Resounding Truth
An acoustic lie detector

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There are those cool-headed types, who can lie through their teeth with a straight face. But in the end it is just a matter of asking the right questions. Sooner or later everyone will get sweaty palms.

Lie detectors are always a great deal of fun at parties. Who is prepared to face up to the challenge from technology? And also: who is able to defeat the machine! The latter is also very dependent on the actual situation — the questioner must not make it too easy for the test subject! When the tension increases, even the best liar can't avoid a subtle but inevitable physiological reaction: sweaty palms.

The operating principle of this lie detector makes use of this phenomenon. When the hands of the person in the hot seat become damp, the electrical resistance of the skin will reduce. This change is relatively easy to detect. In that respect we certainly don't want to claim that the circuit presented here is a feat of brilliant innovation. However, it is the manner in which this device signals the result that sets it apart. That is, this circuit will emit a tone, the frequency of which depends in the resistance of the skin.

Five-five-five

The design of the circuit shown in **Figure 1** is actually a relatively typical application for the well-known 555. This timer-IC has been wired here as an astable multivibrator, that means that at the output there is a signal, the frequency and duty-cycle of which are determined by two resistors and one capacitor. In this case there are actually three resistors and one capacitor. The resistance of the skin is connected in series with R1. In conjunction with R2 and C1, this series connection determines the duration that the output (pin 3 of IC1) is high. When the power supply is switched on, the capacitor is charged, through these resistors, to $^2/_3$ of the power supply voltage. An internal comparator compares, via pin 6, the voltage across the capacitor with this

COMPONENTS LIST

Resistors:
R1,R2 = 27kΩ

Capacitors:
C1 = 4n7

Semiconductors:
IC1 = NE555

Miscellaneous:
BZ1 = buzzer
2 PCB solder pins
2 solder pin receptacles soldered to long wires (stripped ends)
6 pieces of (bare) wire
PCB, prototyping board, order code **UPBS-1** (see Readers Services page)
9 V-battery with clip-on leads

threshold value. When this threshold is exceeded, the output of the IC will change state. This means that the inverting output of the internal flip-flop (Q̄ in **Figure 1**) will become high. This causes an internal transistor to conduct which results in the discharge of the capacitor via pin 7 and R2. Note that the length of time that the output remains low is not dependent on R1 or the skin resistance.

Subsequently, the second internal comparator starts to play a part. Again, the voltage across the capacitor is compared with a threshold value (pin 2). When the voltage is $^1/_3$ of the power supply voltage, the internal flip-flop is set, the output changes state again and the whole process begins anew.

Two pins of IC1 are not used in this configuration. Pin 4, the inverted reset input, can be used to interrupt the charging process of the capacitor prematurely. This can be very useful in other circuits but is not necessary in this design. Here, the reset input has been connected to V_{CC}, so that the internal comparator alone determines when to reset the flip-flop. That leaves the control input (pin 5). Via this input the upper threshold value can be changed. That function is not used here and the input is left open.

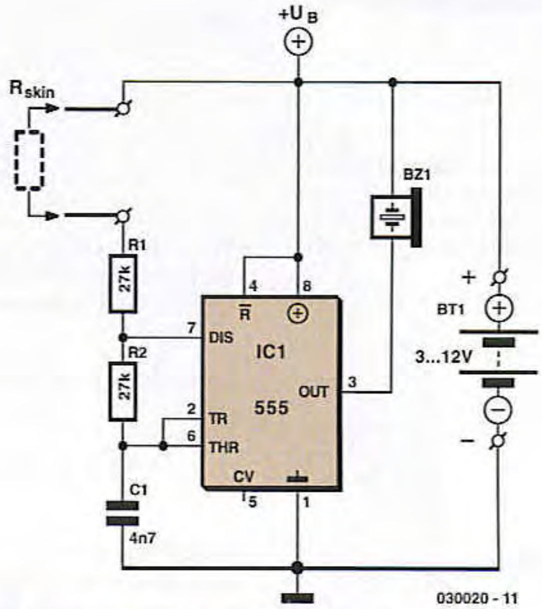

Figure 1. The 555 as an astable multivibrator.

Construction

For this project too, we have designed a printed circuit board. However, this time not quite as you have come to expect from us. **Figure 2** shows a PCB layout for our Universal Prototyping Board size-1 (UPBS-1) which can be purchased ready-made through the *Elektor Electronics* Readers Services. A normal piece of prototyping board, stripboard or Veroboard can be used as well, of course.

We can be brief regarding the actual construction, the only thing that may need some clarification is how to measure the skin resistance. Very simple: attach two wires, one to the positive power supply and one to R1. The stripped ends are then loosely wrapped around two fingers of one hand. That is all.

