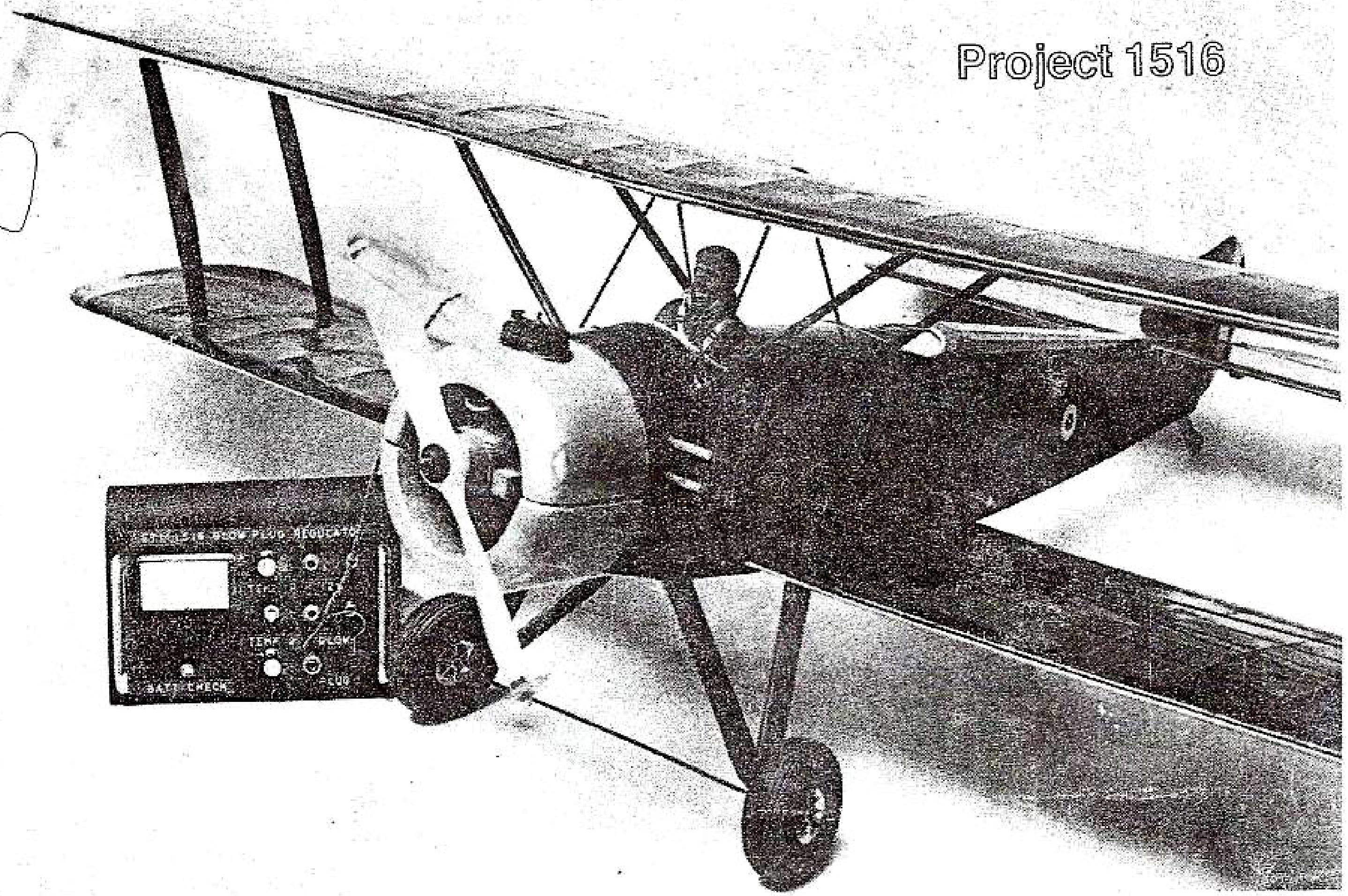
Project 1516



The 'sure start' model engine ignition system

No more flick-flick-sputter, flick-flick-sputter. This 'glow plug regulator' ensures a lively start for that model petrol engine in your favourite model aeroplane, boat or whatever.

Jonathan Scott

HOW MANY OF YOU have one of those infernal model petrol engines lying around the garage or store room somewhere? And why exactly are these things so often left unapproached and undisturbed in these dark crannies — because they are noisy? No. It is usually because they are *so difficult to start* that you have decided that they are not worth the trouble or the cost.

I recall spending ages as a kid with model aeroplanes trying in vain to get them going, wearing my fingers to the bone — flick, flick, flick . . . and no start. Often they would appear to kick over, encouraging the soul, only to remain in that half-starting phase turn after turn.

I gave up then — anyone with any sense and/or no money does. Yet, with the development of the 'magical' ETI-1516, friends and relatives have been volunteering their discarded models for testing, encouraged by the effortless instant starts which can be produced on demand. (The author had already bought several engines and wasn't interested in any more, thank you.)

So this project should provide the incentive to resurrect that long-stored model with the promise of quick ignition which, we hope, will encourage you to give it another go. After all, for under $40 plus fuel you can buy a complete aeroplane kit including the engine and all the accessories to have the thing flying on a control line almost instantly.

Ah, but the experts (read fanatics if you like) seem to be able to get their models to go promptly, so you might think that the complexity of the ETI-1516 is rather unnecessary. What do the regular modellers use to get the same end?

Firstly there is experience. They have probably been just where we have but they didn't give up, the blockheads. However, the endless tinkering and fiddling has payed off; they have tried all the possibilities and learnt to tell quickly what is the problem. Too much fuel or a flat-ish battery are dead giveaways when you have been at it for life. Misadjusted mixture takes thirty seconds to spot with enough experience, while a major failure may be the only problem not eliminated after two minutes.

All this is fine, but useless if you don't have a pet modeller on hand. Next, there are the current commercial inroads made by electronics which are available at the model shops. For around $30 you can buy what is termed a 'power board'.

This thing connects to a car battery and allows you to deliver 0 to 5 A to the plug while giving a rough indication of current by means of a meter. It is basically a single transistor or Darlington and a few resistors, and not surprisingly delivers a lot of heat to the atmosphere and the unwary modeller's fingers! Also, of course, it takes the same current from the main 12 V battery as it delivers to the plug, necessitating the use of a car-sized battery rather than a small set of sealed cells.

