DIGITAL ELECTRONICS BY EXPERIMENT part 7

Continuing our series on TTL digital logic — this month decade counters.

THE 7490 DECADE COUNTER is a single-chip counter containing four flip-flops and various gates, which are arranged so that frequency division and decimal counting can be carried out. To make the counter more versatile, one flip-flop is separately connected so that it can be independently used as a scale-of-two counter, and the remaining three flip-flops are gates so that they act as a scale-of-five. The two sections of the counter can be connected together in different ways, either as a divide-by-ten circuit, or as a decimal counter with BCD outputs.

Twos Into Tens

BCD — meaning Binary-Coded-Decimal — is a form of binary code which is particularly useful if decimal numbers have to be displayed. In a BCD count, each figure of a decimal number is represented by its binary equivalent, so that the number 85 (decimal) becomes 1000 0101, binary B and binary 5. Although more convenient, because each BCD counter can then drive a display unit, this form is longer than a pure binary number (binary 85 = 1010101, only seven figures), and BCD numbers are not so simple to add and subtract as pure binary numbers.

BCD in Practice

Connect the power supplies to the 7490 with pin 10 to earth and pin 5 to +5 V. Pins 2 and 7 should also be earthed for most of the experimental work in this section, although we may use pin 2 later for resetting to zero. Now connect LEDs and their limiting resistors, using the spare pads on the board, to Qa on pin 12 and Qd on pin 11. Connect the clock pulse from the slow oscillator to input A (pin 14) and by watching the clock LED and the LED connected to pin 12 (Qa), note the action of this section of the counter.

Switch off, transfer the clock pulse input to input B on pin 1, and switch on again, watching the clock LED and the Qd LED on pin 11. Note that the counter will operate only if the reset pins, each pair being inputs to an AND gate which operates the reset. Pins 2 and 3 are the reset to zero pins, and earthing either of them enables the counter. If both are allowed to float to logic 1, or are taken to logic 1, the counter resets to zero. Pins 6 and 7 also act through an AND gate, but with both high the reset is to BCD 9 (1001) rather than to zero.

To use the 7490 as a frequency divider (Fig. 2), we connect Qd (pin 11) to INa (pin 14) and take the clock pulse to INb (pin 1). The output will appear at Qa, on pin 12, and the state of this output is monitored by an LED already. Connect up the clock pulse from the slow oscillator on the board, and by counting pulses, confirm that the correct division ratio is being obtained.

For a BCD count, the connections must be changed around (Fig. 3). We now need LED indicators on the Qb (pin 9) and Qc (pin 8) outputs as well as on Qa (pin 12) and Qd (pin 11), and the cross-connections are different, with Qa connected to input B and the clock input taken to input A on pin 14. Label the LEDs as A, B, C, and D, and switch on, noting the values at each stage of the count. Use a de-bounced switch as a clock supply if the oscillator is too fast to follow. Note that in the circuit of Fig. 3 a reset switch has been used; because we are using push-to-make switches, an inverter must be used as shown.

Because the 7490 is on a single chip it may be more convenient to adapt it for counts of less than 10, rather than use separate flip-flops. This is made easier by the arrangement of the reset lines, connected through AND gates. Ignoring the reset-to-nine pins, we can arrange for pin 2 to be driven by a gate whose output must be zero during the count, rising to 1 at the end of the count. Pin 3 must be kept high, or the count will not be interrupted.

Try the circuit of Fig. 4 — can you work out what the count figure will be? Connect up and try the circuit out.

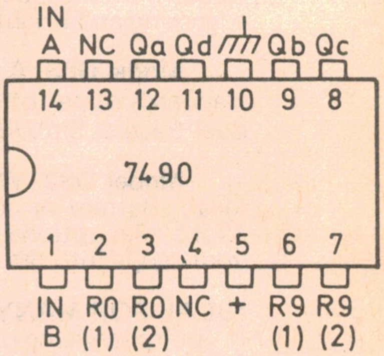


Fig 1. Pinout of 7490 Decade counter.

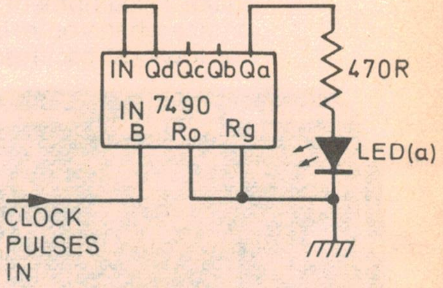


Fig 2. Connections for frequency division by ten — note that the symbol does not show the true pin positions.

Displays

Though several other forms of display exist, the most convenient type for use with TTL circuits is the seven-segment LED display. The type used for this board, the Jumbo DL747 is one of the largest displays of this type available at the time of writing, and has been selected from the point of view of easy reading at a distance. If any other type is substituted, care will have to be taken with the pin connections, since there are several pinout standards for this type of display.

As the name suggests, the seven-segment display consists of seven LEDs made in one chip in the arrangement of a figure-of-eight, as shown in Fig. 5. The letters allocated to the strips are also shown (fortunately these are standardised).

Looking at the arrangement of the segments, we can draw up a table of the segments that will have to be activated (ON) for each number we want to display. Fig. 6. shows such a table for the numbers 0 to 9, and also some of the other characters which can be obtained. We now have to translate this ON/OFF table into terms of logic 1 and 0.

