PROJECT

Digital Experimenter's Unit

A low-cost 5V supply and pulse generator with a wide range of output frequencies.

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Testing even simple prototypes used to be a long and painstaking business. There was no alternative to actually building the unit using some form of soldered construction. What was probably worse than the initial time taken was the difficulty involved in making a few adjustments to circuit values. It required a lot of tedious desoldering and resoldering. Even modest changes could be very difficult to implement, necessitating a substantial amount of dismantling and rebuilding.

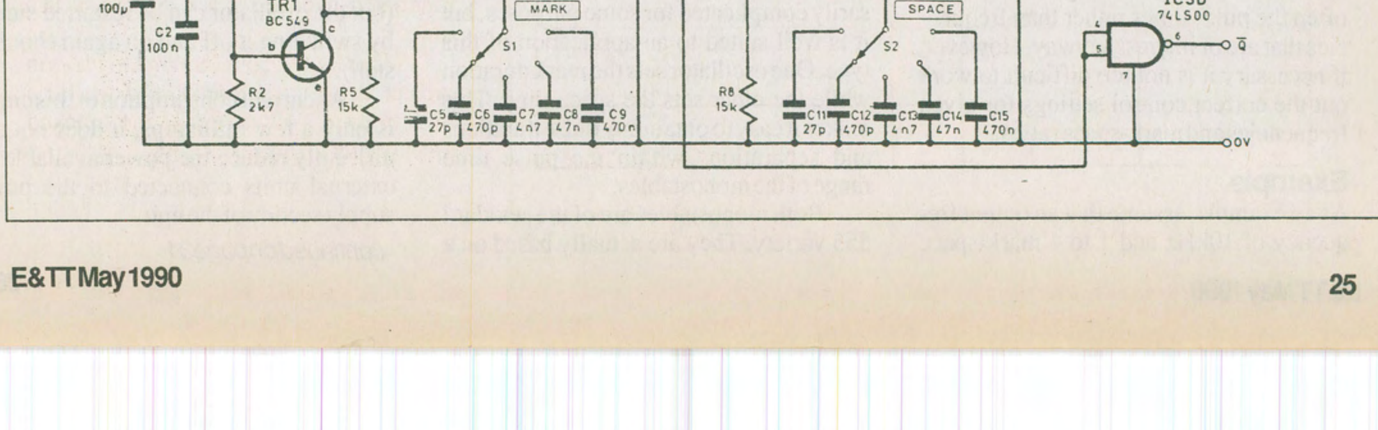
These days there are numerous solderless breadboards available that make building and testing prototypes much easier. Although you might think that these units are only suitable for building relatively small circuits, they can in fact be used for quite complex designs. Suitably large breadboards are available, or several smaller units can be clipped together. Components can be whisked out and new ones fitted with minimal effort. Quite large changes often taken no more than few minutes.

The main requirement for building most prototype digital circuits, apart from the breadboards, are a 5V power supply and a pulse generator to provide clock signals. Readymade units that combine these two functions with a solderless breadboard are available, but tend to be quite expensive. This unit provides a low cost alternative that's fairly basic, but offers a useful level of performance.

Pulse Generator

Pulse generators range from something as simple as a fixed frequency squarewave

Fig. 1. Complete circuit diagram for the Pulse Generator section.



generator to complex crystal- controlled circuits offering a wide range of output frequencies and mark-space ratios. Ideally a unit of this type should be able to operate at very low frequencies (about 1Hz) so that circuits can be run slowly enough for their operation to be accurately followed using a logic probe, or perhaps LEDs temporarily wired to strategic logic outputs. Operation at a higher frequency is also highly desirable so that circuits can be clocked at something approximating their normal rate.

Some circuits require short pulses for their clock signals, and the ability to vary the mark-space ratio to some degree significantly boosts the versatility of a pulse generator. Finally, a few circuits require two-phase clock signals. This simply means antiphase signals and it is a simple feature that should be available on any pulse generator.

This circuit achieves a wide range of output frequencies and mark-space ratios, but it's still quite simple and inexpensive. In fact it can provide any output frequency and mark-space ratio within reason. It lacks the high levels of precision associated with crystal-controlled pulse generator circuits, but for most purposes its accuracy is more than adequate.

