Toy Traffic Lights

Construction Guide

Just like real traffic lights, this toy set cycles from green, to yellow, to red, then back to green.

They can be set to change on their own (automatically), with a preset time on each colour. Or they can be placed into a manual mode, where the lights change at the press of a button.

This project is designed to be battery powered. Since children (and adults? ☺) often forget to turn their toys off, this traffic light set powers itself off, if one hour has passed with no button being pressed.

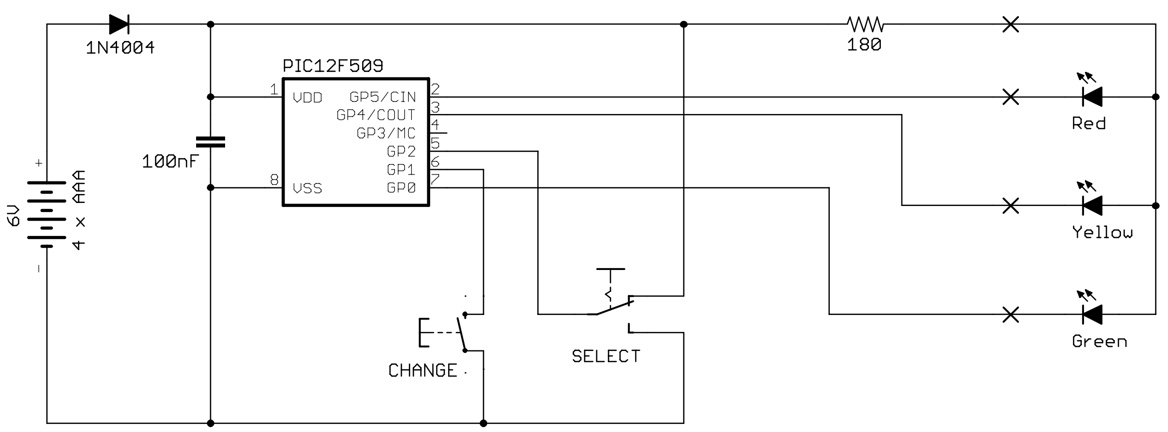
Electrically, this is a very simple project. However, to make it look like a set of real traffic lights, you'll need some basic woodworking (or metalworking) skills to build a realistic enclosure. The construction of a simple wooden enclosure is outlined below, but this is an area where you can make good use of your own ingenuity!

Features

- Battery powered
- Low component count
- 10mm green, yellow and red LED lights
- Selectable automatic or manual operation
- Powers down to standby mode if one hour passes with no button press or mode change
- Current in standby mode < 1µA : batteries should last their shelf life when in standby

How it works

The circuit is shown in the diagram below. It is built around a PIC12F509 microcontroller, which implements the control logic. The PIC is able to directly drive the LEDs, so very few other components are needed.



The four AAA batteries provide a nominal 6V. This is too high for the PIC12F509, which has a maximum supply voltage of 5.5V, so the supply voltage must be reduced a little. This is done by passing it through the 1N4004 diode, which has a forward voltage drop of around 0.6V for the 10mA or so of current that this circuit draws. So the voltage supplied to the PIC is a nominal 5.4V, and that's within spec (barely!).

The diode also provides reverse-polarity protection, in case the batteries are inserted backwards.

There is no power switch. Power is always supplied to the PIC, but it draws < 1µA when in standby mode. Since the LEDs are driven by the PIC, nothing else in the circuit draws any current when the PIC is in standby (except leakage in the capacitor). The batteries are able to supply this tiny standby current for years.

A 100nF bypass capacitor helps to stabilise the power supply to the PIC – not strictly required in such a simple circuit, but good practice.

The LEDs are connected such that current flows through the 180Ω limiting resistor, through whichever LED is turned on, and into an I/O pin on the PIC: GP0 for green, GP4 for yellow or GP5 for red. In this arrangement, the PIC *sinks* the current, instead of *sourcing* it. If the I/O pin is high (close to the supply voltage), no current will flow through the attached LED, leaving it unlit. If the pin goes low (close to 0V), current will flow into it, turning on the LED. This may seem counter-intuitive; to turn a LED on, the corresponding pin is set to '0'.

