MICROPOWER LED FLASHER

We've used flashing LEDs for decades – but alas, the LM3909 Flashing LED IC is no longer available. What to do?

By JOHN CLARKE

Now we know that that there are lots of LED flashers available and that you can also obtain LEDs with in-built flashing. But we still get regular requests for a LED flasher, to provide similar functions to the now obsolete National Semiconductor LM3909 flasher/oscillator.

This new module provides similar functions to the LM3909 but also includes daylight detection with an LDR (light-dependent resistor). Since the LM3909 is no longer available, we have employed a low-cost microcontroller and it drives the LED in a similar way to the National Semiconductor device.

To be specific, it charges a capacitor, then "jacks it up" and dumps the charge through the LED to give a much brighter flash than would be possible with the otherwise limited supply voltage. In fact, you cannot normally drive a blue or white LED reliably with a 3V supply – you need to boost the voltage.

By the way, this module does not have to be battery powered. You can run it from any fixed supply from 3 to 5V, so you can eliminate the button cell and just connect it to any 5V USB source. Alternatively, you can run it from a much higher DC voltage if you connect a suitable resistor in series with the input.

Circuit details

The circuit is shown in Fig.1 and uses a PIC12F675 microcontroller, two diodes and several resistors and capacitors. It runs from a lithium button cell, or you could run it from two alkaline AAA cells or a 5V USB supply.

LDR1 is used to detect whether the LED Flasher is in daylight or in darkness. This is connected in series with a 470kΩ resistor. In darkness, the LDR resistance is typically well over 1MΩ. When the GP4 output is high (ie, at the positive supply voltage), the 470kΩ resistor pulls the GP2 input sufficiently high for IC1 to detect this as a high level. In daylight, the resistance of LDR1 is around 10kΩ and so GP2's input is held near to 0V. IC1 detects this as a low and then goes to sleep to conserve power.

If the GP2 input is high, indicating that the module is in darkness, the micro provides the LED flasher function, which we will come to in a moment. If the LDR is omitted, this input will always be high and so the flasher will run as long as it has power.

The micro has an internal "watchdog" timer and this is used to wake it up every 2.3 seconds so that it can check the voltage level at the GP2 input pin. If it is low, the microcontroller goes back into sleep mode. If it is high, LED flashing is enabled.

The Flasher section of the circuit comprises diode D1, capacitor C1, resistors R1 & R2 and LED1. We show its operation in Fig.2 which depicts the two modes of the circuit: charging the capacitor and then jacking it up while dumping its charge through the LED.

In the first part of the cycle, the GP5 output (pin 2) is taken high while the GP0 output (pin 7) is held low. In this state, capacitor C1 charges via R1 (6.2kΩ) and diode D1. The charge current path is shown in Fig.2 in green. No current flows through the LED and R2 because this process reverse-biases the LED, as its cathode terminal (labelled K) is held high while the capacitor is charging.

During this process, the voltage across C1 is monitored by input pin GP1 (pin 6). The software compensates for the fact that the voltage at this pin is higher than that at the capacitor's positive terminal due to the forward voltage drop of diode D1.

Once the capacitor has charged to the maximum possible level of about 2.2V, the comparator senses this and switches the GP5 output (pin 2) low

Features & Specifications

- Flashes any colour LED
- Flash rate set by resistor & capacitor values
- Optional LDR to disable flash with high ambient light
- Two PCB versions to suit different applications
- Small and easy to build
- Supply voltage range: 3-5.5V or higher with modifications (see text)
- Fixed flash time: 65ms
- Standby current: 10μA @ 5V, 2μA @ 3V
- Operating current: typically 0.7-1.6mA (0.5-2Hz) (see Table 1)

