DIGITAL ELECTRONICS BY EXPERIMENT pt2

THE IC WE HAVE CHOSEN to introduce TTL is the SN7414 Schmitt inverter, placed at the top left hand side of the blob-board. (As all the TTL series start with the letters SN, we shall omit these in future, and refer, for example, to the 7414.)

The circuit of an inverter is that of a high-gain inverting d.c. amplifier (Fig. 1), with the input at the emitter of a transistor and the output from a single-ended push-pull stage which is capable of passing of up to 16mA in either direction (to + 5 V or to earth). This type of design, typical of TTL circuits, has several important implications for us.

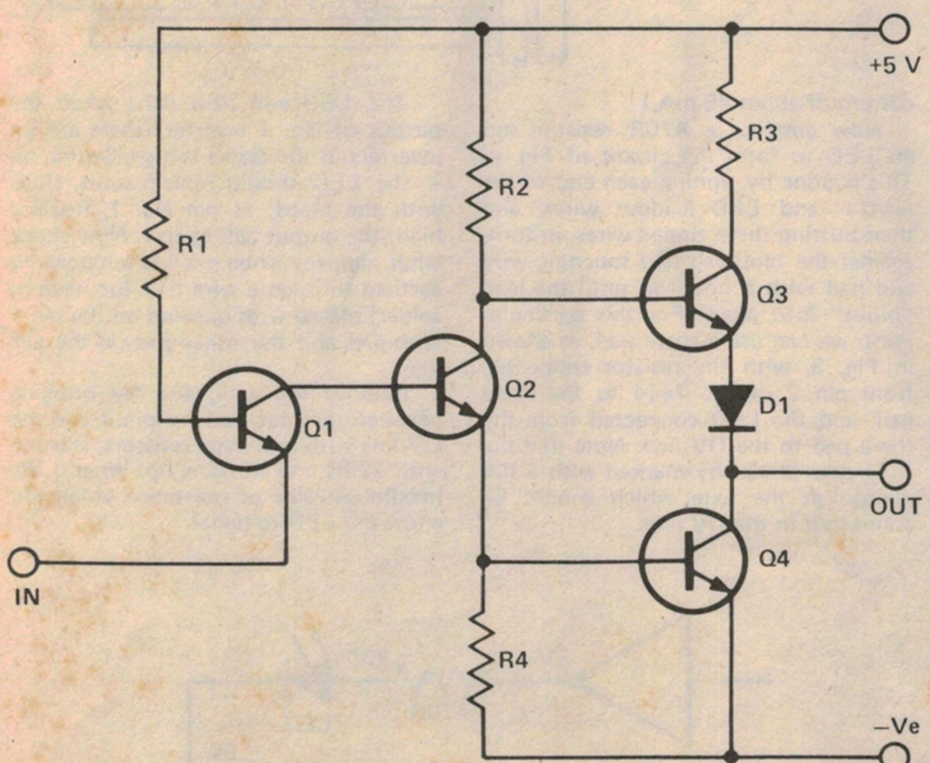
Source or sink

One important result is that the input impedance is fairly low when the input stage is conducting. If the input is left floating, the connection of the base of the first transistor to + 5 V will ensure that the emitter terminal will also be at high (+ 5V) voltage: The first transistor will be cut off in this state. The normal action of an inverter is that a high (or "1") input produces a low ("0") output, so that Q_2 is switched on by the high voltage at the collector of TR_1 and connects the output terminal to earth through Q_4. As mentioned above, this will allow a current of up to 16mA to pass from a positive source; in TTL language, the output stage will sink a current of up to 16mA.

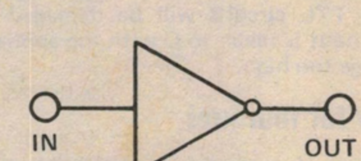
Fanout

When we connect the input of the inverter to earth (0), what we are doing is to earth the emitter of Q_1, with the base still connected, through its current limiting resistor, to +5 V. When this is done, a current of about 1.6 mA (set by the value of the limiting resistor) will flow from base to emitter, and it is very important that any resistance between the emitter (input) and earth should be small enough to prevent the emitter voltage rising above about 0.5 V in normal use. This is ensured when we drive a TTL input from the output of another TTL device, since a TTL output can sink a current of up to 16 mA, the current from ten inputs, without the emitter voltages rising too high for reliable operation. This is referred to as a "fan-out" of ten at the output.

Since in these circuits we are interested only in high and low signal levels,



(a)



(b)

Fig. 1. A typical TTL inverter circuit (a). The value of R1 is about 3k, to limit the base current to 1.6mA. (b) Symbol.