Because only a single LED is ever turned on at one time, they can share a common current limiting resistor. Assuming a forward voltage drop of 2.1V and a supply of 5.4V, the 180Ω resistor limits the current to (5.4V-2.1V)/180Ω = 18mA. That's low enough for the PIC to sink, and high enough to produce a reasonably bright light.

The "change" pushbutton is normally open, and pulls the PIC's GP1 pin to ground when it is pressed. This pin is normally held high by a "weak pull-up" within the PIC. So the GP1 bit normally reads as a '1', but changes to '0' when the button is pressed.

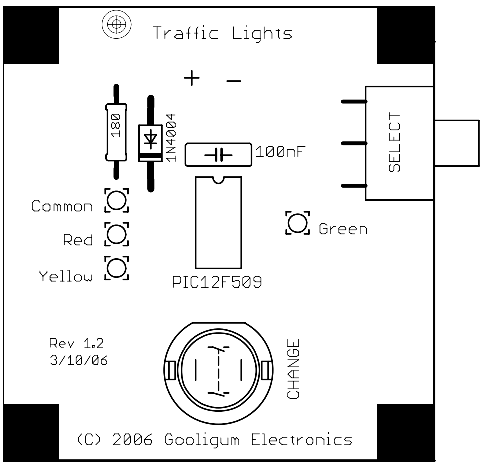
The "select" slide switch is wired so that it connects either 0V or the supply voltage to the PIC's GP2 pin. It was done this way, instead of using an internal weak pull-up, to limit power drain in standby mode. If the pin is switched to 0V, while a weak pull-up is active, current will flow through the pull-up, even when the PIC is in standby mode. Since the traffic lights could be left unused for long periods, with the select switch in either position, use of a weak pull-up could lead to a shorter battery life. By switching directly between the supply rails like this, current drain is minimised.

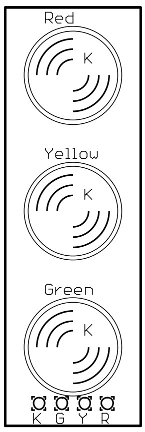
Note that, while the select switch is being changed, there is a point, while the contacts are moving, when the pin is not connected to either rail; it is floating, and its value is indeterminate – it could read as either a '0' or a '1'. That's ok, as the switch is only momentarily between positions, and a software debouncing routine takes care of any fluctuating values during the change.

Construction

The kit contains two printed circuit boards.

The component overlays are shown below:





The larger board holds most of the components, and is intended to sit at the base of the traffic light enclosure. It is slightly smaller than the 4 x AAA battery holder, allowing it to be mounted directly above the battery holder. The batteries are then accessible from under the enclosure, allowing them to be changed and, since the batteries are heavy, improving stability.

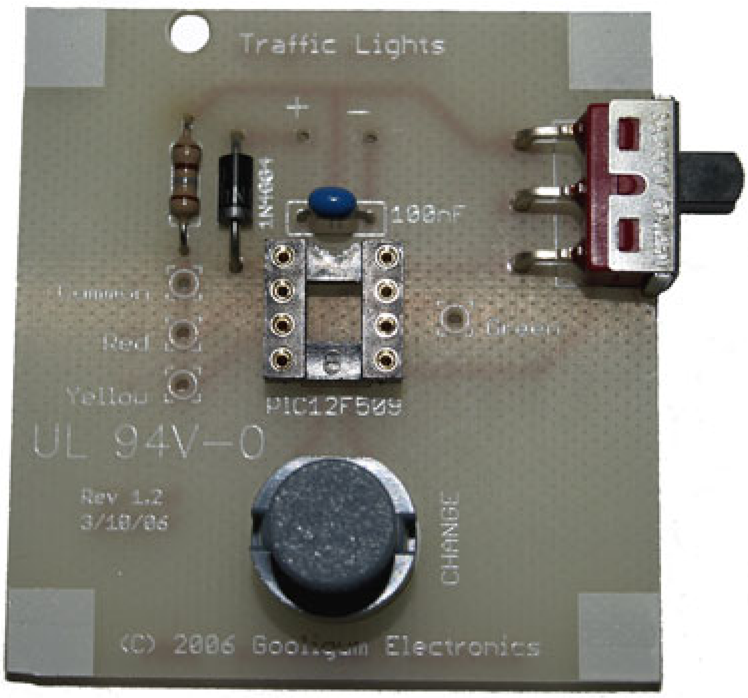
This is connected by a four-wire ribbon cable to the smaller board, which holds the LEDs. This board is intended to be mounted at the top of the enclosure.

