Electronic Throttle Failsafe with Glowplug Switch.

The original idea for this unit was to provide a failsafe for the throttle servo for non-PCM radio systems. The principle is to monitor the control pulse from the receiver, check it is within the permitted range, and then reproduce the pulse on an output. Any pulse which is not valid is simply ignored. Should no valid input pulse be received for a period of 65 milliseconds (about 1/16 of a second) then a failsafe pulse is output which drives the throttle servo to a pre-defined idle setting. Once the unit has entered failsafe operation, then it must receive ten consecutive valid pulses before it will resume normal operation. This will only take about a fifth of a second. The start and end of the input pulse are both measured to an accuracy of +/- 1 microsecond, giving an overall accuracy of +/- 2 microseconds to the measured width of the pulse. This is +/- 0.2%. The output pulse is generated as a whole number of microseconds, providing a resolution of 0.1%.
A second version then followed which included an option to allow control of a flying surface instead. In this mode, the failsafe output pulse can be pre-set to the middle position, or to an offset from this position in either direction.
This version, for throttle use, has an electronic switch added to allow a single NiCd or NiMh cell to be switched to the glowplug when the throttle setting is less than 40% of full throttle. To prevent rapid switching on and off, once it is turned on, the throttle must be advanced to more than 42% before it will turn it off.
This is a simple circuit, which may be built on a small piece of stripboard, rather than use a purpose designed printed circuit board. The circuit is based on a PIC microcontroller. The prototypes have used a PIC16F84 because it is re-programmable, allowing the control program to be changed while it was being developed. A lower cost PIC16C620A is now used. Although it is only programmable once the control program no longer needs changing. The prototype also used a dual in line pack of 4 switches for four of the option links, but it is suggested that wire links are used for greater reliability. This layout does permit the fitting of switches if preferred.

Circuit Description.
The circuit, shown in Figure 1, is very simple, and is designed for use in radio systems with a 4 cell (4.8volt) power pack. Use with a 5 cell (6 volt) power supply will exceed the microcontroller's maximum allowable supply voltage causing it permanent damage.
The supply voltage first passes through diode D1, which serves two purposes. Firstly, it provides protection for the processor chip if the supply is connected the wrong way round. Secondly, it actually lowers the supply voltage. This is necessary because a fully charged Ni-Cd pack may provide more than 5.5 volts, the maximum at which the processor should be operated. The resulting supply is bulk decoupled using C1, a tantalum bead capacitor. Because this type of capacitor has a good high frequency response, it avoids the need for the usual ceramic decoupling capacitor for the processor. The input signal is routed via a signal diode, D2, into the processor which supplies an internal pull up resistor. This diode is needed as the supply voltage used by the processor is lower than the supply voltage of the receiver (due to D1). Without D2, the input signal voltage could exceed the supply voltage of the processor, which might cause the processor to malfunction. D2 is a signal diode having a voltage drop across it which is much lower than an ordinary diode. This is necessary to ensure that the low level voltage at the input pin to the processor meets its specification.
The component RES is a three terminal ceramic resonator which provides the clock and timing reference for the processor. It provides a frequency stability of +/- 0.5%, making this the accuracy of the timing measurements performed by the processor. However, the processing of the input pulse is more accurate, as this same timing reference is used for both the input measurement and the output pulse generation. The output pulse width is therefore very close to the input pulse width.
The remainder of the circuit is simply the five option links used to configure the operation of the program. The processor provides internal pull up resistors, so the option links connect these input pins to ground.

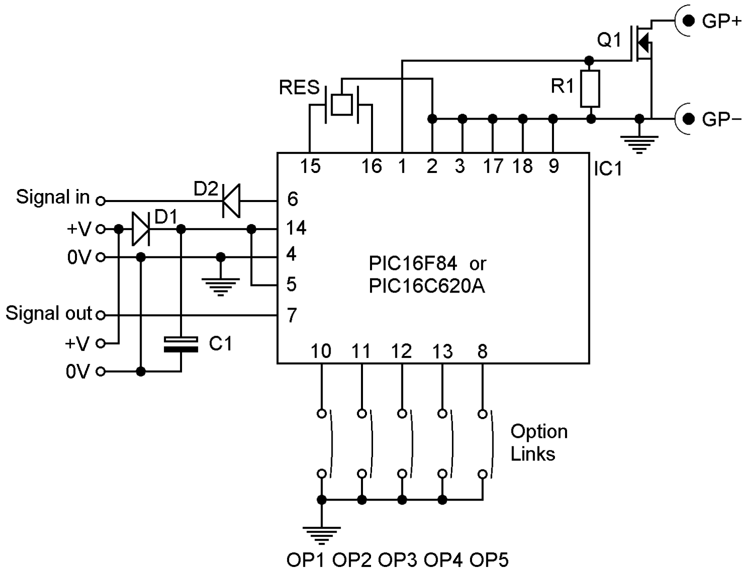


Figure 1

Construction.
The complete circuit can be fitted on a small piece of stripboard, 13 holes by 11 holes with the strips running lengthways. First, cut the strips, where indicated in figure 2, using a spot face cutter, or a 3mm (1/8th inch) drill bit. This shows the board with the copper strips facing. After cutting the strips, clean off any swarf and carefully inspect the cuts to ensure they have completely broken through the copper tracks.
Next, turn the board over, taking care to keep row 1 at the top. Now, add wire links to the board where shown in figure 3, noting the two special cases described below.