Rather than setting an output frequency and mark-space ratio, the circuit is set for specific mark (high) and space (low) output durations. Both are continuously variable over five ranges:

1. 10us-100us
2. 100us-1ms
3. 1ms-10ms
4. 10ms-100ms
5. 100ms-1s

The actual ranges covered are slightly wider than those shown above. This allows for component tolerances and avoids gaps in the coverage. This method of control avoids the erroneous results that can be obtained with simple circuits that have frequency and pulse length controls (that often permit the setting of impossibly long pulse durations for the selected frequency). When dealing with logic circuits it is often the pulse times rather than frequencies that are of interest anyway. However, if necessary it is not too difficult to work out the correct control settings for given frequencies and mark-space ratios.

Example

As an example, assume that an output frequency of 10kHz and 1 to 4 mark-space ratio are required. First work out the duration of one cycle by dividing the required output frequency into one (t = 1/f). With the frequency in hertz, kilohertz, and megahertz, the answer is respectively in seconds, milliseconds and microseconds.

In this example, dividing 1 by 10kHz gives an answer of 0.1ms, or 100us. With a 1 to 4 mark-space ratio the output is obviously in the high state for one-fifth of the time, and low for the other four-fifths. Multiplying 100ms by .2 and .8 gives answers of 20us for the mark and 80us for the space.

The circuit has Q and not-Q antiphase outputs. These are provided by standard LS TTL outputs, and the unit is therefore TTL compatible. It cannot, in theory, be guaranteed to drive CMOS circuits properly. However, in practice the outputs switch between voltages that should enable any CMOS circuits to be driven properly.

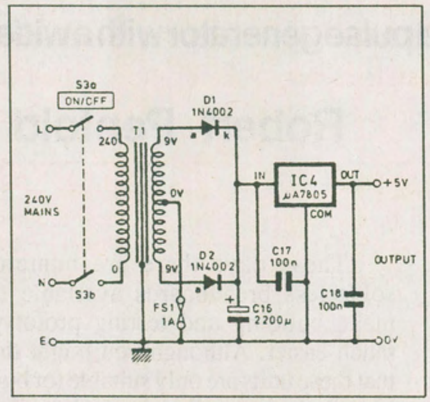


Fig. 2. Circuit diagram for the 5V 1A power supply.

Pulse Generator

The full circuit diagram for the pulse generator appears in Fig. 1. This is based on two monostable multivibrators connected in a type of circuit called a *ring* oscillator. The monostables are connected such that as the pulse from one of them ceases, it triggers the other. Provided that a pulse is applied to one of the monostables at switch-on in order to initiate oscillation, the circuit will then oscillate indefinitely.

An oscillator of this type is unnecessarily complicated for some purposes, but it is well suited to an application of this type. One oscillator sets the mark duration while the other sets the space time. This makes it easy to obtain any pulse durations and separations within the pulse time range of the monostables.

Both monostables are of the standard 555 variety. They are actually based on a low-power version of the 555, the TLC555CP. In this application it is the higher switching speed rather than the low power consumption that is of primary importance. It aids good accuracy at short mark-space ratios. Both monostables have a set of five switched capacitors to provide five ranges, plus a variable resistor to permit the pulse duration to be continuously varied over each range. Although C5 and C11 may look to be about 20p too low in value, the internal capacitance of the 555s makes up for the missing capacitance.

The monostables are of the negative edge-triggered type, and will therefore trigger in the required manner on the falling edge of the positive output pulses. However, the monostables are a form of the retriggerable type, and consequently require brief trigger pulses, or the output pulse durations will be stretched by the trigger pulses. A resistor and capacitor network at the input of the monostables provides suitable biasing and pulse shaping.

A common problem with ring oscillators is a reluctance to start. In order to provide reliable operation there must be a circuit to trigger one of the monostables at power-up. In this case a simple one-shot pulse generator based on TR1 is used to provide the triggering. At switch-on C3 charges up via the base circuit of TR1, momentarily switching on this device. When activated, TR1 pulls pin 2 of IC1 low and triggers it. TR1 then switches off and enables the circuit to operate normally.

Outputs

The outputs of the two monostables provide complementary Q and not-Q outputs. These are buffered by two LS TTL NAND gates (IC3a and IC3b) that provide TTL-compatible output levels.

In practice, the outputs of IC1 and IC2 would probably be quite acceptable without this buffering, but having genuine TTL outputs avoids incompatibility problems. Also, overloads on the output of pulse generator can cause it to stall. Having buffered outputs should avoid this (but the oscillator can be restarted simply by switching it off and on again should it stall).

