits in the gray boxes**.



SOLVE HEXADOKU AND WIN!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for five Elektor store vouchers worth **€50 each**, which should encourage all Elektor readers to participate.

PARTICIPATE!

By September 15th, 2023, supply your name, street address and the solution (the digits in the gray boxes) by email to: **hexadoku@elektor.com**

PRIZE WINNERS

The solution to this Hexadoku and the winners will be posted on elektormagazine.com/hexadoku at the end of September!

F	0	2	C	D	1					4	8	E	7	5	A
	3		9	E	4	F			5	C	D	6		8	
4	A	6											3	1	D
8				9			A	6			1				F
		A	E			0	F	B	9			C	D		
0	6	3		1		4	7	D	F		E		5	B	9
	B		F		D		5	C		2		3		7	
		C			3					8			F		
		D			A					6			0		
	C		2		8		E	0		B		1		A	
7	9	B		4		6	3	8	1		2		C	E	5
		0	1			9	D	4	7			8	B		
A				3			2	F			B				7
B	1	4											8	9	C
	E		7	6	B	D			A	9	0	4		2	
D	2	9	0	7	F					E	C	5	A	6	B

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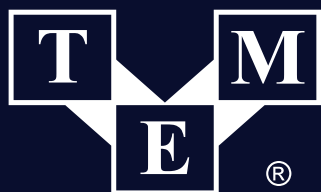


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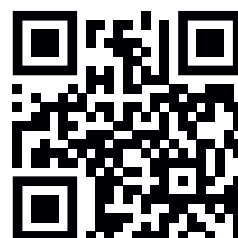


Enjoy the time saved!

2					9			
	9		5				6	
8	1	5		7		9		
1				6	7		9	
9			4	5				2
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	5					8	2	
4							1	6
3			2					7

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