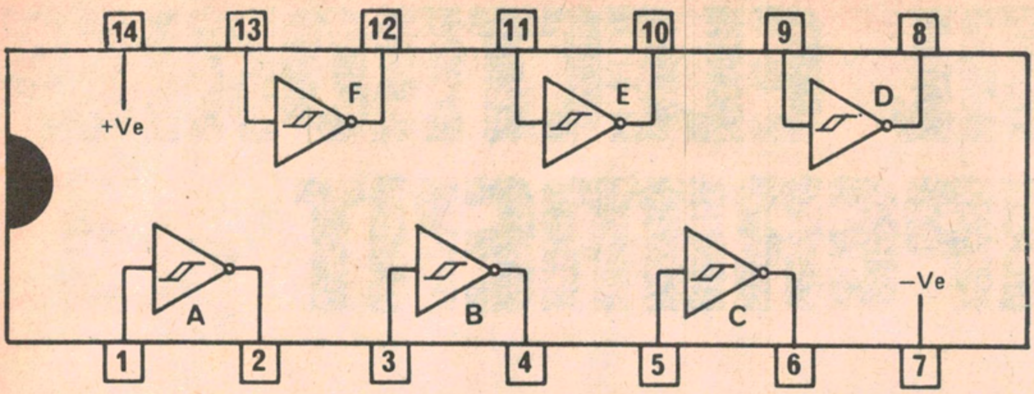


Fig. 2 Pin-out of the SN7414N Hex Schmitt inverter.

we must make sure that there is no uncertainty about either of these levels, and the usual TTL limits are; maximum of 0.8 V for the low; minimum of 2.2 V for the high. We prefer if possible not to approach these limits too closely, and if we drive a TTL input from any other type of output, we must be sure that the source impedance of the driver output will be low enough to allow a current of 1.6 mA to be sunk at a voltage level of 0.5 V or less; this corresponds to an output impedance of 300Ω or less.

Starting work

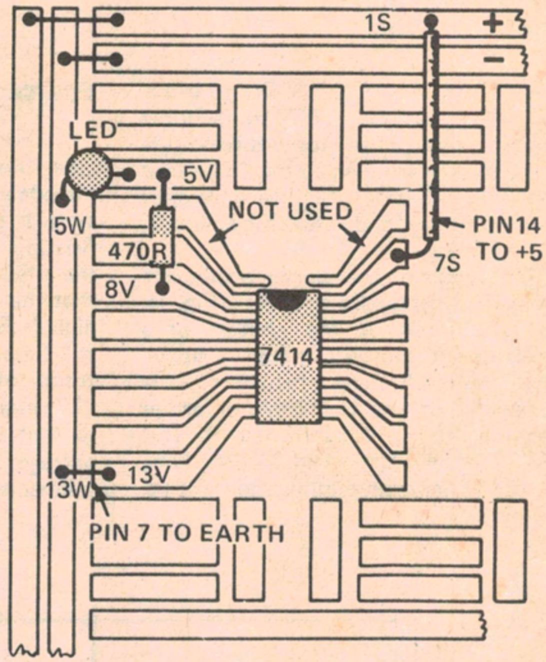
Ensure that the supply lines on your blob-board are fully linked up and, if you are using it, connected to the regulated supply. Join + and − leads to the power supply. If you have a separate supply, these regulated leads, which should be colour coded, will connect directly to the supply lines on the board. If you are using a built on regulator the leads should run to the regulator input.

With no other connections made (none of the ICs wired to the supplies) ensure that the supply voltage is between 4.75V and 5.25V with the supply on. Switch off again. This check should be repeated whenever the board is used from a variable voltage supply, since TTL circuits will be damaged if any input is taken to O with the applied voltage too high.

Four for four uses

Connect the supplies to the 7414, pin 14 to +5V, pin 7 to earth. These connections, like all the connections which follow, are made by soldering short lengths of insulated wire between pads on the blob-board, as shown in Fig. 3. The IC supply connections can be left permanently. (With no other connections made, the IC will draw a current of about 85 mA.)

Fig. 3. Connections to + and − lines using wires. This also shows the LED and its limiting resistor (Fig. 4) in place.



Now connect a 470R resistor and an LED to form the circuit of Fig. 4. This is done by tinning each end of the resistor and LED leadout wires, and then butting these tinned wires, in turn, against the blob-pad and touching wire and pad with a hot iron until the lead "blobs" into place. For this particular joint, we can use a spare pad, as shown in Fig. 3, with the resistor connected from pin 2 of the 7414 to the spare pad, and the LED connected from the spare pad to the OV line. Note that the LED case is usually marked with a flat section at the wire which should be connected to the OV line.