As current consumption of this circuit is only a few milliamps, it does not significantly reduce the power available for external units connected to the power supply section of the unit.

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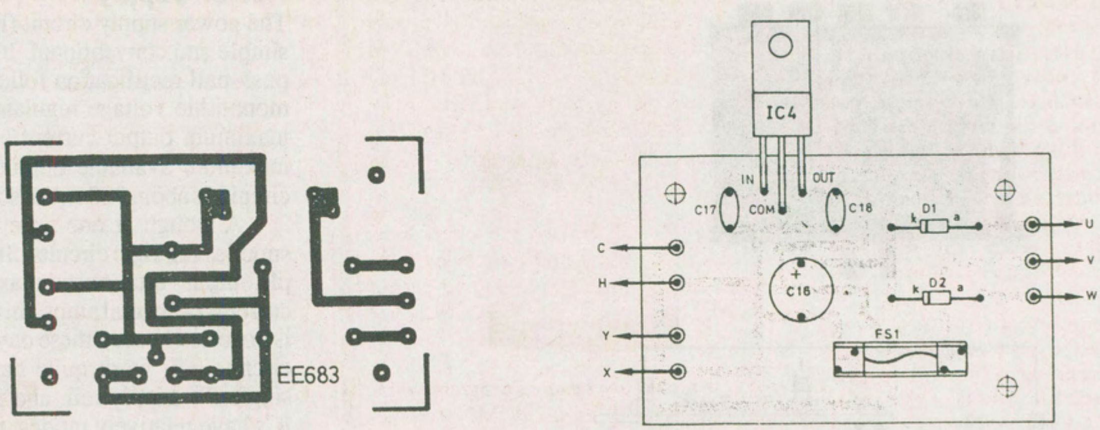


Fig. 3. Component layout and fullsized PCB foil pattern for the Power Supply.

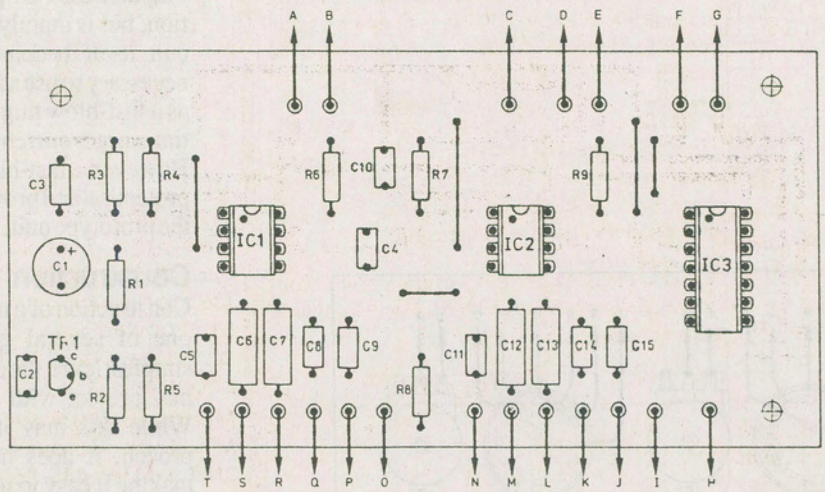
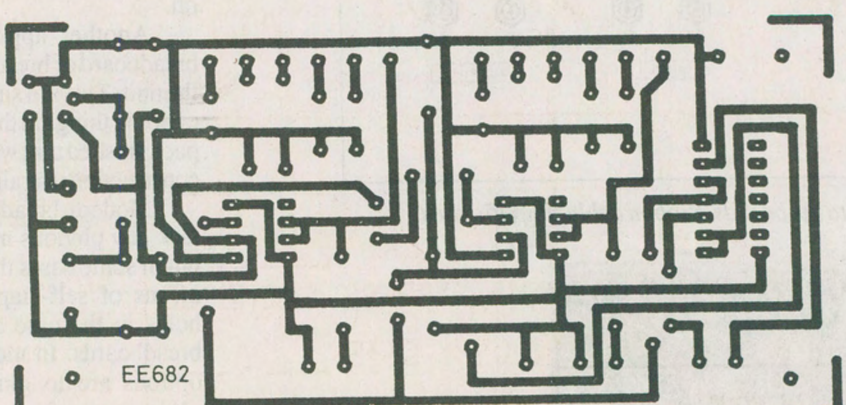
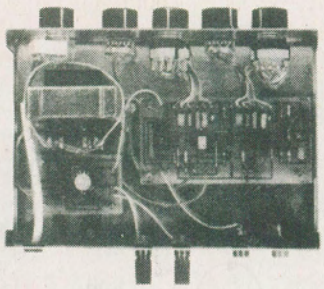


Fig. 4. Pulse Generator PCB component layout and copper foil master pattern.