Note that the following instructions assume that you are building a wooden enclosure similar to that in the prototype. But this project could be readily adapted to other physical forms. For example, instead of using 10mm LEDs mounted on a PCB, you could build smaller traffic lights by mounting 5mm or even 3mm

LEDs in a smaller enclosure, perhaps glued in place, with the control wires soldered directly to the leads of the LEDs, with the base board mounted in a separate control box. That type of arrangement might be appropriate for a model railway, for example. Or the box containing the LEDs could be suspended, instead of sitting on a pole, the wires running back overhead to a control box. Or you could retain this basic design, but build a metal enclosure instead of a wooden one.

Finally, if you're prepared to modify the circuit (and design and build your own PCB), you could use transistors or even relays to control much larger lights. You'd still use the same PIC and program, but with more elaborate drive circuitry and power supply.

But assuming that you're building something similar to the prototype, read on!



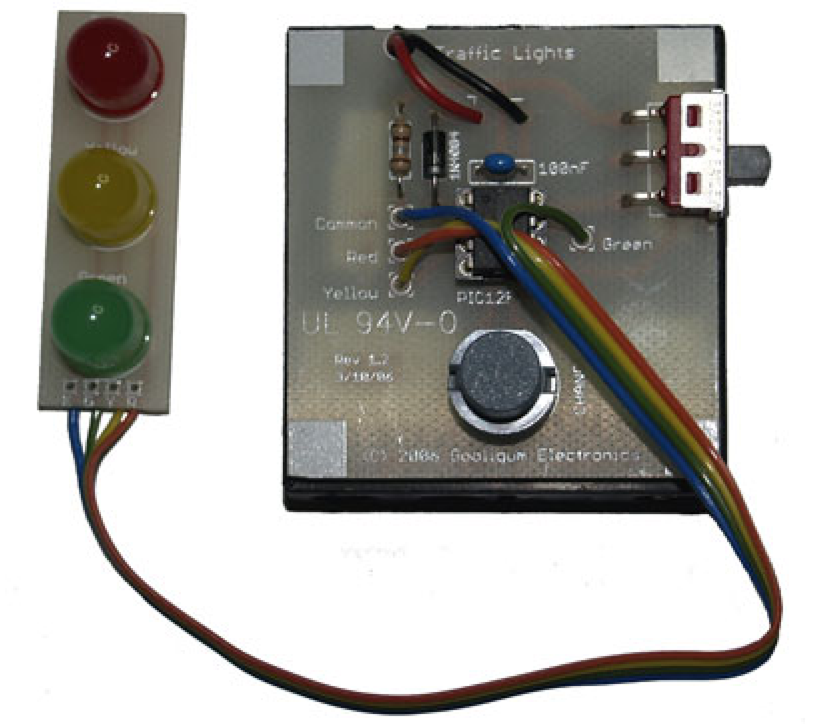
Start by soldering the resistor and diode (be careful of polarity!) to the base board. It's a good idea to use an IC socket for the PIC, to avoid damaging it before you've checked the circuit. But note that using a socket means that the top of the IC will be higher, which can make fitting the board into the enclosure more difficult (see instructions, below). If you're using an IC socket, install it next, being careful to align the notch with that shown on the overlay. Then add the bypass capacitor, followed the two switches. Note that the pushbutton switch has a flat side that must line up with the flat on the overlay. The slide switch overhangs the edge of the board, with the two pins at the front right on the edge. These may be difficult to solder, as the holes are intersected by the PCB edge, but although they make no electrical connection, it is important to solder them in as well as you can, to hold the switch securely.

Solder the LEDs to the LED board next. Again, take care to insert them the right way around. There is no flat side on these 10mm LEDs to show the correct orientation, so you must rely on the lead length.