The LED will now light when the output of No. 1 inverter (there are six inverters in the pack) is high. Switch on − the LED should remain unlit, since with the input, at pin No. 1, floating high, the output will be low. Now check what happens when pin 1 is temporarily earthed through a wire link (no need to solder) placed with one end on the pin 1 blob-pad and the other end on the OV line.

Remove the wire, and try bridging between the blob-pad for pin 1 and the OV line with low value resistors, starting with 220R and working up. What is the maximum value of resistance which will allow the LED to light?

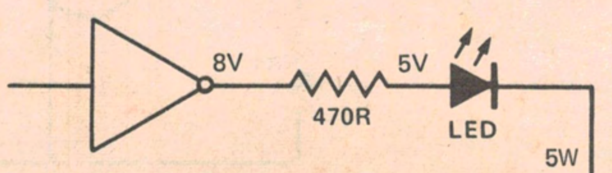


Fig. 4. LED indicator circuit.

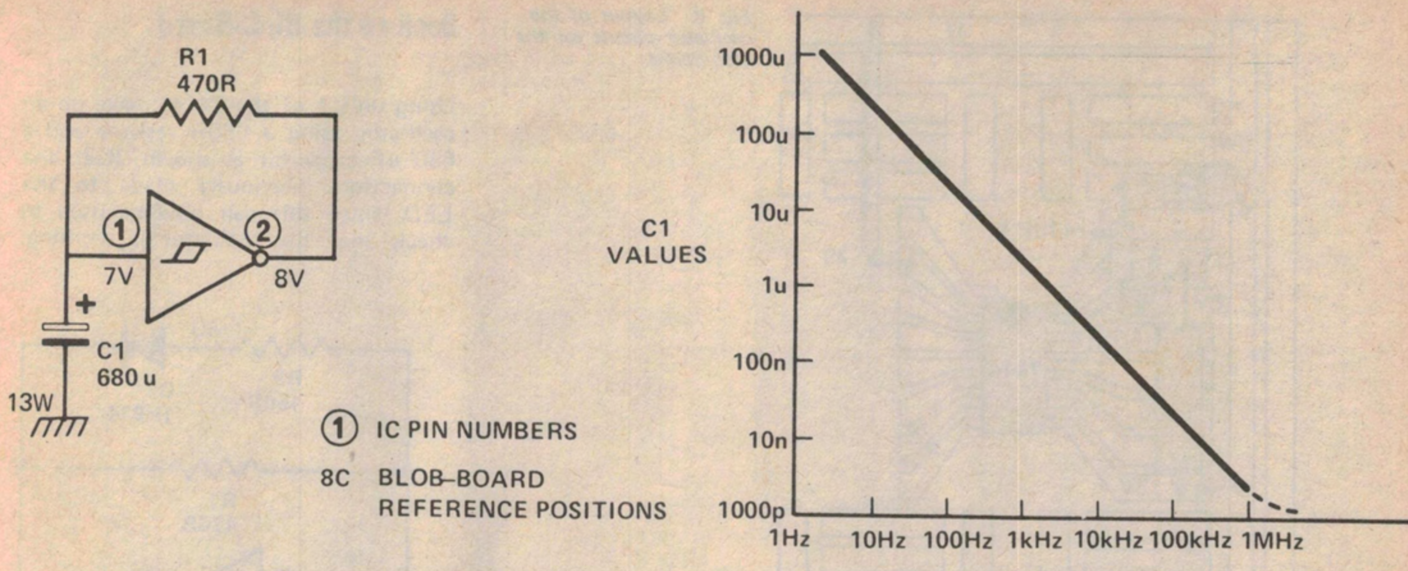


Fig. 6. Oscillator circuit, with a graph of approximate frequency against capacitor value. The frequency changes considerably when the operating voltage is changed, also as the resistor value is varied.

Schmitten with complexity

The actual circuit of the 7414 is more elaborate than the outline which has been shown in Fig. 1. These inverters are Schmitt trigger inverters, indicated by the symbol of Fig. 5(a), in which some positive feedback is used to make the changeover between 1 and 0 very much more rapid than that of an amplifier alone.

