Build a Voltage and Current Peak Detector

Here is a simple portable device that can help answer the question about peak voltage and peak current requirements and whether or not your power amplifier is capable of driving your loudspeaker without clipping.

Photo 1: The completed peak detector device is shown.

By
George Ntanavaras
(Greece)

Before I began designing this device, I decided several key objectives. I wanted this device to include all the necessary connectors and cabling so that its connection between the power amplifier and the loudspeaker would be easy. It should also be able to simultaneously measure the peak value of the voltage and the peak value of the current with a flat frequency response across the audio spectrum.

And, I wanted it to be able to measure the peak value of a half-cycle period of a 10-kHz sinus signal and have a long storage time for the peak value to enable easy reading of the values with an external DC voltmeter.

For the device's power supply, I chose a 9-V battery to increase its flexibility since it is not always easy to found a line voltage supply. Also, the battery eliminates possible problems due to grounding or to floating power amplifiers outputs (with no reference to the ground). **Photo 1** shows the completed detector.

The Electronic Circuit

Figure 1 shows the detector's block diagram. Four sockets exist in the device's front plate for easy connection of the external signals. Two of them are used to connect to the power amplifier output and the other two are for the loudspeaker connection. A shunt resistor with a very low value is used to "sense" the current and transform it into voltage.

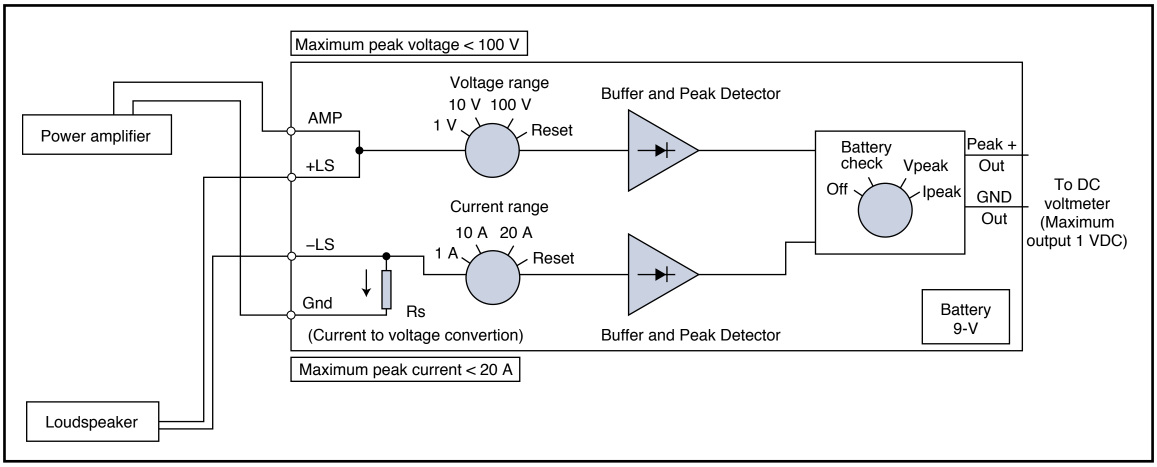


Figure 1: I used this block diagram to build my voltage and current peak detector.

Two resistor dividers are used to attenuate the voltages before they are driven to the inputs of the peak detectors. These will only detect the signal's positive peak value. When I designed the first version of this device, I included both positive and negative value peak detectors. But during the tests with a real music program, I discovered that the positive and the negative peak values were almost always the same. So, I decided to omit the circuit of the negative value detector to simplify the detector's construction and to reduce the power consumption.

At the output, a switch is used to power on the device and to send the half-battery voltage at the output connector where it can be easily measured by an external DC voltmeter and select as indication either the peak voltage or the peak current.

Finally, a simple circuit continuously checks the battery voltage level and illuminates a red LED when the battery voltage is above the minimum acceptable level.

At the heart of the device is the peak detector circuit, which I chose after testing several topologies. The main problem I had with most of them was the storage time of the peak value. **Figure 2a** shows the circuit that gave the best results in all the tests I performed. It is also the one I chose to use. It is based on a circuit described in Figure 4.40 of the book *The Art of Electronics* by Paul Horowitz and Winfield Hill (2nd edition, Cambridge University Press, 1989). There, it is proposed as a much better solution for a peak detector circuit, and really it is.