Again, with experience, but less this time, you can adjust it neatly so as to allow starting without regular incineration of the glow plug.

But for a similar outlay, our new unit is significantly superior in its operation. Firstly, it regulates not the current (bad) or ▶

the voltage (better) but the actual resistance of the glow coil, and hence the temperature of the plug (best).

Secondly, it employs a switchmode supply, which means that it dissipates only a modicum of power, typically five watts, rather than something over 50 watts.

What is more, it draws only a small fraction of the current that it delivers to the load, typically 20 to 25%! Result: less of a heat problem and smaller batteries for the same performance (penlite NiCads are fine) or even longer, lighter wires, running to your car cigarette lighter or whatever.

In addition to these features, it has a few more. It is cleanly and sharply current limited, which makes it infinitely harder to ruin a glow plug. We have equipped it with a button to allow the current meter to act as a battery check meter.

It has two potentiometers which are alternately selected by another switch: these can be preset to provide the correct starting temperature for two different engines or two different grades of glow plug for the one competition engine.

In case you thought that 'glow plugs was glow plugs' then it is about time that you took another wander through a model and hobby shop and saw the range of glow plugs which are available for tuning your engine. There are even several devious speciality twists you can get for improving some aspect of the running performance.

These features put the ETI-1516 ahead of anything commercially available, and coupled with its relatively simple construction and lack of critical or rare components, we feel it is the best option both for those not heavily involved in modelling and as a replacement piece of equipment for the serious model enthusiast.

Construction

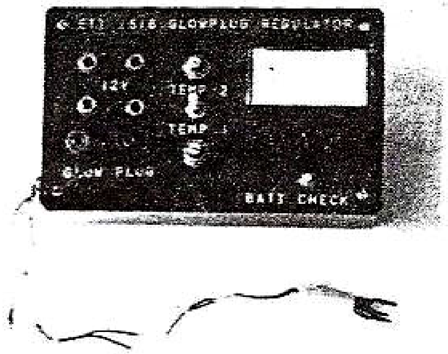
The commercial power boards I saw sold at hobby shops are constructed on a small flat plate of aluminium with the components mounted by bolts or silicone glue, to the back of the plate. The user is presumably free to mount this plate in a box or use it as is.

Out of a desire to conform to the expected structural format, I built one prototype on such a small plate, but it is the front panel of a jiffy box, so that you have a ready-made enclosure if you want.

If you are not concerned with the compactness or the appearance but rather the robustness, I recommend using a tent-shaped panel quickly bent up from 14 or 16 gauge aluminium sheet or similar.

This structure provides its own heatsink/mount for the power transistor (Q7), as well as allowing access to the innards at short notice (very handy with the situations you find cropping up on the runway when you're miles from home). I built another unit like this. If your metalworking facilities do not stretch to this, the jiffy box is easier to prepare.

Also provided as a convenience, because commercial units often have it, is a second pair of banana sockets for the 12 volt supply so that more than one device running on the same source can be accommodated simultaneously without piggyback plugs. This can be deleted if you prefer.



Jiffy box model. This one I constructed on the metal lid of a suitably-sized jiffy box. Note that the layout is laterally reversed to the model pictured on the front cover.

Perhaps the first stage to construction is the winding of the coil, L1. I wound about 50 turns of 1.45 mm (15 B&S) enamelled copper wire on the former of an FX2243 45 mm diameter potcore assembly. This produces 20 mH inductance and is easy to buy and wind. In fact, any value of inductance from a minimum of about 5 mH up to 50 mH will do, but remember that it must be wound of wire sufficient to handle five amps. I suggest that you use 1.45 mm diameter wire, but at the very least 1 mm wire might do as the unit will not be used continuously. This inductor is the bulkiest component, so choose the box you wish to use with an eye to the size of this as well as the meter, M1. The next stage is to drill and prepare the front panel. My advice here is not to go overboard on the cosmetic side as the working environment and chemicals will make a mockery of any efforts at glamorous packaging.

While indelible pen is probably the most cost effective method of marking the front panel, I sprayed it with aerosol paint and marked the controls with labels on one prototype which were later covered with some clear lacquer. The result is clear and durable. *Scotchcal is a bad investment!*

If you have the panel area, the pc board can be mounted on it. I have made provision for mounting holes on the board.

Next mount all the panel components. I used pots with the short ribbed spindles and screwdriver slots, intended as 'chassis presets'. I recommended them as you do not want to alter the settings often and knobs make it likely that there will be some potentially hazardous (to the glow plug) twiddling by well-meaning or curious persons.

For the pushbutton, SW2, I used one of the small positive action momentary switches which cost a little more but are crisp in their action and fairly robust.

Now comes the assembly of the pc board. Two factors are worth noting. Firstly, if there is no chance of the incoming polarity being reversed, forget D3, the supply protection diode. Otherwise fit it either as I did, between the pc board V+ connection and the lead going to the terminal, or at the incoming terminal junction.

You could even fit it in such a fashion as to protect components further down the chain by placing it between the first and second positive input banana sockets.

I used the banana sockets as these are what the commercial units are normally equipped with, but a polarised-type plug would be preferable as D2 can be dropped and then you can run to a lower input voltage before the electronics gives up.

As the voltage coming in to the box must run the op-amp, it is desirable to keep the input as high as possible. My prototype ran down to 9 V (after D2) comfortably.

Warning: polarity reversal will be quite lethal, so use D2 if you are not otherwise guarded.

The second factor concerns the heatsink on Q1. If you will not be running the unit for more than one or two minutes at most (the usual case), about 3 cm x 3 cm of heatsink is quite adequate, but a 6 cm x 4 cm heatsink at least must be used if you wish complete protection from burnout in continuous operation.