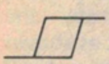
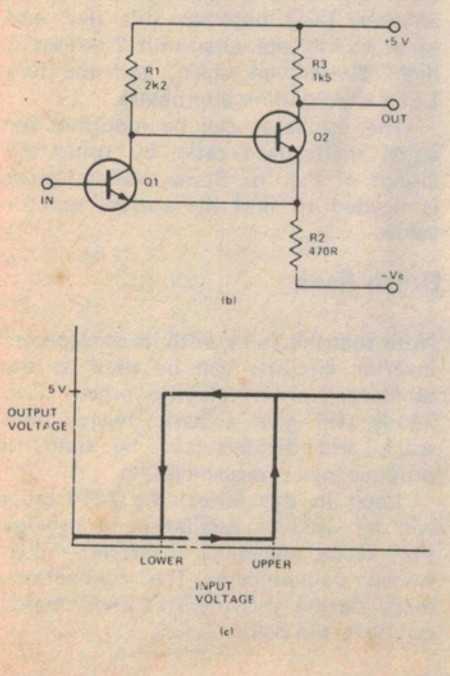


Fig. 5. Schmitt Trigger. (a) Symbol. (b) Typical circuit. (c) Graph of output voltage plotted against input voltage.



Let's examine what happens as the input rises from 0 V. When the input voltage reaches approximately 2.2 V, the current into the base of Q2 will drop to less than that needed to hold Q2 in saturation. The voltage on Q2 collector will therefore rise, reducing the current in R3 and hence R2. Herr Ohm has told us that the voltage across R2 must drop as a consequence, thus forward biasing Q1 even further, and reducing the current into the base of Q2, and so on, until Q2 is finally off. Positive feedback at work!

The voltage across R2 is maintained (at 0.6 V less than Vin) by the emitter current of Q1, which is, of course, the collector current flowing through R1 plus Q1 base current. When Vin drops below 1.48 V, the base current is too low to hold Q1 in saturation. At this point the voltage across R2 is 0.88 V. Current will now flow into the base of Q2 and the resulting current in R3 raises the voltage across R2, turning Q1 off, thus saturating Q2 again.

Slow, slow, quick quick . . .

Since the normal type of TTL circuit consists of a very high gain d.c. amplifier, there is a risk of positive feedback, causing high frequency oscillations, if the amplifier is ever operated, even momentarily, in a linear region, that is with the input biased so that the output voltage is between 1 and 0, or slowly changing. There is no problem if the change between 1 and 0 is fast, 30 ns or so, but slow in this context can mean 1 μs!

Slowly changing waveforms are most likely to be found when other circuits such as photocell amplifiers, microswitches or tacho-generators are connected to TTL inputs. This is an interface problem. Using a Schmitt stage at the input solves this, assuming we have a low enough impedance to drive the Schmitt, since the Schmitt action will give a 30 ns rise or fall time at its

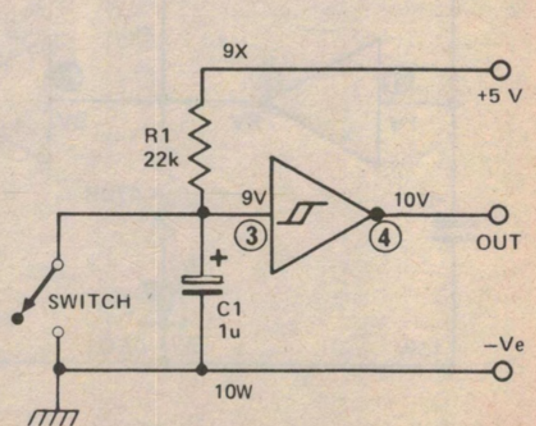


Fig. 7. Switch de-bouncing circuit.

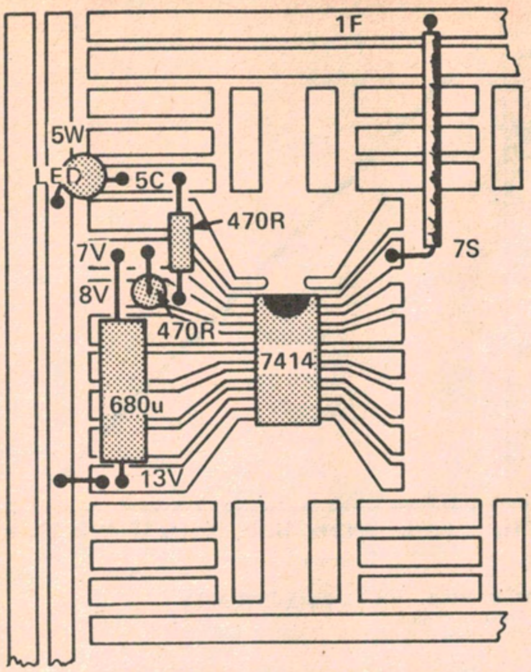


Fig. 8. Layout of the oscillator circuit on the Blob-board.

outpit for any type of input, however slowly changing. Once the Schmitt has triggered, a comparitively large voltage swing is needed to make it change back. A Schmitt stage with high input impedance is also available (SN72560).