During the circuit's operation IC1 charges the storage capacitor C1 with the peak voltage through both diodes. When the input voltage drops below the peak value, IC1 goes into negative saturation but IC2 keeps the point X between the two diodes to the same voltage as of the capacitor C, eliminating the leakage from diode D2. The only leakage comes from the input bias current of IC2 which should be very low.

Figure 2b shows the final circuit design. I replaced the second diode with a N-channel J-FET connected as a diode to further decrease the leakage current and to increase the storage time of the peak voltage at the capacitor C1.

For the op-amp, I chose the TLC277. This is a LinCMOS precision dual-operational amplifier with an extremely high input impedance and very low input bias current.

The voltage range required for its operation is from 3 to 16 V, which are excellent limits when the circuit is supplied by a 9-V battery.

For the capacitor C1 that stores the peak value of the voltage, I used a 4.7-nF capacitor. This was a good compromise between a fast rising time and a long storage time. A low leakage and low dielectric capacitor should be used here, so I used a polypropylene capacitor. I also used a 100-Ω resistor in series with the capacitor to damp any peaking of

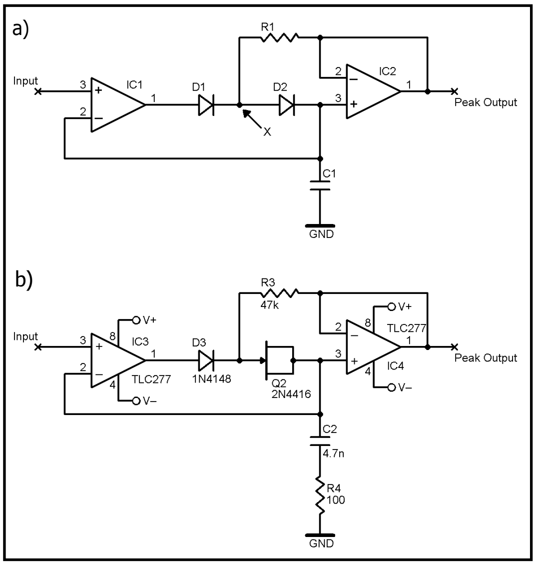


Figure 2: I based the detector on this circuit (a). This is my final circuit design (b).