The shortest lead is the cathode. It must be inserted into the hole marked with a 'K' on the PCB component-side overlay. The cathode hole is also identified on the solder-side PCB track by a square (not round) pad.

So make sure that the short lead on each LED goes into the hole marked 'K' on the overlay, and identified by a square pad on the solder side.

Next, solder the ribbon cable to the back of the LED board, as shown at the right. This is only temporary; you will have to de-solder it later, so that you can thread the ribbon cable through the pole later. But it's important to make this temporary connection so that you can test the circuit before you build the enclosure – when it will be too late to fix it!



Solder the other end of the ribbon cable to the corresponding holes on the base board:

G $\rightarrow$ Green

Y $\rightarrow$ Yellow

R $\rightarrow$ Red

K $\rightarrow$ Common

[Why 'K' for 'common'? In the first version of this circuit, the logic was reversed, with a 'high' at the PIC pin turning on each LED, and the LEDs connected with the cathodes in common. 'K' is often used to denote 'cathode'. The change to a common anode connection wasn't reflected in the printed circuit board design.]

Before soldering the battery holder leads, you should test the circuit.

Insert the batteries into the holder, and plug the positive (red) battery lead into pin 1 of the IC socket. Pin 1 is immediately to the left of the notch on the top end of the socket, when viewed from above. The pins are numbered counter-clockwise, with pin 8 to the right of the notch. If you're not using an IC socket, you'll have to work with the solder pads under the board; from under the board, the IC pins are numbered clockwise.

If you now touch the negative (black) battery lead to pin 2, the red LED, and only the red LED, should light. Similarly, if you touch the negative lead to pin 3, the yellow LED (only) should light, and for the negative on pin 7, the green LED should light. You should also test the negative lead on pin 8; no LEDs should light. If you do get any LED lighting when it shouldn't, you probably have a short somewhere. If the wrong LED lights, check how you've connected the ribbon cable. If one or more LED doesn't light, it may be installed the wrong way around. You can test that by reversing the battery leads.

Using the continuity test function on a multimeter, you should check that pin 5 on the IC socket is connected to pin 1 (only) when the Select switch is in one position (toward the "top" of the board), and connected to pin 8 (only) in the other position.

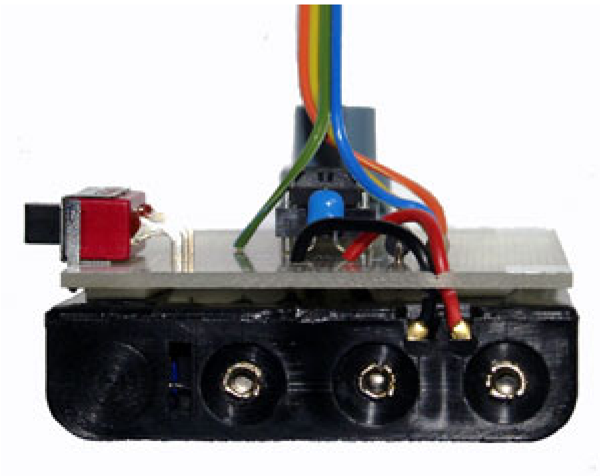
You can also check that pin 6 on the IC socket is connected to pin 8 (only) when the Change button is pressed.

If these checks are all ok, you should remove the batteries from the holder before cutting the battery leads short (2 to 3cm, or 1 inch), threading them through the hole at the top of the board, from the back, as shown in the photo above, then soldering them with the red lead in the '+' hole and the black lead in the '–'.

Now insert the PIC into the IC socket (or solder it to the board, if you're not using a socket), taking care to install it the right way around – the notch in the chip aligns with the notch in the socket, and the PCB overlay. Then put the batteries back in the battery holder.

The traffic lights should now be operational, although it is likely that none of the LEDs are lit. If a LED is lit, it should be the green one. If not, pressing the change button should turn the green LED on. If it doesn't, you have a problem, so go back and check your circuit, and that you have the PIC installed correctly.

It's a good idea to fully test the operation of the lights at this stage, to check that both switches and all three lights are working. See the section on operating the traffic lights, below, for details.