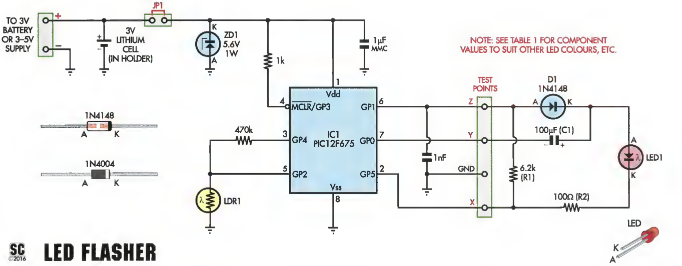


Fig.1: complete circuit for the LED Flasher. IC1 charges capacitor C1 via pins 2 and 7 and diode D1. C1 is then discharged through LED1 and R2, with a total flash voltage of about 5V when the circuit is powered from a 3V button cell. This is sufficient to allow blue or white LEDs to be used.

and the GP0 output (pin 7) high (up towards +3V). This has the effect of "jacking up" the negative side of the charged capacitor by about 2.6V or so, which means that the positive terminal will be at around 5V. This is fed to the LED to give a brief and very bright flash. The LED current path is shown in red in Fig.2.

The cycle then restarts, with GP5 and GP0 swapping polarity, so that capacitor C1 can charge up again.

Since the timing of this cycle is controlled by the component values, the flash rate is set mainly by the values of C1 and R1 but to a lesser extent, the type of LED and the supply voltage.

Table 1 shows typical flash rates and the corresponding component values required for various different LED types. Note that green LEDs require values which are somewhere between those specified for red and blue (depending on the exact construction).

To further demonstrate how this process works, see the scope grab, Fig.3, which shows four traces. The top blue trace is the voltage at GP0, pin 7, which is zero most of the time and switches high for about 65 milliseconds. The green trace below is the voltage at GP5, pin 2, which is high most of the time and then drops low during the same 65 millisecond period. The yellow trace shows the voltage at the positive side of capacitor C1.

As you can see, each time GP5 (green trace) goes high, the capacitor voltage starts to ramp up and after slightly less than one second, when GP5 goes low (stopping the charge) and GP0 flicks high, the capacitor voltage takes a sudden jump up. The capacitor voltage then drops over a period of 65ms as it discharges through the LED and the cycle repeats.

The mauve trace is the difference between the voltages at the positive terminal of the capacitor (yellow) and GP5 (green) and it shows a maximum value of 3.6V. This is the effective peak voltage applied to the LED and current limiting resistor R2.

Referring back to Table 1, note that the peak current is higher with a lower voltage drop LED (eg, red) compared to a higher voltage drop LED (blue or white). Also be aware that electrolytic capacitors typically have a wide tolerance range of -20% to +100%, so the flash rate may vary from the cal-

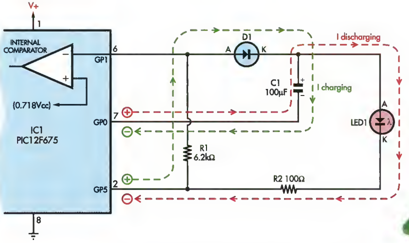


Fig.2: the charge and discharge currents for timing/boost capacitor C1. The charge current path is shown in green while the discharge current path is shown in red. Output pins 2 and 7 reverse polarity to switch current flow between the two paths while pin 6 monitors C1's charge status to determine when to switch between charging and discharging.

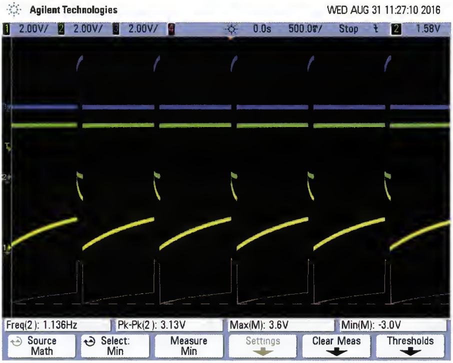


Fig.3: scope grab showing the critical voltages. The blue trace is pin 7 (GP0), green trace is pin 2 (GP5), yellow trace is the positive terminal of capacitor C1 while the mauve trace is the voltage across LED1 and R2. This shows a peak value of 3.6V, despite the 3V supply.

culated rate, depending on the actual capacitance.

Flash brightness can be increased by reducing the value of R2 or using a larger capacitor (up to 470µF) and scaling down R1's value proportionally. The minimum recommended value for R2 is 100Ω. For example, to flash a blue LED at 1Hz, you could increase C1 to 220µF and reduce R1 to 33kΩ and this will roughly double the LED current (as well as increasing the supply current drawn).