Component values

In the inset you can read how the component values in the circuit are calcu-

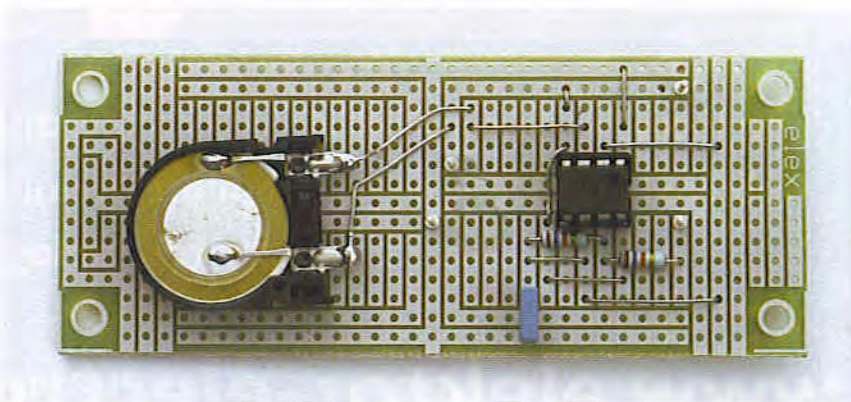

Figure 2. Suggested construction on an UPBS-1 prototyping board.

ReCapping...

When a capacitor is charged through a resistor, the charging current is not constant. As a consequence, the change of voltage across the capacitor follows a typical curve (Figure 3 refers):

$$U(t) = U_b\,(1 - e^{-t/RC})$$

In this equation, the product of capacitance and resistance stands out: the RC time constant. This determines how long it will take before the capacitor is charged to a certain value. By rearranging the equation we can determine this time accurately:

$$t = -RC\,\log_e\,(1 - U(t) / V_{cc})$$

Here U(t) is the desired voltage at instant t and U_b is the charging voltage. The time it takes to charge the capacitor to $^2/_3$ of the power supply voltage is therefore:

$$t = -RC\,\log_e\,(1 - (^2/_3 / 1))$$
$$= 1.10\ RC$$

Once the circuit is operating, the capacitor only needs to be charged starting from $^1/_3$ of the power supply voltage. If we subtract the time this takes from the value previously calculated, we then know the duration of the on-period:

$$t_{on} = 1.10\ RC - 0.41\ RC = 0.69\ RC$$

For the off-period (the discharging of the capacitor) we can write another equation. In general:

$$U(t) = U_0\,e^{-t/RC}$$

or

$$t_{off} = -\log_e\,(U(t) / U_0)\ RC$$

Here we are looking for the time it will take to discharge the capacitor to $^1/_3\ U_b$, when the initial value is $^2/_3\ U_b$:

$$t_{off} = -\log_e\,(^1/_2)\ RC = 0.69\ RC$$

Now that we know exactly how long it takes for one cycle, i.e., what the period is, we can determine the frequency of the signal at the output:

$$f = 1 / T, \text{ where } T = t_{on} + t_{off}$$

Substituting the capacitance and resistance values into the equations for the on- and off-times (note: when discharging only R2 is part of the RC network) we can calculate the frequency of the tone we'll hear:

$$f = 1 / (t_{on} + t_{off})$$
$$f = 1.4 / C1\,(R_{skin} + R1 + 2\,R2)$$

Here:

$$f = 319 \times 10^6 / (R_{skin} + 81 \times 10^3)$$

QED: only the resistance of the skin determines the frequency.

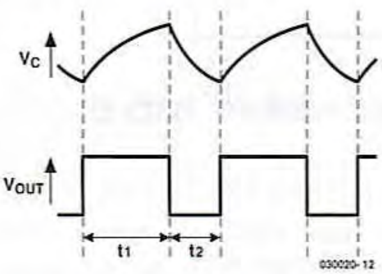

Figure 3. The voltage across the capacitor (top) and the corresponding output signal (bottom).

lated. If you are only interested in the result, then only the last equation is of importance. Normally, the resistance of the skin will be between 10 and 500 kΩ. With the component values as shown, this will produce a tone from buzzer Bz1 with a frequency between 500 to 3500 Hz. The frequency is mainly dependent on the dampness of the skin: the more sweat, the better the conduction and therefore the lower the resistance. When the resistance reduces, that is, the test subject becomes nervous, the pitch increases. Note that the pitch is not an absolute measure of 'the truth'. One person has a naturally better conducting skin than another. That makes no difference here, because it is the change that matters. Human hearing is actually quite sensitive to such changes in pitch. An additional feature is that the test subject can hear the tone as well. This often leads from bad to worse. Despite the best intentions not to break under duress, this psychological feedback is usually the last straw that breaks the camel's back.

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