When you are sure that everything is working correctly, you can remove the batteries, and then attach the battery holder to the back of the base circuit board, using double-sided adhesive mounting tape, as illustrated.

As this tape can be difficult to remove, you can see why if is a good idea to fully test the circuit before doing this.

Building the Enclosure

To build a wooden enclosure similar to the prototype, you will need pieces of 3mm and 6mm MDF, cut to the following sizes:

Base enclosure

3mm MDF:

- 2 × 57mm × 27mm
- 2 × 54mm × 27mm

6mm MDF:

- 1 × 57mm × 61mm

Light enclosure

3mm MDF:

- 1 × 20mm × 22mm
- 1 × 48mm × 22mm
- 2 × 48mm × 17mm
- 1 × 28mm × 62mm

6mm MDF:

- 1 × 20mm × 22mm

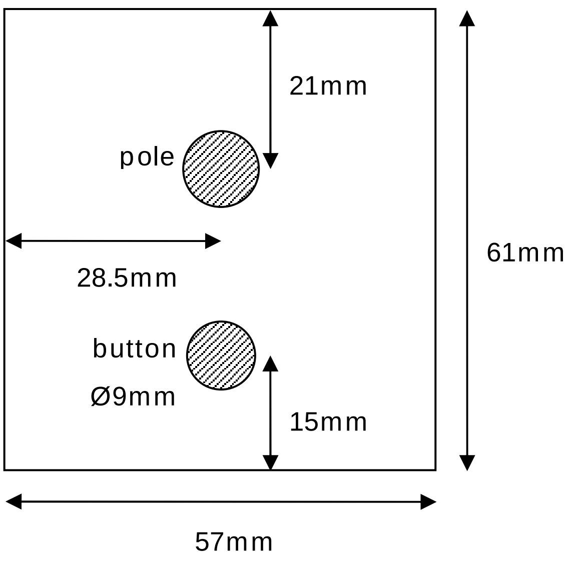
You'll also need a tube to form the pole (through which the light control wires are run). It should be approx. 115mm long and 8mm diameter. You can make it from a length of dowel, if you are able to drill a hole through it for the cable, but unless you have a drill press, it is very difficult to keep the drill straight enough to avoid it coming out of the side of the dowel, part way along. And few people would have a bit long enough to drill all the way through, so you probably need to drill from both ends and hope the holes meet in the middle!

Perhaps the simplest way to make the pole is to use a piece of bamboo. It's not too difficult to find, at your local garden centre, in the garden stakes section, a length of bamboo that's reasonably round, straight, and already hollow in the middle. The only real downside is that, being shiny, bamboo is difficult to paint.

Another option would be to use a metal tube, e.g. brass piping, if you are comfortable with attaching metal to wood; most glues are not very successful.

The 6mm MDF is used to form the top of the base and the bottom of the light enclosure. The thicker material is used because it has to be able to rigidly support the pole.

Saw the top of the base: 61mm × 57mm.



Drill a 9mm hole for the button, 15mm back from the centre of the front edge – see the diagram on the right.

Ideally, the pole supporting the lights would be mounted in the centre of the base. However, because the IC is in the centre of the circuit board, if you have used an IC socket, you will find that there is very little clearance above the IC. That could be a problem, because the ribbon cable has to pass up through the pole.

So, if you have used an IC socket, you will probably need to mount the pole a little (at least 9mm) toward the back, as shown in the diagram, to provide enough space for the ribbon cable. If your IC isn't socketed, there should be no problem in placing the pole in the centre of the base. Or, if the IC is socketed, you can still mount the pole in the centre, if you don't mind the button being a little recessed (normally the top of the button would be flush with the top of the base).

When you have decided where to place the pole, drill a hole for it – as close to the diameter of your pole as you can manage. Slightly smaller is best, and then gradually enlarge it until the pole is a tight fit. You can now glue it in place, using a wood glue (or even "super glue"), taking care that it remains perpendicular.

Next make the bottom of the light enclosure: 22mm × 20mm. But you may find it easiest to drill the hole for the top end of the pole (probably the same size as the hole in the base, but not necessarily, if you're using bamboo for the pole), before you saw off this small piece of MDF. Glue it to the top of the pole, again taking care that it is perpendicular, and aligning the 22mm edge of the top with the 57mm (front) edge of the base.