Note that the flash rate is inversely proportional to the supply voltage and is about 50% faster at 2V and 22% slower at 5V, compared to 3V.

Zener diode ZD1, across IC1's supply, protects IC1 from reverse supply polarity as it will be forward-biased under this condition. Its typical leakage current during normal operation with a 3V cell is around 10nA. JP1 functions as an off/switch.

ZD1 also provides protection against over-voltage to the microcontroller and it limits the supply to around 5.5V if you are using a much higher DC input voltage together with a series dropping resistor. In that case, the dropping resistor could be installed on the PCB in the place of JP1 (see "Higher supply voltages"). But we are getting a little ahead of ourselves.

PCB assembly

The LED Flasher is constructed on a PCB coded 16109161, measuring 45 x 47mm. If you wish, the PCB can be clipped into a small UB5 case (83 x 54 x 31mm), although most constructors probably will not bother.

Before you start assembling the PCB, you need to select the components required for R1, R2, C1 and the LED colour, eg, red, yellow, blue or white. Table 1 shows typical component values.

Fig.4 shows the PCB overlay. Begin construction by installing the resistors, using a multimeter to check the value of each before inserting it into the PCB.

Diodes D1 and ZD1 can now be installed, taking care to orient these correctly. The socket for IC1 is then fitted, with the notch towards the top of the board. Install the capacitors and if using a polarised electrolytic for C1, then this must be fitted with the shown polarity, ie, the longer lead inserted through the pad towards the top of the board.

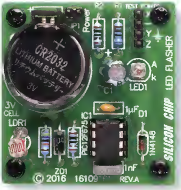
Then solder in the 2-way pin header for JP1. The 4-way header is optional and it can provide convenient test points if you want to check the module's operation or display the various waveforms on a scope.

Install the cell holder, if using the 3V lithium cell as the supply. The positive side of the holder must be oriented as shown, to the top of the PCB.

If you are not going to use the cell holder, you can install two PC stakes for supply connections instead. Note that there are two 3mm diameter holes in the PCB located where the cell holder would otherwise sit. These are for looping the connecting wires through for stress relief. That's so the wires do not break off where they connect to the power PC stakes.

Alternatively, you can elect to install an SMD mini-USB type B socket on the underside of the PCB (ie, instead of installing the cell holder) for convenient connection to a USB source.

LED1 is mounted with the anode "A" oriented as shown and LDR1 can be installed now as well. Note that if



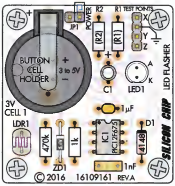
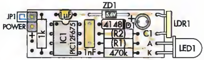


Fig.4 (left): the larger of the two flasher boards. Use this as a guide during assembly and take care with the polarity of IC1, C1, D1 and ZD1.

Fig.5 (right): fit the components to the smaller flasher board in this manner. Taller passive components such as C1 can be fitted to the bottom of the board and laid over to save space.



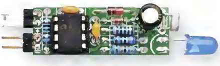


Table 1: LED Flasher Component Selection for 3V Supply						
LED Colour	Supply Current @3V Supply	Peak LED Flash Current	C1	R1	R2	Flash Rate
Blue/white	680μA	3.6mA	100μF	15kΩ	330Ω	0.5Hz
Blue/white	760μA	3.6mA	100μF	10kΩ	330Ω	0.75Hz
Blue/white	830μA	3.6mA	100μF	7.5kΩ	330Ω	1Hz
Blue/white	1.0mA	6mA	100μF	7.5kΩ	100Ω	1Hz
Blue/white	1.1mA	3.6mA	100μF	3.9kΩ	330Ω	2Hz
Red/orange/yellow	750μA	6mA	100μF	12kΩ	330Ω	0.5Hz
Red/orange/yellow	860μA	6mA	100μF	8.2kΩ	330Ω	0.75Hz
Red/orange/yellow	950μA	6mA	100μF	6.2kΩ	330Ω	1Hz
Red/orange/yellow	1.1mA	10mA	100μF	6.2kΩ	100Ω	1Hz
Red/orange/yellow	1.6mA	6mA	100μF	2.7kΩ	330Ω	2Hz

be installed now as well. Note that if you do not want the circuit to switch off in the day, omit LDR1.