The consideration of operation duration also effects the choice of D1, the freewheel diode. It should actually be rated for about four amps continuous forward current but a three amp diode will be quite safe if you are only running it for a minute or two at a spell. Five amp diodes are more costly and harder to get, and our unit ran quite well using a three amp type. Higher current diodes tend not to be pigtail types too, which complicates mounting. ▶

HOW IT WORKS — ETI-1516

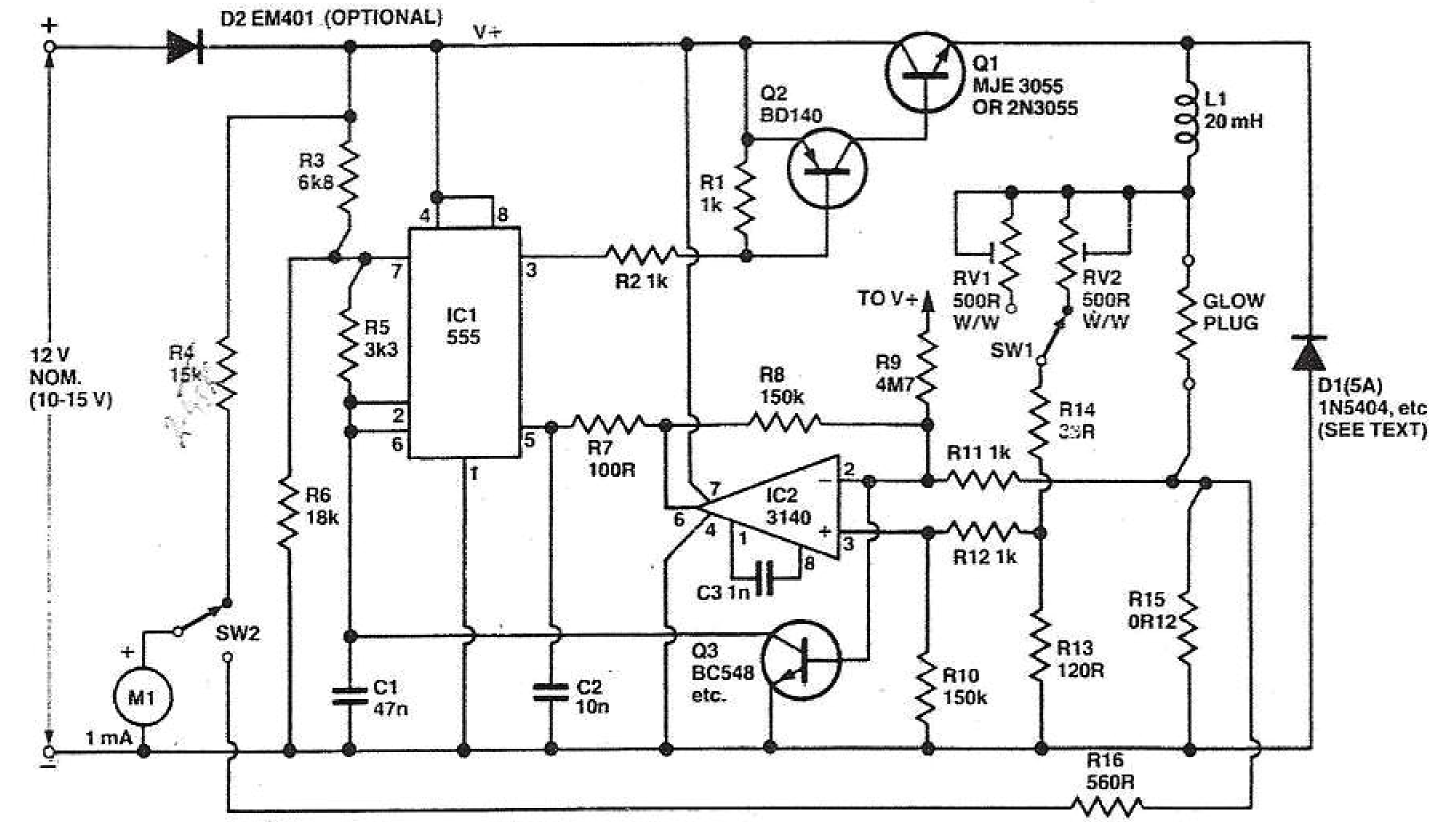
The block diagram of this unit is shown in Figure 1. There are three main parts to it: the resistance 'bridge' and the bridge amplifier, the pulse generator and the switching regulator.

The pulse generator provides constant-width pulses at regular intervals to the switching regulator. This provides current to the bridge, most of which (I_L) flows down through the glow plug (R_L) and a low value resistor (R_S). The ratio of R_A:R_B is compared to R_L:R_S by the bridge amp. If the ratios are different, then a voltage will appear across the op-amp inputs. If the glow plug (R_L) is cold, its resistance will be low. The ratio of R_A:R_B is set such that, when the glow plug is cold, R_A:R_B is greater than R_L:R_S.

Under these circumstances, the output of the bridge amp will cause the pulse generator to speed up, increasing the output of the switching regulator which then drives more current through the glow plug. The glow plug's resistance then increases and the ratio of R_L:R_S decreases. This causes the bridge amp to slow up the pulse generator until R_L:R_S equals R_A:R_B, i.e: the bridge is 'balanced'. The pulse generator then provides pulses at such a rate to the switching regulator so as to maintain the resistance, and thus the temperature, of the glow plug as desired. Varying the value of R_A thus sets the temperature of the glow plug.

Note that the majority of current supplied by the switching regulator passes down the R_L-R_S 'leg' of the bridge, only a small amount passing down the R_A-R_B side. The load current (I_L) thus flows through R_S and the voltage across R_S is used to drive the current-limit circuitry.

Looking at the circuit, the bridge consists of RV1/RV2-R14 (R_A), R13 (R_B), R15 (R_S) and the glow plug (R_L). The bridge amplifier comprises IC2 and associated components. The pulse generator is provided by IC1 and associated components while the switching regulator comprises Q1, Q2, L1 and D1. The voltage drop across R15, through which the glow plug current



(I_L) flows, is sensed by Q3 which provides current-limiting.

Initially, C1 will be discharged and the output of IC1 will be high (i.e: at +12 V). Thus Q2, and therefore Q1, will be biased off. C1 will begin to charge via R3 and R5. Now, the inverting input of IC2 has a small positive bias applied to it via R9 and thus IC2's output is low (0 V), pulling pin 5 of IC1 (the control pin) low. This allows the 555 to trigger its output to the low state after C1 has charged only a little way.