Debouncing

One of the unique features of this type of stage is that it can very simply act as an oscillator or as a switch debouncer. Oscillating action is achieved by connecting a resistor of between 330R and 820R between output and input, with a capacitor between input and earth. The circuit is shown in Fig. 6. The output waveform is a square wave with very short rise and fall times, and unequal mark and space times.

When mechanical switches are used to provide waveforms for TTL circuits, contact bounce may cause problems. It occurs as contacts close, and cause a TTL input to be left briefly floating during the time of the bounce.

The effect of this can be to cause several output pulses from the switch where only one is intended. This is harmless if the switch is simply setting d.c. levels, but causes errors if the pulses are being counted. To de-bounce a switch, the circuit of Fig. 7 can be used. The principle is that the time constant is longer than the bounce time of the switch, so that the voltage change when the contacts bounce is small, less than than the hysteresis of the Schmitt circuit, hence no change in the trigger output when the bounce occurs.

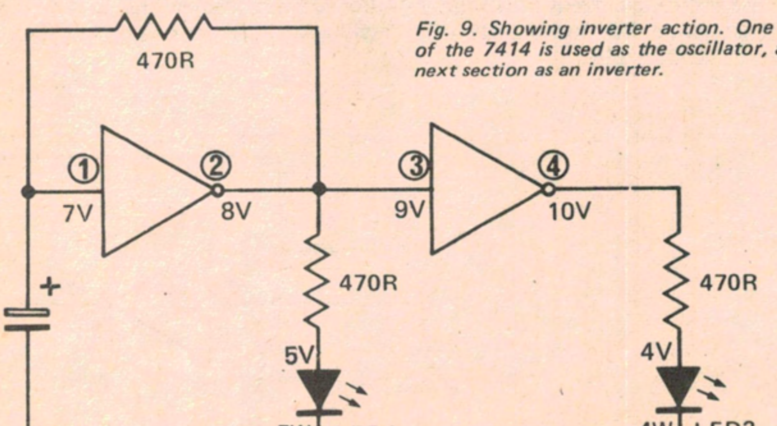


Fig. 9. Showing inverter action. One section of the 7414 is used as the oscillator, and the next section as an inverter.

Back to the Blob-Board

Using unit 1 of the 7414, make up an oscillator using a 680R resistor and a 680 μF capacitor as shown. Keep the connections previously made to the LED, since this can now be used to check that the oscillator is working.

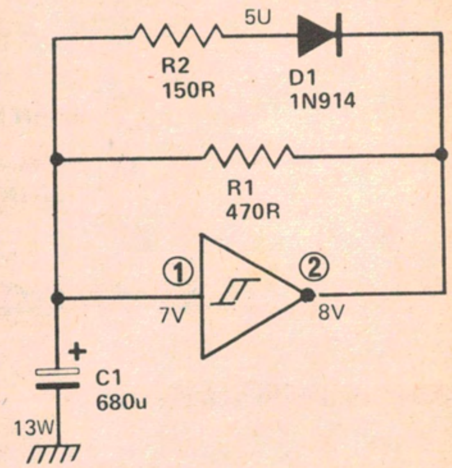


Fig. 10. Modification of the oscillator circuit for equal mark-space ratio. This is not needed for any of the applications in this series.

Estimate the frequency by counting the number of LED flashes in one minute, and then dividing the number counted by 60. Demonstrate the inverter action by using unit 2 as shown in Fig. 9. Wire a connection from pin 2 to pin 3 of the IC, and a 470R resistor from pin 4 to a spare pad. Connect another LED between this pad and earth to indicate when unit 2 output is high. Switch on again, and the two LEDs should blink alternately.

The oscillator can be modified for equal mark-space ratio by using the circuit of Fig. 10. Some trial and error is needed to find the correct resistor value.

Organ Bank

Note that the 7414, with its six separate inverter circuits, can be used as the oscillator for an electric organ. Two 7414s will give a basic twelve note scale, and dividers can be used to produce lower frequencies.

Later in this series, the 7414 units will be used as oscillators to provide slow clock pulses, as inverters, and as switch de-bouncers. The connections made during this month's experiments can be left in place.