If required, the PCB can be used fitted with four 9mm tapped spacers at each corner of the PCB, attached with short M3 machine screws.

A pre-programmed PIC12F675-I/P can be purchased from our Online Shop. Alternatively, if you intend to program the PIC yourself, the firmware file (1610916A.HEX) can be downloaded from the SILICON CHIP website.

Powering it up

Insert IC1 into the socket, making sure it is oriented correctly. Watch out that you don't bend any pins under the IC. Now install the CR2032 cell in its holder (or apply 3-5V DC) and place the jumper link onto the 2-way header (JPI). If all is well, LED1 will begin to flash.

Version 2: a tiny PCB

For some applications where you want a tiny flasher module, the PCB with its on-board cell holder will be too large. For example, you might want to install the LED flasher inside an HO/OO model diesel locomotive or inside an HO/OO wagon at the end of a train as a BOG (battery operated guard).

For these other applications requiring a tiny module, we have produced an alternative PCB which measures only 36 x 13mm and this board is coded 16109162. We could have made it even smaller if we had designed it to use surface-mount devices, but we know that some readers, and particularly model railway enthusiasts, are not keen on soldering SMDs.

The same components are installed on the smaller PCB, except that it does not have provision for the button cell holder or optional 4-way pin header. Refer to Fig.5 when building this version. Note that some components could be installed laid over on their side on the bottom of the PCB, to reduce the overall size of the package (eg, C1).

Higher supply voltages

If you want to run the PCB from more than 5V, you will need to install a suitable dropping resistor across the input link, JP1. For a 12V supply, we suggest a value of 1kΩ with a rating of 1/4W.

If you want to run the tiny module in a model railway locomotive or freight wagon as an end-of-train device, you will need to take account of the track polarity. To do this, use a small bridge rectifier from the track (eg, type W01). Its two AC connections go to the track connections inside the loco or wagon and the DC wires go to the appropriate DC input wires on the PCB.

Parts List

1 PCB coded 16109161 (45 x 47mm) OR
1 PCB coded 16109162 (36 x 13mm)
1 20mm button cell holder** (Jaycar PH-9238, Altronics S 5056)
1 CR2032 Lithium cell** (3V)
1 SMD mini-USB socket* (CON1)
1 10kΩ light-dependent resistor* (Altronics Z 1621; Jaycar RD-3480) (LDR1)
1 DIL8 IC socket*
4 M3 x 9mm spacers*
4 M3 x 6mm machine screws*
1 2-way pin header, 2.54mm pitch (JP1)
1 jumper shunt for JP1
1 4-way pin header, 2.54mm pitch*
2 PC stakes*
** optional component*
*** not fitted to smaller PCB*

Semiconductors
1 PIC12F675-I/P programmed with 1610916A.HEX (IC1)
1 1N4148 diode (D1)
1 5.1V or 5.6V zener diode (ZD1) (see text)
1 3mm or 5mm high-brightness LED (LED1)

Capacitors
1 100μF 16V electrolytic capacitor^ (C1)
1 1μF multi-layer ceramic
1 1nF 63V or 100V MKT polyester

Resistors (0.25W, 1%)
1 470kΩ 1 1kΩ
1 6.2kΩ# 1 330Ω#
 # change values to vary flash rate and brightness; see text and Table 1

Furthermore, to provide for operation when the track is not energised, you could substitute a .047F or 1F 5.5V supercap for the 1μF MMC capacitor on the board. You will likely need to connect it via insulated flying leads. In this case, change ZD1 to a 5.1V type to ensure the super-capacitor can not be charged beyond its 5.5V rating. SC

RESISTOR COLOUR CODES

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❑	1	1kΩ	brown black red brown	brown black black brown brown

CAPACITOR CODES

Value	μF Value	IEC Code	EIA Code
1μF	1μF	1u0	105
1nF	0.001μF	1n	102