When pin 3 (the output) of IC1 goes low, Q2 will be biased on, turning Q1 on. This applies 12 V to L1 and current will commence to flow through L1, the glow plug and R15 (also a little through RV1/RV2-R14 and R13). Because of the inductance of L1, the load current (via the glow plug, etc) will rise slowly. As the glow plug is cold to start with, the ratio of the glow plug resistance to R15 will be much less than the ratio of RV1/RV2+R14 to R13. Thus, the voltage at the inverting input of IC2 will be greater than that at the non-inverting input and the output of IC2 will continue to hold pin 5 of IC1 low. Thus, Q2 and Q1 will remain on, allowing the current through L1 and the glow plug to continue building up.

When IC1 first triggers, pin 7 goes low and C1 will begin to discharge via R5. The output of IC1 will remain low for as long as it takes C1 to discharge to half the level it was previously charged to, at which point pin 3 of IC1 goes high again and Q2-Q1 turn off.

The magnetic field built up in L1, having nothing to sustain it now, will begin to collapse, the voltage across L1 will reverse and forward bias D1. Thus, the current generated by the collapsing magnetic field in L1 will continue to flow through the glow plug and R15, but now via D1.

The current now supplied by L1 will fall as the coil's energy is dissipated by the glow plug and R15. As the glow plug is still relatively cold, the inverting input of IC2 will be higher than the non-inverting input as the voltage drop across the glow plug will be less than the voltage drop across RV1/RV2+R14. Thus, IC2's output will hold pin 5 of IC1 low, allowing C1 to charge again.

When pin 3 of IC1 went high, pin 7 also went high, thus allowing C1 to charge again. When the voltage across C1 reaches the trigger point of IC1, pin 3 again goes low, turning Q2-Q1 on again.

Once again, current is applied to the glow plug, which continues to heat up. As the glow plug heats up, the voltage on the inverting input of IC2 will eventually reach that on the non-inverting input and the output of IC2 will then switch to the high state. This drives pin 5 of IC1 high and pin 3 low once C1 has completed its current discharge cycle.

The time taken for C1 to discharge will remain constant irrespective of the level on pin 5 of IC1. Thus, the pulses produced by IC1 will be of constant length, but the level on pin 5 will affect the pulse rate. If the glow plug is cool, the pulse rate will be high. As the glow plug heats up and its resistance increases, the pulse rate will decrease.

With IC1 operating at a high pulse rate, Q2-Q1 turn on more frequently, delivering a lot of power to the glow plug. When IC1 operates at a slow pulse rate, less power is delivered to the glow plug.

Switch SW1 selects either of the two preset pots, RV1 or RV2. As the setting of these determines the ratio of R_A to R_B, they will determine the ultimate temperature of the glow plug.

If the current through the glow plug exceeds that necessary to develop a voltage drop across R15 of about 0.6 V (about 5 A), then Q3 will be biased into conduction. The collector-emitter junction of Q3 then shorts C1, preventing IC1 from firing, turning Q2-Q1 off until the current through R15 drops below the limit. Thus, the current through the glow plug is limited to a safe value, preventing burnouts.

A 1 mA meter is used to monitor the supply voltage and the glow plug current. Resistor R4 provides the meter with 1 mA of current at a supply of 15 V. Resistor R16 provides 1 mA of current through the meter when 5 A flows through R15. Switch SW2 allows switching the meter so that it reads supply voltage and glow plug current as you wish.

Capacitor C2 protects IC1 against 'spikes' present on pin 5 of IC1. Capacitor C3 compensates IC2.

A diode, D2, may be added to prevent damage to the unit should the supply be connected in reverse polarity.

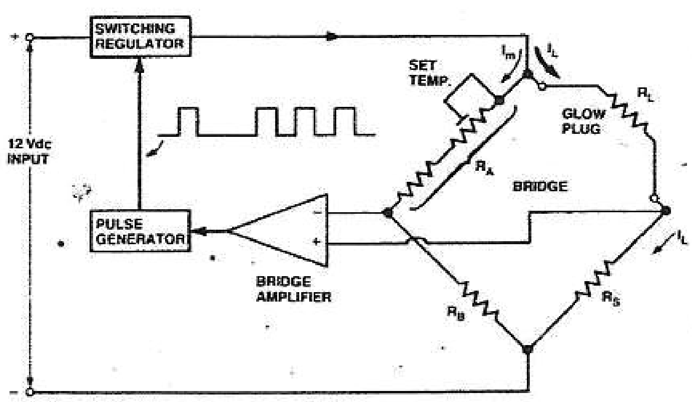
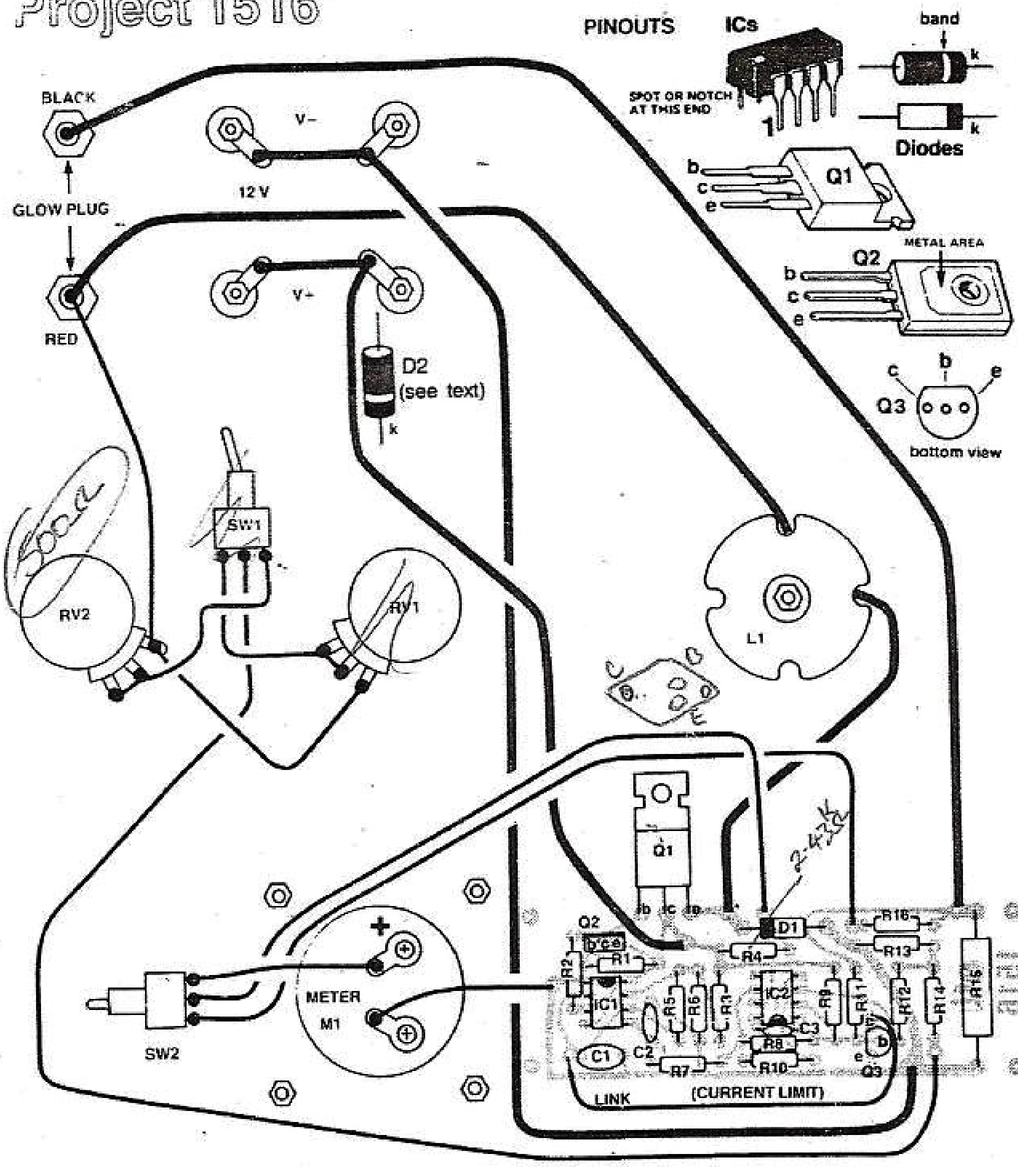