Figure 2

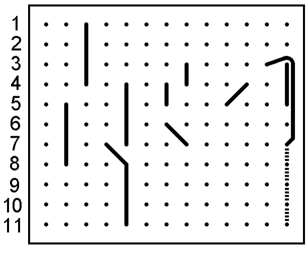


Figure 3

Use solid, tinned copper wire for these links. Component leg offcuts are often useful here.
There are two special cases. Firstly a link which is bent to avoid other components. This link starts at J7, goes diagonally over the top of I8, and is connected at I11. The second special case is the link which provides the ground connection for four of the option links. This starts at B3, is bent around the link between A3 and A5, passes through the board at A7, and then travels on the copper side of the board (shown dotted in figure 3) connecting to each of A8, A9, A10, and A11. This link, and the link from A3 to A5 are the same signal so do not need to be insulated from each other. If a pack of switches is to be fitted instead of using wire links, do not solder this link to positions A8 to A11 yet, as these holes are needed for the switch connections.
Now, all the actual components may be fitted. Their positions are shown in figure 4. Start by fitting the two diodes being careful to orient them correctly. Next fit the capacitor, the positive lead is usually longer than the negative lead, followed by resistor R1. Note how one of the leads of R1 is bent to connect at I3. Next fit the resonator (RES) which does not matter which way round it is fitted.

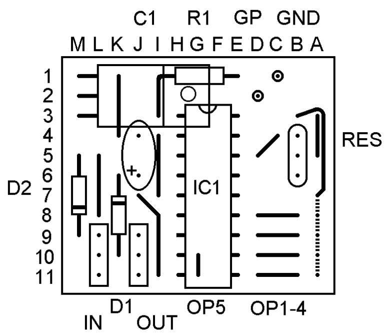
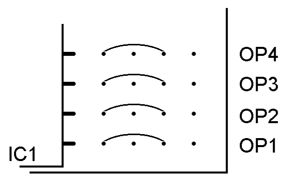


Figure 4

The wire links are shown to help position the components. Care should be taken with IC1 and Q1 as these are sensitive to static electricity. Pin 1 of IC1 is located a position H3. Q1 is fitted so that when it is folded flat, the metal tab is uppermost, and fits over the top of IC1. I found it easiest to bend the legs of Q1, and check its fit, before soldering it in place. If fitting a set of dual in line switches instead of wire links for OP1-4, then these are fitted through holes D8-11 and A8-11, soldering the wire link at the same time. Wire links for the five options OP1-OP5 may be fitted later when the function is being defined.
To connect to the servo, the easiest way is to obtain a servo extension lead, and cut it in half, connect the socket end to the IN position and the plug end to the OUT position. The negative wires connect to positions L11 and J11, the positive wires connect to L10 and J10, while the input signal goes to L9, and the output signal to J9.

Configuration.
At this point the function of the failsafe needs to be determined. If it is for the throttle, then link OP5 is not fitted. If it is for a control surface, then OP5 is fitted, on the solder side of the board as it is under the processor.
The function of the remaining links depend on whether the OP5 is fitted or not. For the throttle function, OP4 controls which end position relates to the idle position. This will depend on the particular radio used, and whether servo reverse has been selected or not. OP3 controls the range of input pulses considered valid. Almost all radios use a pulse width of 1mS to 2mS for the servos, but some use a wider range of 0.8mS to 2.2 mS. If OP3 is not fitted then the narrower, more common, range is selected, while if it is fitted then the wider range is selected. OP2 and OP1 are used to set the actual idle position, as using the extreme pulse width value usually stops the engine. These 4 links are summarised below, with figure 5 detailing which link is which.
If OP3 is not fitted, the range of received



pulses accepted as valid is from 0.9mS to 2.1mS. This range is slightly wider than the expected range to prevent the failsafe being invoked in normal operation. There are always some slight errors in the actual pulse widths and in their measurement (e.g. the resonator has a possible 0.5% error). The three other links then provide the following failsafe pulse width.

OP5 not fitted, OP3 not fitted			
OP1	OP2	OP4	Failsafe pulse width(mS)
Out	Out	Out	1.250
In	Out	Out	1.200
Out	In	Out	1.150
In	In	Out	1.000
Out	Out	In	1.750
In	Out	In	1.800
Out	In	In	1.850
In	In	In	2.000

If OP3 is fitted, the range of received pulses accepted as valid is from 0.7mS to 2.3mS. The three other links then provide the following failsafe pulse width.