You can now remove the batteries, de-solder the ribbon cable from the LED board, thread it through the pole, and then re-solder it, as illustrated below, taking care that the cable is still wired correctly.

Re-install the batteries, test the lights again (it will be your last chance while the circuit is still accessible!), and then remove the batteries before continuing the construction.

Cut two 57mm × 27mm pieces of 3mm MDF; these will form the front and back the base enclosure. Glue one of the 57mm edges of the front piece to the underside of the front of the 6mm base top, taking care that the front is 90° to the top.

Next cut the two sides: each is a 54mm × 27mm piece of 3mm MDF. Glue one to the underside of the *left* edge of the 6mm base top (as viewed from above), so that it abuts the front piece (glue this corner join as well), so that it will form a rigid corner when the glue dries.

You can now mount the base circuit board, with attached battery holder, as shown at left. Do this by gluing the battery holder (which should extend a little past the PCB on each side) to the front and side pieces. You'll need to use glue that can bond to both plastic and MDF; "super glue" works well.

Position the circuit board so that the top of the pushbutton is flush with the top of the base, and is able to travel easily, without sticking. Check this before you glue the board into place! If necessary, enlarge the button hole, while you still can. You don't want a set of traffic lights with the on/off/change button stuck in one position!

The right-hand side comes next, but before you glue it into place, you must first cut a rectangular slot for the slide switch, as shown in the picture on the right.

The slot should be around 8mm × 5mm.

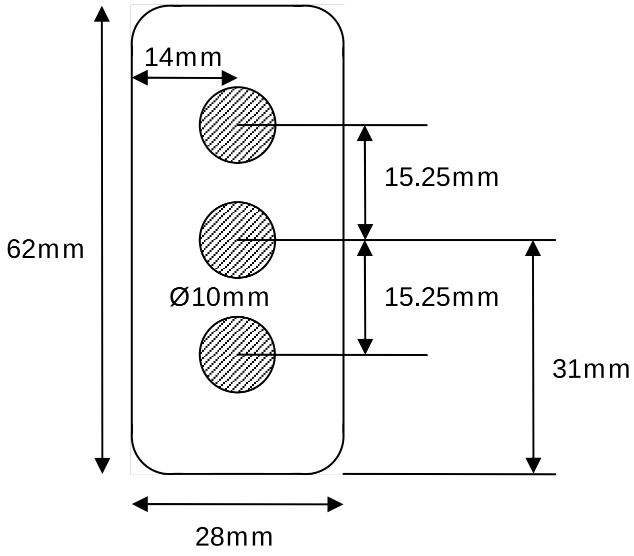
It should be centred approximately 17mm from the back of the side piece, and the top of the slot should be approximately 3mm from the top of the side piece. But don't rely on these dimensions – for the most accurate positioning, line up the side piece with the switch and mark where the slot needs to go (as you can see was done for the prototype). The precise positioning will vary, depending on how you have mounted your circuit board.

Cutting a small rectangular slot such as this is easily done by marking it out, then drilling a series of small holes within the marked area. The inside can then be punched out, and the slot expanded with a small flat file, until the correct size is obtained (check it by trying to fit the side piece over the switch; don't rely only on your markings).

Before gluing the right-side piece in place, it's a good idea to paint the metal front of the slide switch black; this wasn't done in the prototype shown in the photograph above, and you can see a sliver of silver showing next to the switch. You can avoid that by blackening the switch before fitting the side piece on top.

You can now go ahead and glue the right-side piece – front and top edges as shown, but also glue it to the battery holder, as was done for the front and left-side pieces.

Finally, glue the 57mm × 27mm back piece into place, completing the base. It should fit neatly under the back edge of the top piece; there should be a 3mm gap behind the side pieces, as in the photo above. Note that it may not be possible to glue the back piece to the battery holder, as the battery holder may not extend far enough. That's ok; the battery holder (and attached circuit board) is held securely by gluing along three sides, including the front where the button is pushed.



To make the light enclosure, start by cutting the front piece of 3mm MDF, following the dimensions in the diagram on the right. The corners are rounded off at about a 4mm radius (just file and sand until they're right).