Figure 1.



Component overlay and wiring diagram.
General wiring diagram and pc board assembly. Note that SW2 is a pushbutton switch. Push in to read voltage.

Components & Kits
Suppliers of components and kits for this project are listed in the 'Shoparound' page in this issue. ETI does not sell kits or components for projects.

PARTS LIST — ETI-1516

Resistors .... all ½ W, 5% unless noted
- R1, 2, 11, 12 ...... 1k
- R3 .... 6k8
- R4 .... 15k
- R5 .... 3k3
- R6 .... 18k
- R7 .... 100R
- R8, R10 .... 150k
- R9 .... 4M7
- R13 .... 120R
- R14 .... 33R
- R15 .... 0R12, 5 W
- R16 .... ~~18k~~ 560R
- RV1, ~~RV2~~ .... 500R preset or panel mount type pots

Capacitors
- C1 .... 47n greencap
- C2 .... 10n greencap
- C3 .... 1n greencap

Semiconductors
- D1 .... 3 A or 5 A, 100 PIV (e.g. 1N5405 or 1N5408)
- D2 .... EM401, EM402, 1N4001, 1N4002
- IC1 .... uA555, NE555, LM555 etc
- IC2 .... CA3140
- ~~Q1~~ .... MJE3055, ~~RP3055, 2N3055~~
- Q2 .... BD140
- Q3 .... BC548, BC108, DS548 etc

Miscellaneous
- L1 .... 20 mH inductor, wound on FX2243 potcore assembly with 1.5 mm enamelled copper wire, 40 mm 4 BA bolt, nut and fibre washers
- M1 .... 1 mA meter movement; e.g: University TD48 or Minipa MU45.
- ~~SW1~~ .... SPDT or DPDT miniature toggle switch; e.g: D.S.E. S-1245 or similar.
- ~~SW2~~ .... SPDT or DPDT momentary action pushbutton; e.g: D.S.E. S-1220 or similar.

ETI-1516 pc board; banana sockets or polarised plug/socket; metalwork (see text); heavy duty hookup wire (24 x 0.2 mm or heavier); meter scale; terminals for plug cable termination; standoff pillars, nuts, bolts, wire, solder etc.

Price estimate $35 — $40

So, having settled for the option you wish, assemble the pc board components with particular attention to the IC polarity. Note that the two ICs are oriented oppositely to simplify the pc board pattern. There are no electrolytic (polarity conscious) capacitors specified. If you are far away from the battery you may find you need a 10 uf/16 V tantalum capacitor across the supply terminals, but my prototype was quite happy without one. Check the board when you've finished it.

The last stage of assembly is to fit the pc board and run the interconnecting wires. Be sure to use heavy guage hookup or automotive wire for the connections to L1, the supply, D1 and the glow plug current loop. Fit Q1 to its heatsink using some thermal compound. Use an insulating washer if you are fitting it to the panel as a heatsink. Be sure to remove any burrs from the mounting holes which might prevent close mating of the transistor and heatsink, or puncture the washer if used.

My prototypes used the least reliable option in each of the above cases, to prove that the unit could work that way: small heatsink on Q1, 3 A diode for D1, a diode in place for D2, no capacitor on the supply and the whole thing inside a jiffy box.

After five minutes of heavy work (at 3 A) I had to turn it off to prevent Q1 failing, but all else worked.

If you are not skimping we think that you should use a large heatsink on Q1 and perhaps a capacitor on the supply terminals if you are not sure what leads will be used in the field. The other construction suggestions will all aid reliability also.

The second unit tested used the tent-shaped metalwork and Q1 was bolted to the rear panel. This will run indefinitely without sign of failure.

Once construction is completed, check it over thoroughly. When you're satisfied all's well, apply power and listen carefully before connecting up the glow plug. The inductor is almost certain to emit a 'singing' noise as the switcher idles along. Short the output and the current meter will respond with about 4½ amps and the singing note will change. This indicates normal operation.