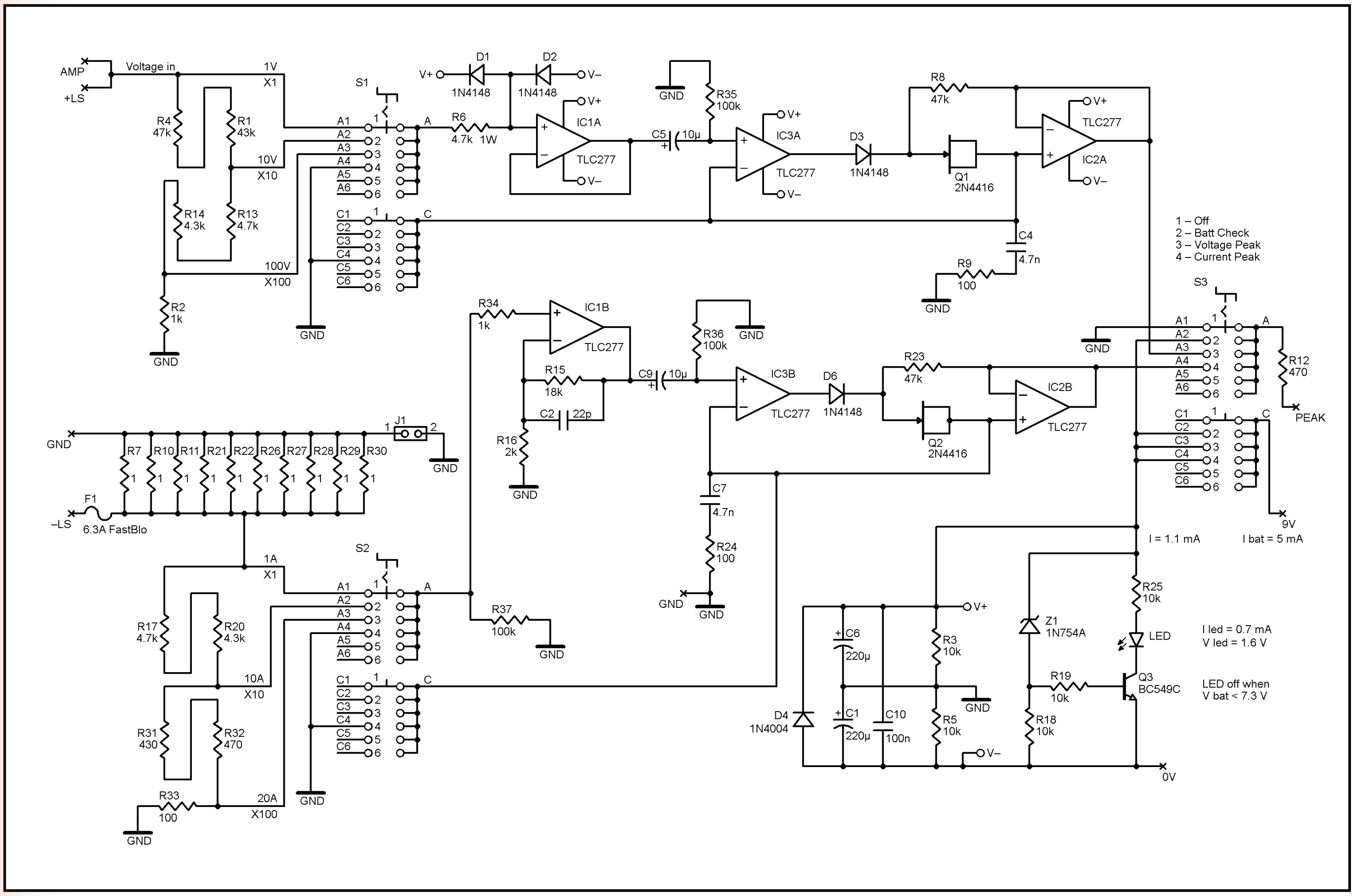


Figure 3: The peak detector's complete schematic diagram is detailed here.

the capacitor voltage during fast transients. **Figure 3** shows the detector's compete schematic diagram.

The input for the voltage are between the pins +AMP (or +LS) and GND. Here the maximum voltage should always be kept at less than 100 V_{PEAK}.

Resistors R4, R1, R14, R13, and R2 create a divider for the input voltage. This divider provides attenuation of 10 and 100 times. Switch S1 selects the proper level to avoid the overload of the next stages and drives the buffer IC1A. The second part of the S1 is used when necessary to reset the voltage of the capacitor C4, which holds the peak value. Resistor R6 and diodes D1 and D2 provide more protection from over voltages to the circuit. The high-pass filter of C5 and R35 removes any DC offset from the input signal. The circuit around IC3A and IC2A is the voltage peak detector that was previously analyzed.

The input for the current is between pins –LS and GND. For safety reasons, the maximum peak current input to the device should always be kept at less than 20 A_{PEAK} and for a very short time (milliseconds). This is a very high current that I have not previously encountered in the several loudspeaker measurements I have performed. Also, I should mention that if the current is that high, a corresponding large voltage drop will occur on the sense resistor (2 V). This could affect the measurement. Additionally, the ohmic resistance of the cables will start to play a major role.

F1 is a 6.3-A, quick-blow fuse that protects the circuit from over currents. According to this fuse's time-current characteristic curve, a peak current of 20 A will be permitted for a few hundred milliseconds before the fuse blows.

The input current is sensed by the 10 parallel resistors R7, R10, R11, R21–R22, and R26–R30. These are 1-Ω/2-W resistors that provide an equivalent value of 0.1 Ω/20 W. I use 10 resistors not only to increase the power consumption of the