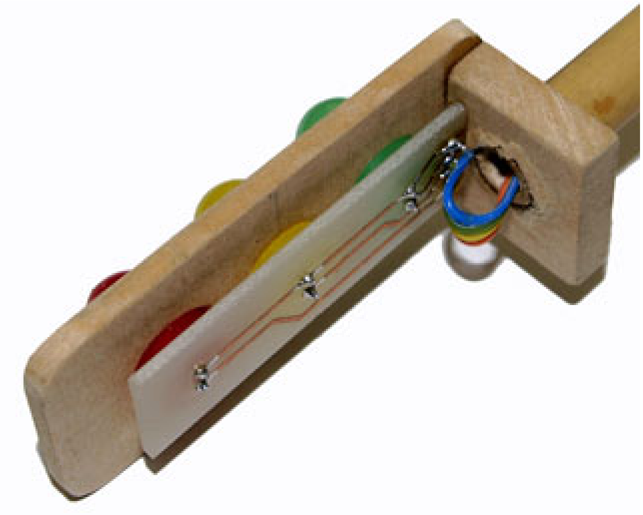
First mark out the hole for the centre (yellow) LED (in the centre of the front piece), then mark the distance to the top and bottom LEDs from that central point: 15.25mm, or exactly 0.60 inches.

The holes are nominally 10mm, but you may need enlarge them a little to get the LEDs on the PCB to fit. For a neat appearance, drill them to a little less than 10mm, then expand them using a round file, a little at a time, testing the fit of the PCB as you work.

When you have a good fit to the LEDs, glue the front piece onto the flange at the base of the LEDs.

Again, "super glue" bonds well to both the plastic of the LEDs and the MDF of the front piece.

With the PCB attached, glue the front piece to the base of the light enclosure, as shown in the photo on the right. Take care that it is 90° to the base, and that the ribbon cable attachment doesn't come loose. You may want to re-test the lights at this point, to ensure that the connections to the back of the LED PCB are still ok.



Cut the two sides of the light enclosure: 48mm × 17mm pieces of 3mm MDF.

Glue them to the base and front pieces, as shown in the photo on the left. They should abut the edges of the PCB; you can glue those edges as well.

Next comes the back of the light enclosure, a 48mm × 22mm piece of 3mm MDF. This should fit neatly to the back edges of the side pieces, flush with the back of the base. Try it first before you glue it; if it overhangs the base, you'll need to file the side pieces down a little. When it fits neatly, glue it into place.

Finally comes the top, a 22mm × 20mm piece of 3mm MDF. You may need to trim it a little before gluing it in place (or you might need to cut a bigger piece!), so check it first, then glue it on top of the sides and back.

That's the physical construction finished. You'll probably want to do a little filing and sanding to tidy the edges, and then of course paint it!

Operation

The traffic lights operate in two modes: automatic or manual, selected using the switch on the side. Changing the select switch changes the mode immediately.

Regardless of which mode they are in, if they are turned off, pressing the button turns them on.

Automatic mode: select switch to front

The lights cycle automatically, with each light on for the following times:

Green	12 sec
Yellow	3 sec
Red	10 sec

then repeat.

Pressing the button turns the lights off.

Manual mode: select switch to rear

Starting with green, the lights change only when the button is pressed.

To turn the lights off, first switch to automatic mode, and then press the button.

In either mode, if the button is not pressed, or the mode switch not changed, for 60 minutes, the lights turn themselves off, to save batteries.

That's all – have fun playing with your traffic lights!

Parts List

1	Pre-programmed PIC12F509-I/P
1	100nF monolithic capacitor
1	180Ω 1/4W resistor
1	1N4004 (or similar) diode
3	10mm LEDs – 1 × green, 1× yellow, 1 × red
1	9mm PCB push button switch
1	Sub miniature horizontal PCB SPDT slide switch
1	4-way AAA flat battery holder with fly leads
4	AAA cell batteries (preferably alkaline)
	Double-sided foam tape (to mount battery holder)
	4-way ribbon cable (150mm for described enclosure – see text)
	Supply of 3mm and 6mm MDF (if building described enclosure – see text)