Meter scale. Full size reproduction of the meter scale. For those who want to make their own from Scotchcal, a same-size negative or positive transparency can be had for $1 post paid from: **ETI-1516 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to 'ETI Artwork Sales'. Ensure you ask for a **positive or negative** according to your requirements.

Using it

In practice, nothing could be simpler than this device to use. Ideally, you should set the temperature control while viewing the glow plug removed from the head of the engine.

Connect a 12 V battery to the input of the unit. Remove the glow plug from the engine head. Reduce the selected temperature pot. to minimum resistance and connect the glow plug to the output terminals. Slowly bring the temperature up by adjusting the pot. *away* from the minimum resistance end of its travel (rotate clockwise). The plug coil will begin to glow.

Clearly, if you bring the temperature up too far you will burn the plug out, so be careful. A glow just beyond red is best, just tending to orange. If you are in doubt, it is best to try a lower setting and go up later.

You can set one pot. for red-orange plug coil and the other for orange-white, using this higher setting by flipping the temperature select switch if the lower setting will not effect motor starting.

Once you have seen the level which causes no starting problems it is simple to set up all further plugs in a like manner.

Once the plug is reinstalled in the head you should proceed to start the engine in the usual manner as recommended by the manufacturer. Because of the temperature regulating action of the controller you will find it much more difficult to foul the plug or flood the engine.

Any foreign matter in the glow plug fitting tends to cool the element and so elicit an increase in the power delivered, burning the extraneous stuff off quickly. The current limit mechanism prevents plug failures due to one part of the coil cooling and producing higher currents while another part of the coil is uncooled and overstressed.

You will also notice certain other effects. When coming close to starting by firing on the first compression stroke, but not further ones, the current needle will be seen to dip momentarily. This is on account of the heat produced by the single ignition, which heats the plug somewhat, reducing in turn the need for the controller to supply heat to keep the coil up to the commanded temperature.

On the other hand, too rich a fuel mixture or tendency to flood will be evidenced as the reverse; momentary rises in the current delivered to the plug indicate that the coil has been splashed or otherwise cooled, necessitating a moment of boost. (You may feel free to consider at these moments how another system would be labouring to boil off the contaminant).

Again, when the engine has started there will be a significant fall in current, simply because the repeated combustion explosions in the head are doing most of the heating of the glow plug.

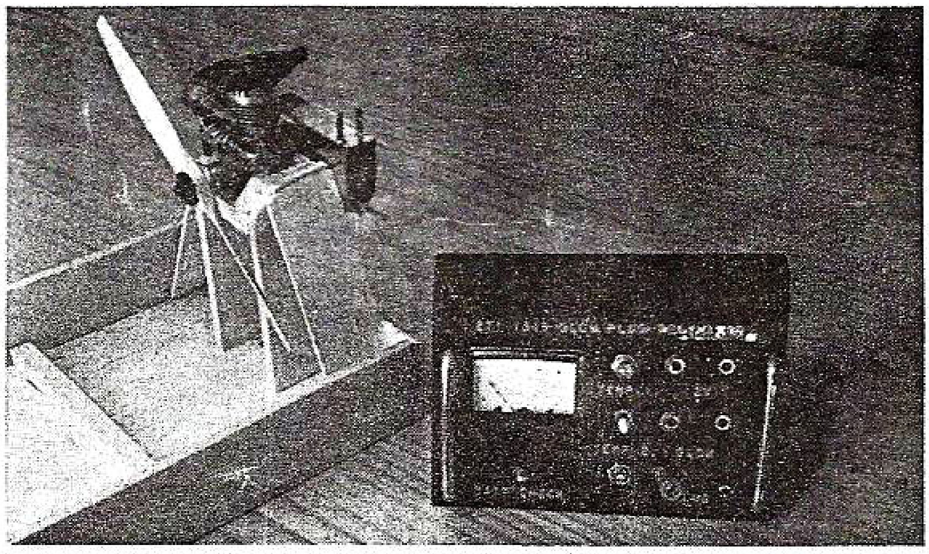
Other non-temperature sensitive systems would tend to overload the glow plug at this point, a fact that was only brought to our attention by the observation of the power drop upon starting.

One final note: The ETI-1516 may seem like overkill to some, realising that there would be significant feedback action if the glow plug were merely connected to a sound voltage regulated output, (preferably with remote sensing to eliminate the constant resistances of wires and so forth) by virtue of the sharply non-linear nature of the temperature/resistance characteristic.

This is indeed true, but the complexity of a current-limited switchmode voltage supply falls short of the complexity of the system here by only such a small margin that it turns out not to really be worth it.

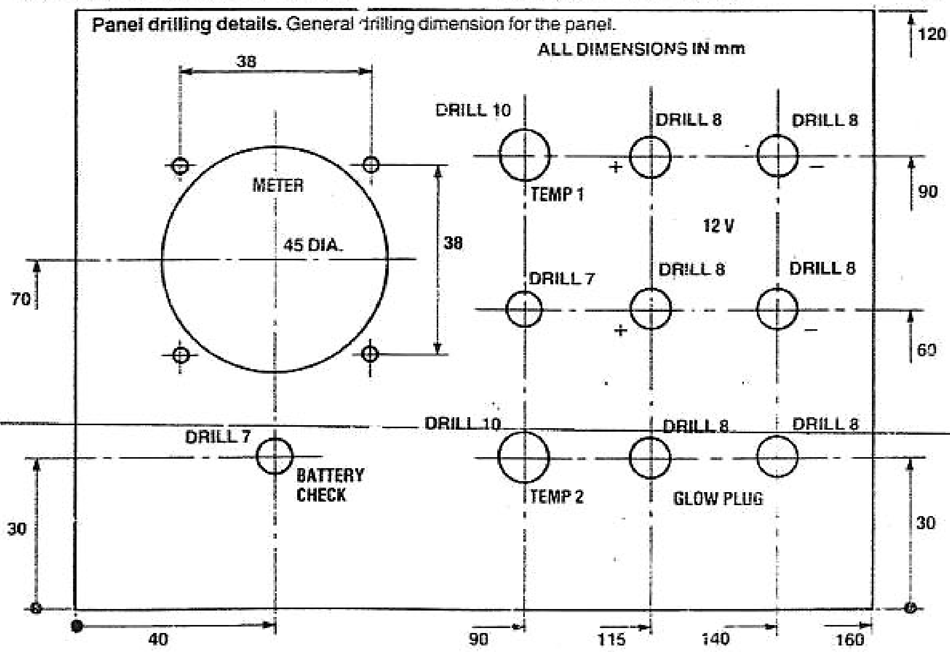
One could save the odd few resistors and a diode or so, but it would require all the major semiconducting elements with which we have managed to achieve temperature regulation merely to provide a sharp low impedance source, so why not go the whole hog, so to speak?