About the Author

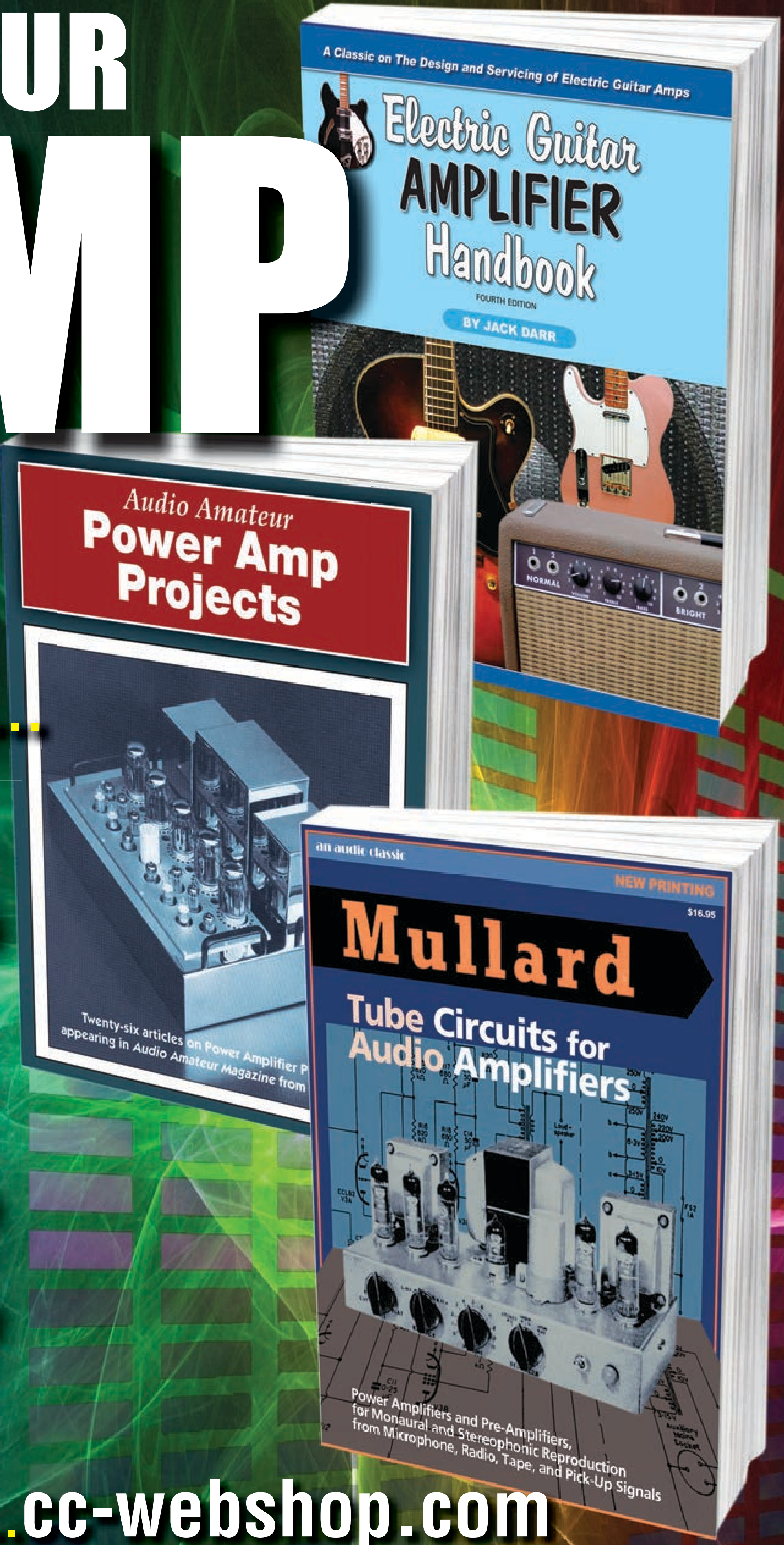
George Ntanavaras graduated from the National Technical University, Athens, Greece, in 1986 with a degree in Electronic Engineering. He currently works in the Development Department for a Greek electronics company. He is interested in the design of preamplifiers, active crossovers, power amplifiers, and most loudspeakers. He also enjoys listening to classical music.

What's YOUR AMP

Design it...

Build it...

Fix it...



Electric Guitar Amplifier Handbook

Everything you need to know about how each part of the amp works and what to do when it doesn't.

Power Amp Projects

An array of designs for those who prefer to build their own audio equipment.

Mullard Tube Circuits for Audio Amplifiers

A complete guide to building 11 power and control amps for a sound system with vacuum tubes.

Resources for the audio enthusiast...cc-webshop.com sense resistor to more safer values but also to better distribute the heat dissipation.

The sensitivity of the current sensing circuit is 0.1 V/A. This will be increased at the next stage.