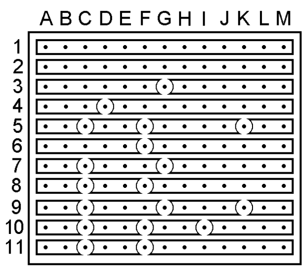
OP5 not fitted, OP3 fitted			
OP1	OP2	OP4	Failsafe pulse width(mS)
Out	Out	Out	1.100
In	Out	Out	1.000
Out	In	Out	0.900
In	In	Out	0.800
Out	Out	In	1.900
In	Out	In	2.000
Out	In	In	2.100
In	In	In	2.200

If OP5 is fitted, then the failsafe pulse widths generated with OP3 not fitted are as follows.

OP5 fitted, OP3 not fitted			
OP1	OP2	OP4	Failsafe pulse width(mS)
Out	Out	Out	1.500
In	Out	Out	1.600
Out	In	Out	1.700
In	In	Out	1.800
Out	Out	In	1.500
In	Out	In	1.400
Out	In	In	1.300
In	In	In	1.200

If OP3 is fitted then the three other links then provide the following failsafe pulse width.

OP5 fitted, OP3 fitted			
OP1	OP2	OP4	Failsafe pulse width(mS)
Out	Out	Out	1.500
In	Out	Out	1.640
Out	In	Out	1.780
In	In	Out	1.920
Out	Out	In	1.500
In	Out	In	1.360
Out	In	In	1.220
In	In	In	1.080



Parts List.

D1	1N4148
D2	BAT85
C1	47uF 10V Tantalum bead
R1	10K 5% 0.25W Metal film
Q1	BUZ100SL
RES	4.00 Mhz Resonator
IC1	PIC16C620A-04P
or	PIC16F84-04P

Possible supplier order codes.

Part	Farnell	Maplin
D1	368-106 (10 off)	QL80B
D2	367-862 (5 off)	
C1	966-678	WW75S
R1	543-627 (50 off)	
Q1	165-300	
RES	295-349	
IC1	PIC16C620A-04P	
Optionally, switches for the option links		
OPx	780-091	

Also required are a servo extension lead to suit your radio system.
If the glowplug switch is not required, then rows 1 and 2 of the stripboard are not needed, the wire link from K1 to K5 is omitted, and R1 and Q1 are not needed.

Connecting the Glowplug.
The glowplug needs to be connected using wire capable of handling 3 amps. The method I use to wire up the glowplug is shown in figure 6.

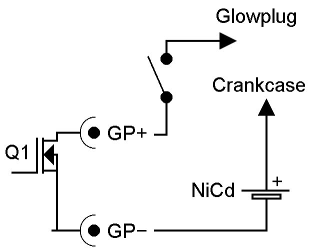


Figure 6

The negative of the NiCd cell is connected directly to the ground of the circuit (position C1). The positive of the cell is connected to the crankcase of the engine. I use an extra nut on one of the engine mounting bolts, and sandwich this wire between it and the existing nut. The switched output from the circuit (position D2) I connect to a small switch so that I can disable the glowplug. This is useful to avoid draining the cell when carrying out pre-flight range testing etc. This switch also needs to be capable of carrying 3 amps. The switch is then connected to the centre terminal of the glowplug. The method used to connect is up to you. I have used half of a ‘popper’ stud (as used in dressmaking) before, and currently use some fine piano wire bent into a clip. I include a heavy duty plug and socket on the connections to the NiCd cell to allow me to remove the cell for recharging.
In operation, I leave the switch off until I am ready to start the engine. Then I switch on, and set the throttle to a fast idle. A quick flip with the starter motor and the engine is running. Since the glowplug power is off at middle to full throttle settings, you cannot start the engine at high power, a good safety feature. With no external glowplug connector to remove, you have another reason for keeping fingers away from the fast spinning blades.
The choice of NiCd cell depends on what you have available. I am using an old 1200 mAh cell left from my electric flight days 20 years ago. This should give over half an hour of glowplug power which, since it is only used at low power settings, should give a couple of hours flying. Any similar cell of 1200 to 3000 mAh capable of supplying 2 to 3 amps easily is suitable.

With the unit complete, all that remains is to put it into a case. The case is necessary as the oscillator circuit can be upset unless it is insulated. I made a case using 1.5mm thick polystyrene sheet. Simply cut a base the same size as the stripboard, and four sides tall enough to exceed the height of the assembled unit by at least 2 mm. Do not forget to allow for the thickness of the base when cutting the sides. Glue the sides to the edges of the base, giving you an open top box.
When the glue has set, cut or file slots in the sides to allow all the wires out. Finally cut a top to fit over the case. Put the unit in the box, placing a small piece of foam rubber over it so that when the top is fitted it holds the unit lightly but firmly in place. To allow access to the circuit, the top is held in place with a small rubber band.