May your starts be many, now that they're virtually all 'sure starts'! ●

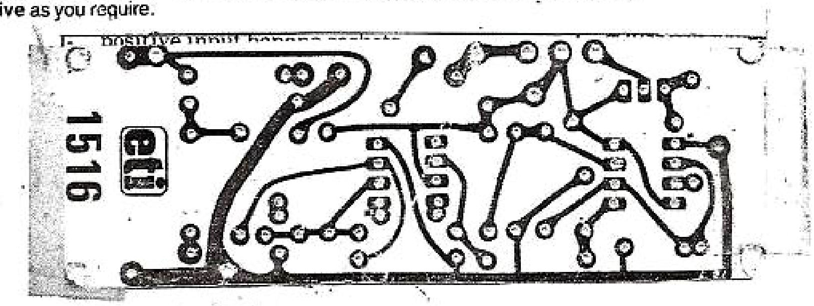


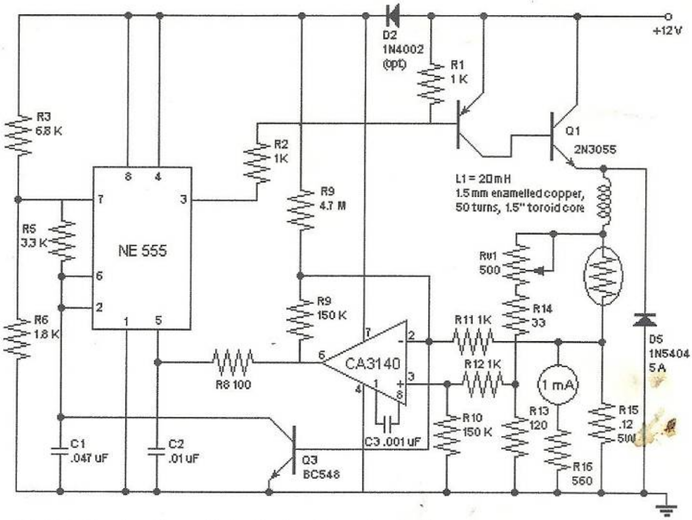
Tent model. This is the tent-shaped model I built. The wiring diagram on the previous page shows the physical layout of the rear panel of this unit.

Panel drilling details. General drilling dimension for the panel.

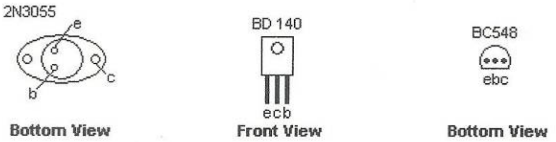


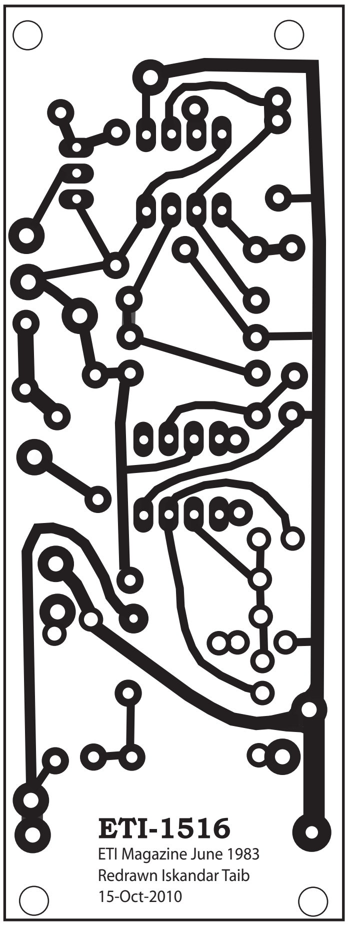
Printed circuit artwork. Full-size layout of the pc board, copper side. A same-size positive or negative transparency can be had for $1 post paid from: **ETI-1516 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to 'ETI Artwork Sales'. Ensure you ask for a **positive** or **negative** as you require.

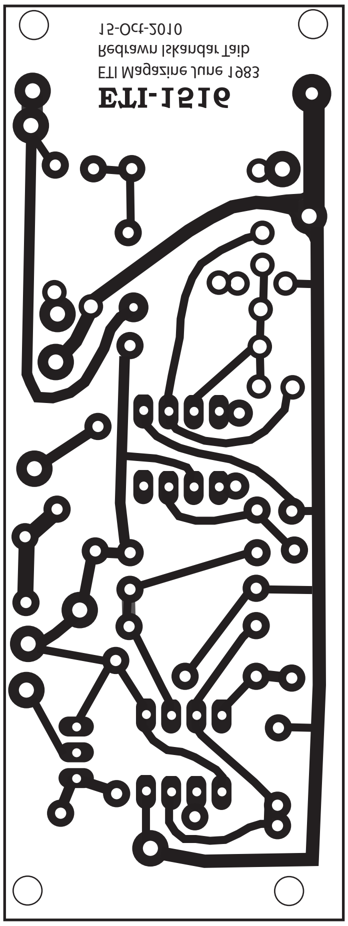




ETI-1516 Glowplug driver with feedback and current protection
Jonathan Scott, ETI June 1983
Revised June 1997, Gert Nieuwoudt