In the same way as described above, resistors R17, R20, and R31–R33 provide a divider for the corresponding voltage of the current sense resistors. Switch S2 selects the proper level and drives the input of IC1B. This is a gain times 10 stage that will give a 1 V/A sensitivity at its output. The second part

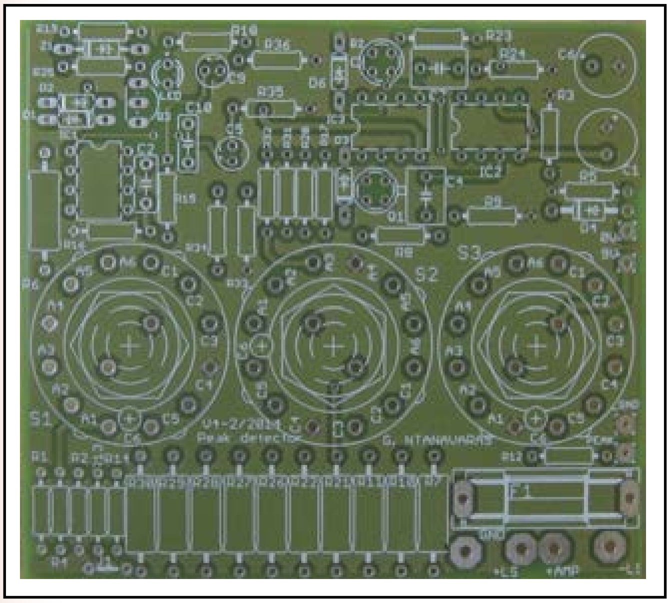


Photo 2: I used this high-quality PCB for the peak detector

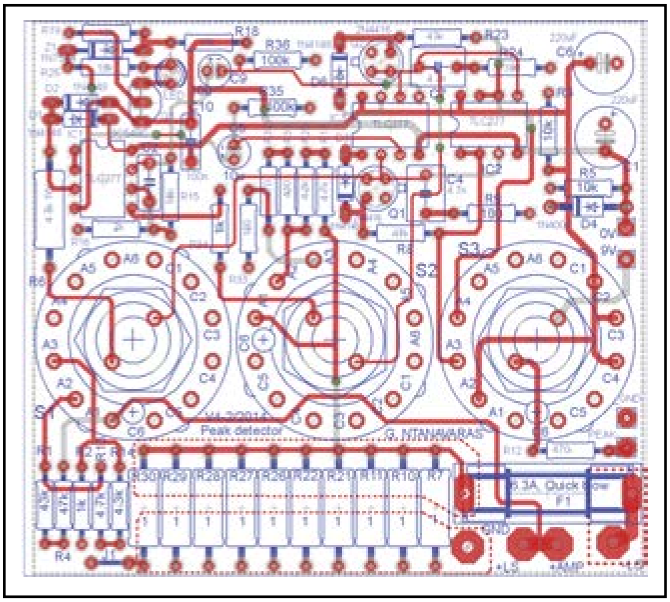


Figure 4: This diagram shows the lay out of the components on the PCB.

Part	Value	Description
C1, C6	220 µF, 16 V	Electrolytic capacitor, RM = 3.5, diameter = 8 mm
C2	22 pF	Capacitor ceramic
C4, C7	4.7 nF	Capacitor MKP
C5, C9	10 µF 16V	Electrolytic capacitor
C10	100 nF	Capacitor MKT
D1,D2, D3, D6	1N4148	Diode
D4	1N4004	Diode
IC1, IC2, IC3	TLC277	Op-amp
LED		LED 3 mm (1 mA) – Farnell 1003210
Q1, Q2	2N4416	N-Channel J-FET
Q3	BC549C	NPN Transistor
R1	43 kΩ	Resistor
R2, R34	1 kΩ	Resistor
R3, R5, R18, R19, R25	10 kΩ	Resistor
R4, R8, R23	47 kΩ	Resistor
R6	10 kΩ/2 W	Resistor
R7, R10, R11, R21, R22, R26, R27, R28, R29, R30	1 Ω/2 W	Resistor
R9, R24, R33	100 Ω	Resistor
R12	47 Ω	Resistor
R13, R17	4.7 kΩ	Resistor
R14, R20	4.3 kΩ	Resistor
R15	18 kΩ	Resistor
R16	2 kΩ	Resistor
R32	470 Ω	Resistor
R31	430 Ω	Resistor
R35, R36, R37	100 kΩ	Resistor
S1, S2, S3		CK102x06, Rotary switch
Z1	BZX55C6V8	6.8 V, Zener diode
Plastic box		CASE, ABS, PP3, Farnell 775812
Fuse holder		Fuse holder, 20 × 5 mm, Farnell 1162740
fuse		Quick blow, 6.3 A, 20 × 5 mm
Battery connector		9-V Battery clip
Battery		9-V Battery
Output connector		Socket, 3.5 mm, Panel, Farnell 1267382
Input connectors		Metal socket, 4 mm, Farnell 1176436
All resistors are 0.5 W, 1% except as noted		

Table 1: The peak detector's list of components are detailed.