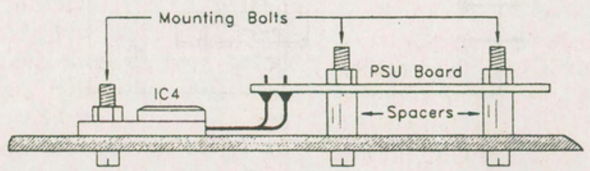


Fig. 5. A simple method of using the bottom of the aluminum case as a heatsink.

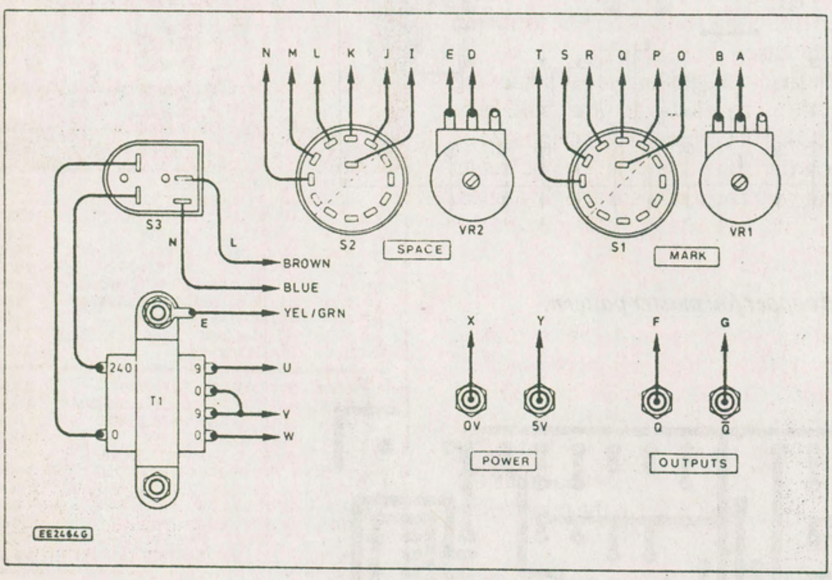
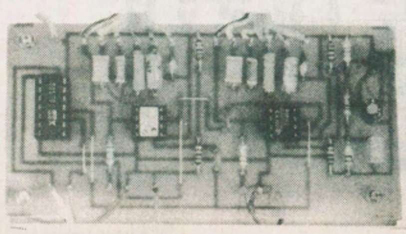


Fig. 6. Details of interwiring to the boards. Ribbon cable simplifies this.



Power Supply

The power supply circuit (Fig. 2) is very simple and conventional. It has fullwave push-pull rectification followed by a 5V monolithic voltage regulator (IC4). The maximum output current is 1 amp. The maximum available output for external circuits is about 980mA or so.

Although at one time bench power supplies for logic circuits often had multiple output voltages and maximum output currents of several amps, this type of thing is not often needed these days. Most logic circuits will work quite happily from a single 5V supply rail, and modern logic ICs have relatively modest power supply requirements.

IC4 incorporates output current limiting which protects the unit against overloads and accidental short circuits on the output. Fuse FS1 provides further protection, but is mainly needed in case the circuit itself becomes faulty. It might be necessary to use a slow-blow fuse for FS1, as a fast-blow might be opened by the initial surge current as C16 charges up. However, a fast-blow gives slightly better protection and proved to be satisfactory on the prototype unit.

Construction

Construction of a unit such as this can take one of several general forms. At the simplest level, the unit can be built as a normal project with separate breadboards. While this may not be the neatest approach, it does have the advantage of making it easy to use the unit with several breadboards. Often two or three circuits are under development at any one time, and with this discrete approach it is easy to have several breadboard circuits, and to connect up whatever one you want to work on.

Another approach is to have the breadboard or breadboards fitted on top of the unit. This is a simple but effective way of doing things in that it gives quite a compact finished unit which is easy to use, and construction is straightforward.