ETI-1516
ETI Magazine June 1983
Redrawn Iskandar Taib
15-Oct-2010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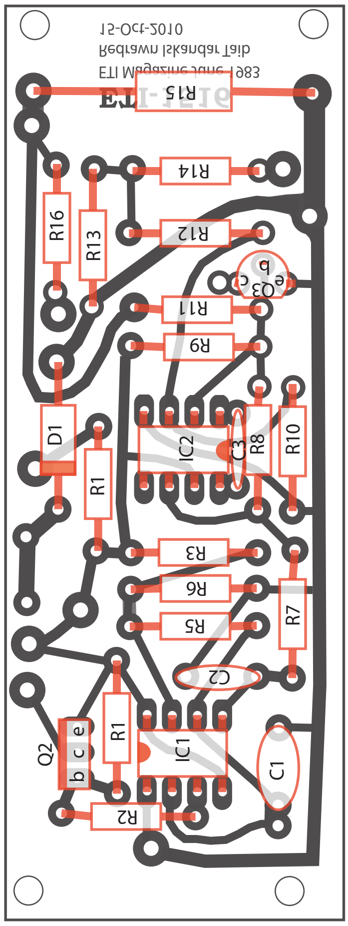
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Redrawn Iskandar Taib
R15
R14
R16
R13
R12
Q3
e c b
R11
R9
D1
R1
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IC1
C1
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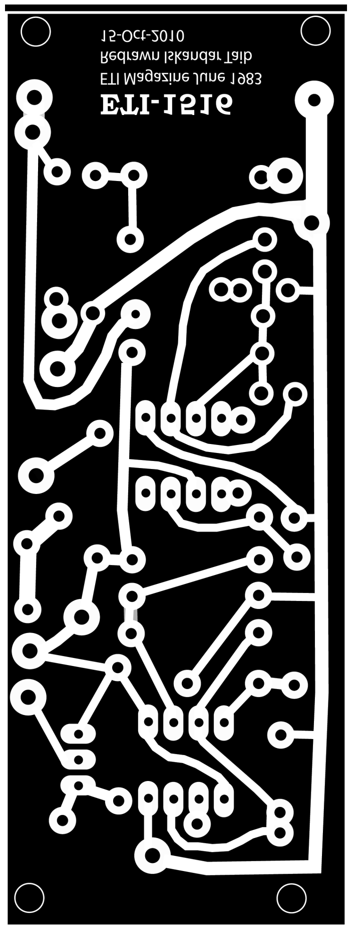
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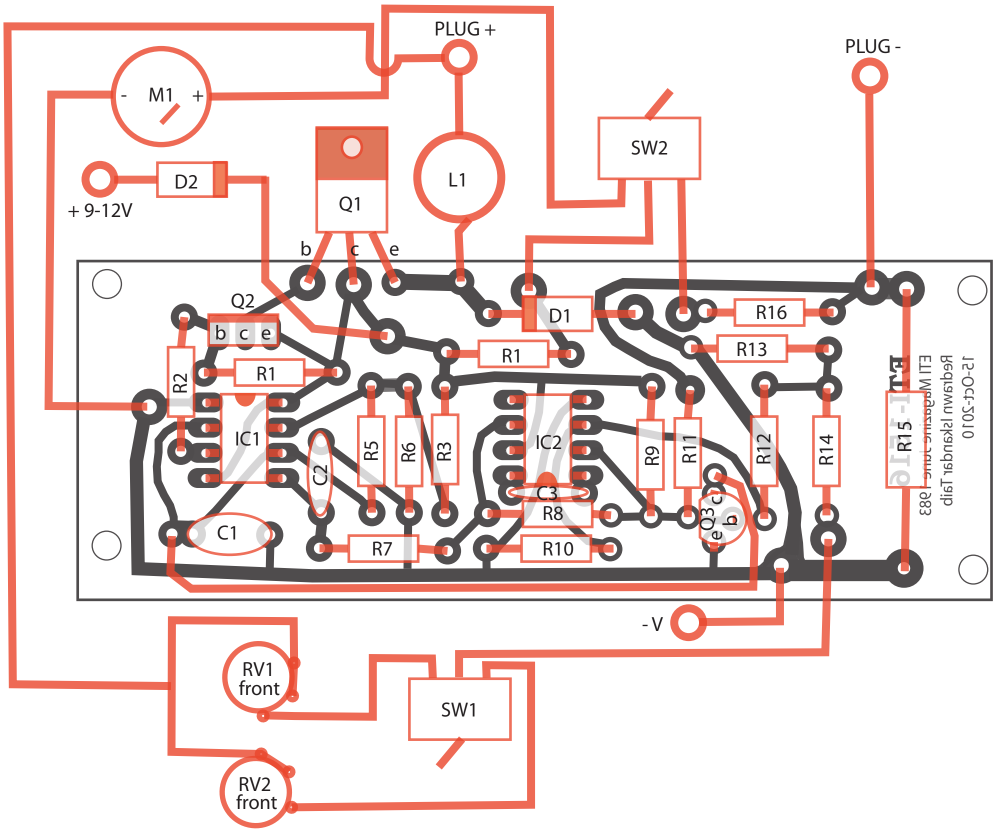
PLUG +
PLUG -
M1
-
+
D2
+ 9-12V
Q1
b
c
e
L1
SW2
Q2
b c e
D1
R16
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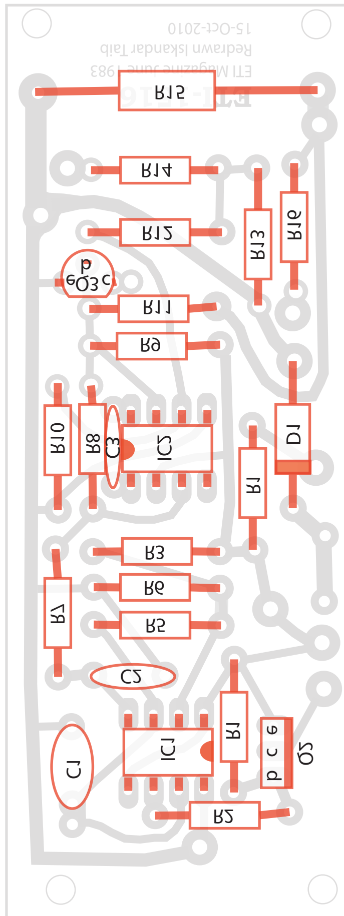
RV2
front


15-Oct-2010
Redrawn Iskandar Taib
R15
R14
R12
R13
R16
Q3
R11
R9
R10
R8
C3
IC2
R1
D1
R3
R6
R5
R7
C2
C1
IC1
R1
Q2
R2