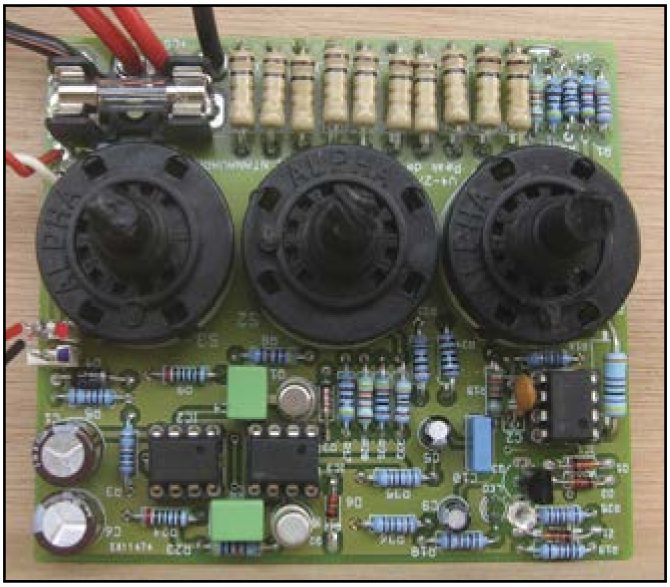


Photo 3: This shows the peak detector's PCB assembly.

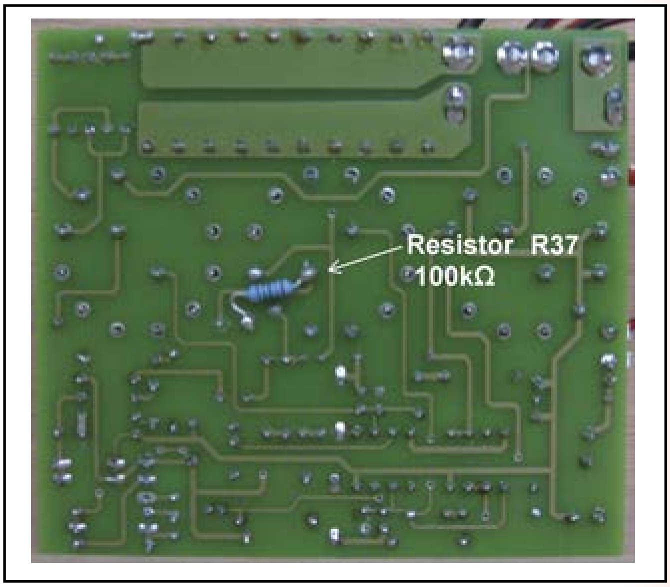


Photo 4: I implemented a necessary modification on the bottom of the PCB.

of the S2 is used to reset the current peak value of the capacitor C7 when necessary.

The high-pass filter of C9 and R36 removes any DC offset from the input signal to the peak detector of the current. The circuit around IC3B and IC2B is the current peak detector that was previously analyzed.

The output switch S3 has four different functions. First it is used as a power Off switch. Moving to the next position, it will power on the device and connect the half-battery voltage at the output where it can be easily measured with a DC voltmeter. At the third position, it will send the voltage peak value at the output connector. On the fourth position, it will give the current peak value at the output.

I used a 9-V rechargeable battery to operate the detector, so the circuit around transistor Q3 and Zener diode Z1 (6.8 V) continuously monitors the battery voltage. The red LED illuminates when the battery voltage is above 7.3 V. When the LED is off, the battery should be replaced with a fresh one. I used a 3-mm LED with a low drive current (1 mA), which in the final circuit I reduced even further to 0.7 mA.

The change reduced the monitoring circuit's consumption to about 1.1 mA. Although it will affect the battery life, I decided to use it because I wanted to avoid fault indications when the detector's battery voltage was low. The circuit's total consumption is low (about 5 mA at 9 V), which will ensure a long battery life.

