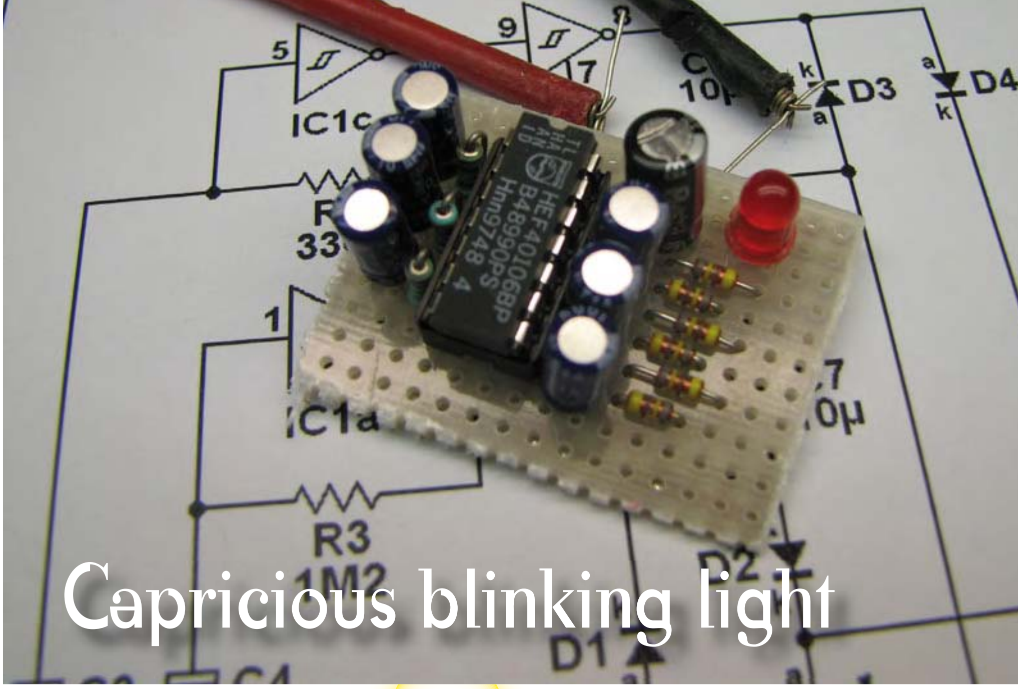
Capricious blinking light



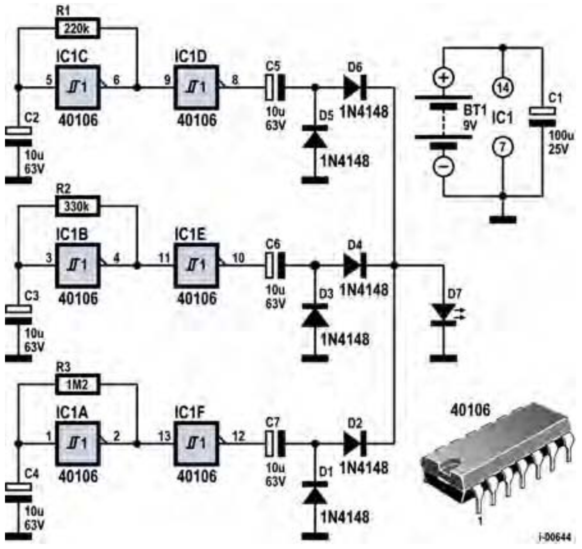
Design: Thomas Scarborough
(South Africa)

One of the many good features of electronic circuits is their reliability. When you switch on your television set, you expect to see a picture appear on the screen a short time later. If the screen remains dark, you can rightfully assume that there's something wrong somewhere. This predictability even extends to the behaviour of DIY circuits and their components, as can be seen from the explosion and cloud of smoke that usually occur if you accidentally connect an electrolytic capacitor the wrong way round. To put it briefly, we could say that it's almost impossible to build a circuit whose behaviour cannot be predicted – but is this really true?

To give an example, you can quickly and easily put together a circuit that uses astable multivibrators (AMVs) to drive blinking LEDs. A characteristic feature of all such circuits is that the LEDs blink at regular intervals. However, it would be much more amusing to cause a LED to blink in a purely random manner, so that its behaviour would not be predictable.

The circuit shown here uses three AMVs built around Schmitt-trigger inverters (IC1a, IC1b. and IC1c), each of which is followed by a buffer (IC1d, IC1e, and IC1f).
To understand how this works, first assume that the output of inverter 1 is presently high. In this case, capacitor C2 at its input will be charged via the resistor (R1) connected between the output and the input. After a certain length of time, the voltage on the capacitor will reach a level that causes the inverter to change state, and the output will switch to the low level. Now the capacitor will be discharged via the resistor until the inverter changes state again, after which the process will start again from the beginning. This sequence will be repeated endlessly, or at least until the battery is used up. The time interval between the state changes depends on the values of capacitor C1 and resistor R1.

You should note that this sort of oscillator design only works properly with a Schmitt trigger. Normal inverters (and normal logic gates) cannot tolerate 'undefined' input voltages in the grey zone between the high and low levels, since such voltages can have unpredictable effects on the behaviour of the IC, and in the worst case they can lead to the destruction of the IC.
By contrast, Schmitt triggers do not have an undefined input voltage range, and the voltage ranges corresponding to the high and low input levels actually overlap.



The only task of the buffers here is to decouple the three multivibrators from the components on the right-hand side of the schematic drawing. As a capacitor cannot pass a DC voltage, capacitors C5–C7 are used to convert the rising edges of the buffer outputs into voltage pulses that cause the LED to blink briefly but brightly. This keeps the current consumption within bounds, since it primarily consists of the brief current pulses that flow when the LED blinks.
Diodes D2, D4 and D6 collectively implement a logic OR function. As a result of this arrangement, the LED blinks when it receives a voltage pulse via D2, D4 or D6. This randomness of the circuit also arises from this. Each oscillator operates at a different frequency, so the pattern of pulses at the junction of D2, D4 and D4 is constantly changing. As a result, the LED blinks in a random manner, as shown in the following diagram.

Of course, the behaviour of the circuit is not truly random, so it would perhaps be better to call it a 'pseudo-random blinker'. The three oscillators always operate at the same frequencies, so the pattern of superimposed pulses from the oscillators repeats periodically after a certain length of time. However, this time interval is so long that the repetition cannot be recognised by simply observing the blinking LED.
True random-number generators take advantage of unpredictable phenomena such as the thermal noise of resistors and semiconductors. This noise is so weak that strong amplification is necessary before it can be used. The circuitry necessary for this would be much more complex than the present circuit.

If this circuit is powered by a 9-V battery, the average current consumption (as measured over several minutes) is approximately 0.84 mA, at least with our prototypes. The peak current through the LED is 16 mA. This means that the circuit can operate for around one month from a 600-mA battery.

With a supply voltage of 12 V, the output resistance of the output transistors in the 40106 decreases, which causes the peak current through the LED to rises to approximately 28 mA. Naturally, the average current consumption of the circuit also increases accordingly.