Modern breadboards often seem to lack any obvious means of screw fixing, but in some cases they can be fastened by means of self- tapping screws through holes in the case and into holes in the breadboards. In most instances the only options are to glue the breadboard in place, or to improvise some form of mounting bracket.

A third approach is to build the unit in the normal way, and then to fasten it and the breadboards on a fairly large

Parts List

Resistors

R1	4k7
R2	2k7
R3	100k
R4,5,7,8,	15k
R6,9	180k

Potentiometers

VR1,2	2M2 linear

Capacitors

C1	100u 10V
C2,17,18	100n
C3	220n
C4,10	22p
C5,11	27p
C6,12	470p
C7,13	4n7
C8,14	47n
C9,15	470n
C16	2200u

Semiconductors

IC1,2	TLC555CP timer
IC3	74LS00 NAND gate
IC4	7805 5V regulator
D1,2	1N4002 1A 100V diode
TR1	2N3904

Miscellaneous

T1	9-0-9 volt, 1A
S1,2	12-way 1-pole rotary
S3	power switch
FS1	1A fast-blow fuse

Metal instrument case, PCBs, red, black, green and blue terminals, 5 knobs, 2 8-pin DIP sockets, 14-pin DIP socket.

baseboard. The PSU/generator is fastened to the rear of the baseboard with the breadboards mounted toward the front. However, the breadboards and their components may tend to obstruct the operating controls of the generator. Either mount the unit well to the rear, or mount it on something that will hold it above and well clear of the breadboards.

PSU/Generator

Whatever basic form the unit takes, the PSU/generator will presumably be constructed as a regular project first and then merged with the breadboards once it has been built and tested. Here we will only consider the construction of the unit itself — constructors can please themselves as far as the overall form is concerned.

The PSU/generator circuits are built on separate PCBs (Fig. 3 and 4). This complicates construction slightly, but it does make things easier if you only want to build one or the other of these circuits. Construction of these boards is straightforward. None of the ICs are static sensitive, but we would still recommend the use of sockets for IC1 to IC3.

Five link wires are needed on the pulse generator board, and these can be made from hookup wire or resistor leads. The capacitors should be of the specified types or they may not fit into the board layouts easily. Fit pins to the points where connections to off-board components will be made.

Heatsink

There is a slight complication with the power supply board in that IC4 will need to dissipate quite high power levels at high output currents and this necessitates the use of a substantial heatsink. The cheapest solution is to house the unit in a metal case which then acts as a heatsink as well. Some means of bolting IC4's heat-tab and the circuit board to the base panel is then required (the circuit board must be insulated from the case).

Probably the easiest way of achieving this is to use the method outlined in Fig. 5. Here IC4 is not mounted on the top side of the board in the usual manner, but has its leadout wires bent upward at right angles, and is fastened on the underside of the board.

Case

A metal instrument case approximately 200 by 150 by 50mm will accommodate the parts. The PSU board and T1 are mounted toward the right, leaving room for the pulse generator on the right. For reasons of safety it is essential that the metal case be grounded to the power cord ground.

Controls

The five controls are mounted on the front panel with S3 close to T1. Due to a lack of front panel space I mounted the output sockets on the rear panel, but if a larger case is used you can mount them on the front.

There is a fair amount of hard wiring to be done, as shown in Fig. 6, which should be used in conjunction with Fig. 3 and 4. Each connection point in one diagram connects to the point of the same letter in one of the other two diagrams (point A in Fig. 4. to point A in Fig. 6). Ordinary hookup wire is suitable, but ribbon cable is probably easier to use and neater.

Testing

Before connecting the output of the PSU to a circuit, use a multimeter to confirm that the correct voltage is present; it should be with five percent of five volts. If not, switch off and recheck all the wiring.

You really need a scope to thoroughly check the pulse generator. However, it can be checked by driving LEDs from the Q and not-Q outputs, with a 330 ohm resistor being used to limit the current. The cathode (k) terminals of the LEDs are the ones which connect to the 0 volt rail. With long mark and space durations you should be able to see the LEDs flash on and off as the outputs change state, with one LED switching on as the other switches off.

At short pulse durations the flashing of the IEDs will be too rapid for the eye to perceive it properly. However, varying the mark-space ratio of the output signal will alter the apparent brightness of the LEDs. The greater the proportion of the time the output is high, the brighter the LED driven from that output will be.