Device Construction

For the detector's construction, I designed a PCB with the demonstration version of the Eagle Layout editor. The demo version can be downloaded for free from Cadsoft's website. It is fully operational except for the limitation of the PCB's maximum dimensions,

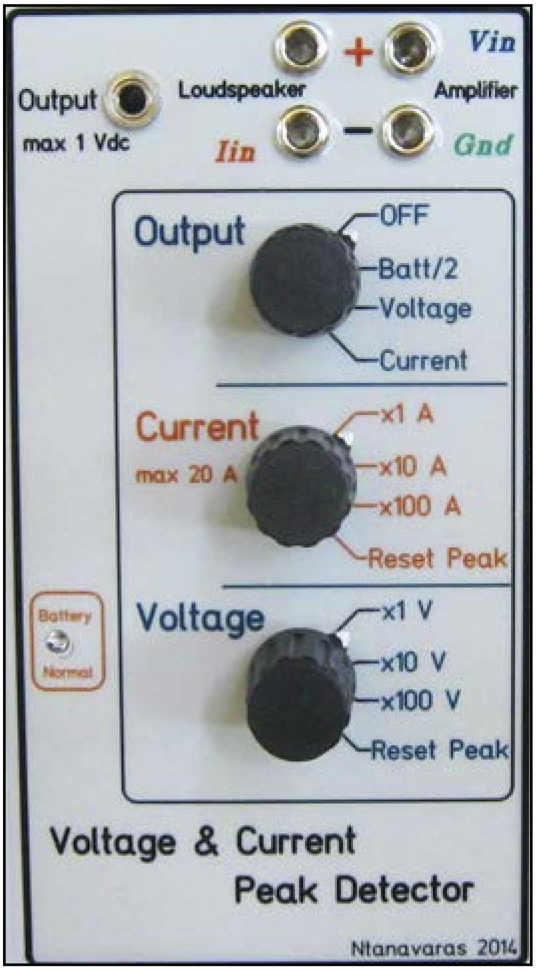


Photo 5: I used a simple software program to design the peak detector's front plate.

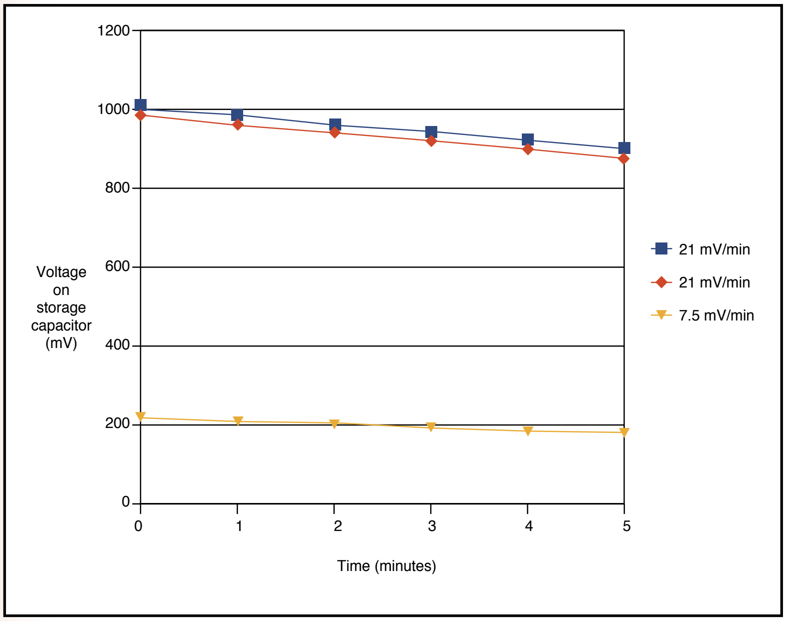


Figure 5: This is the voltage drop on the storage capacitor.

which was not a problem for this project. Almost all the detector's components were placed on the PCB, which simplified the construction.

Photo 2 shows the high-quality PCB that I used. It was manufactured from board material FR4 with a 1.6-mm thickness with 35-µm copper. It also had plated through holes, with solder resist on both sides and silkscreen on the top side.

Figure 4 shows the PCB's complete guide assembly. **Table 1** provides the parts list. **Photo 3** shows the final assembled PCB.

Photo 4 shows a small modification that is necessary to ensure the circuit's operation. The resistor R37 (100 kΩ) is placed on the bottom side of the PCB. This modification eliminated some random peaks that occurred when the switch S2 changed positions during a measurement.

I used a handheld plastic enclosure to house the PCB and the detector's connectors. The four 4-mm connectors for the input voltage and the current were placed close to the PCB. I connect them to it with proper thick cables to keep the resistance to a minimum.

On the enclosure's back side is a removable cover that makes battery replacement very easy. The enclosure's external dimensions were: 143.1 mm (width) × 82.6 mm (depth) × 38.4 mm (height).

I used the "Front Panel Designer" program to create the text on the front plate. I printed the file on a transparent self-adhesive sheet with my ink-jet printer. Then, I used a transparent acrylic spray to protect the adhesive sheet.

I used the same diagram as a guide for the openings of all the holes on the plastic enclosure that were needed (e.g., the rotary switches, the input and output sockets, and the LED). **Photo 5** shows the resulting front plate for the device.

The Testing

When I finished assembling the PCB, I used a continuous sine wave from the output of my waveform generator to preform a first check of the device. Both peak values of voltage and current were measured with great accuracy (within 2%) and I compared them with the RMS values of my True RMS multimeter (peak value = 1.4142 × RMS value for a pure sine wave).

The next test was the measurement of the storage capacitor's droop voltage. This is also a very important parameter of the peak detector.

Figure 5 shows the results of my three measurements. The first two measurements were at the top range of the output peak voltage and indicated a droop voltage of about 21 mV/min. The third measurement was at the bottom range and indicates 7.5 mV/min. All these are excellent results and assure that none of the peak values will be missed.

Next, I wanted to check the peak detector's accuracy during dynamic conditions in the same way the device will be used. After some thought, I created a special test signal using the Audacity program.

Figure 6 shows the test signal that I used. It consists of three parts. The first part contains a continuous sinus wave which lasts for 10 s. The second part is complete silence for another 10 s. The third part contains one positive half-cycle of the previous sinus wave, which has the same peak value as the first part.

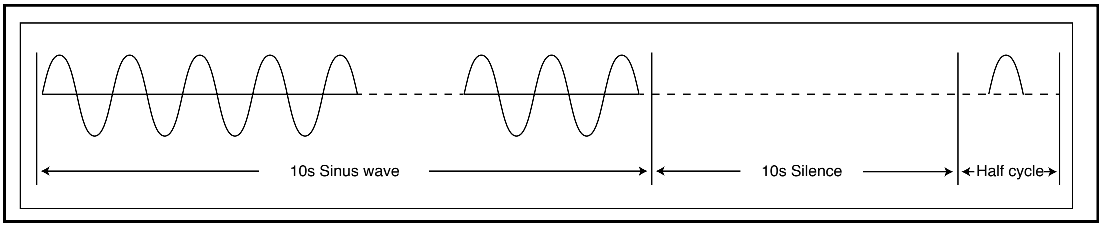


Figure 6: I used a signal to test the peak detector.

For the test, I used my True RMS Voltmeter, which has very good accuracy up to 20 kHz. If such a voltmeter is not available, an oscilloscope could be used. I used the first part to measure the signal's RMS value with the reference voltmeter. I also used the peak detector to measure the peak voltage and the two measurements should have the relation Peak value = 1.4142 × RMS value.

Then, when the signal dropped to silence for the next 10 s, the peak detector value should be reset by the relevant switch. Finally, when the half cycle was reproduced, the peak detector should measure the same peak value as it previously measured with the continuous signal. I checked the peak detector's accuracy at several frequencies using the above method, and I determined its accuracy was excellent even for the half period at 10 kHz.

Benefits

I have found the detector to be a very useful piece of test equipment. It measures with good accuracy the positive peak voltages up to 100 V and the positive peak currents up to 20 A within the entire audio range. It is also portable and very reliable. If you don't have such equipment in your lab, this is a good opportunity to build one.

Author's Note: I have a small quantity of PCBs (manufactured as shown in Photo 3) for the construction of this device. If you are interested, send me an e-mail at gntanavaras@gmail.com.

Resources

Audacity free open-source software, http://audacity.sourceforge.net.

P. Horowitz and W. Hill, *The Art of Electronics,* 2nd edition, Cambridge University Press, 1989.

Sources

Eagle software program
Cadsoft | www.cadsoftusa.com

Front Panel Designer software
Front Panel Express, LLC | www.frontpanelexpress.com/download/front-panel-designer/index.html

TLC277 Op-amp
Texas Instruments, Inc. | www.ti.com