The next step depends on the type of display that is being used — common cathode or common anode. As the name suggests, the common cathode display has all of the LED cathodes connected together to logic 0, and each anode must be taken to logic 1 to be illuminated. To prevent excessive current flowing — because the normal forward voltage across the LED is less than the +5 V of the logic circuits — we must wire a limiting resistor in the connection to each anode. We cannot use one single resistor in the cathode lead, as this would cause the brightness of the display to alter according to the number of segments lit.

The other possibility is to connect the anodes of the LEDs together and take the cathodes out to separate pins. In this common-anode type of display, the segments will be lit when their respective cathodes are at logic zero, and once again limiting resistors must be used between each cathode and the TTL driving stage.

The type of display specified for this board is a common anode type, with several of the pins on the display connected to the common anode. Only one of these pins need be connected to the 5V line.

Decoders

To obtain a decimal readout from the BCD output of the 7490 counter, a decoder stage, is needed with the truth table shown in Fig. 7.

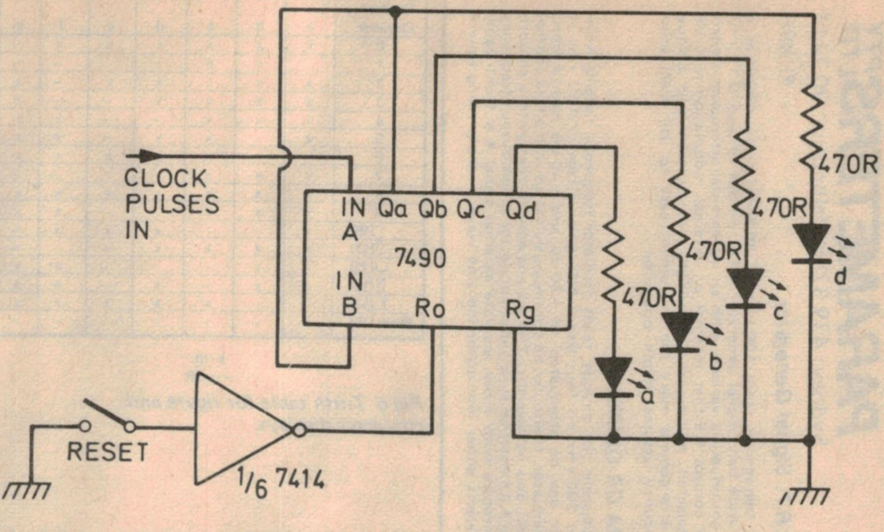


Fig 3. Connections for BCD counting, with reset switch. The reset pin must be kept at logic zero for counting, and taken to logic 1 for reset, so that an inverter must be used along with the push-button switch.

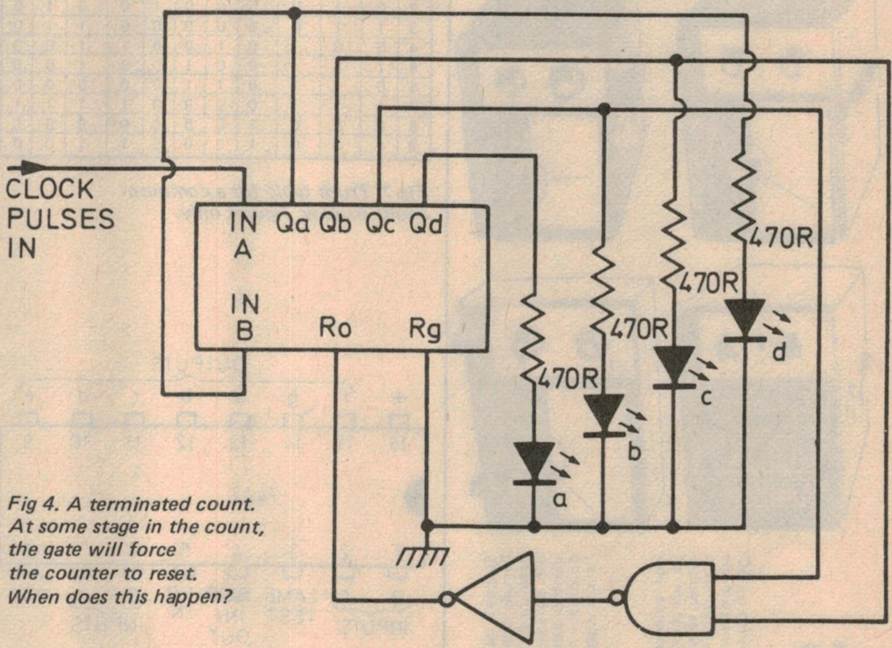
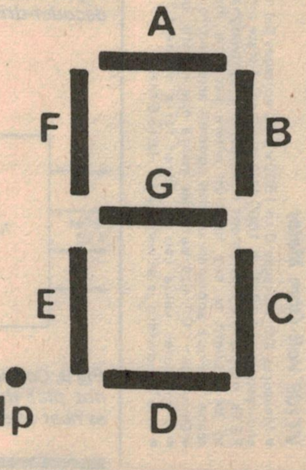


Fig 4. A terminated count. At some stage in the count, the gate will force the counter to reset. When does this happen?



Number/ Character	a	b	c	d	e	f	g
0	x	x	x	x	x	x	–
1	-	x	x	–	–	–	–
2	x	x	–	x	x	–	x
3	x	x	x	x	–	–	x
4	–	x	x	–	–	x	x
5	x	–	x	x	–	x	x
6	–	–	x	x	x	x	x
7	x	x	x	–	–	–	–
8	x	x	x	x	x	x	x
9	x	x	x	–	–	x	x
⊏(10)	x	–	–	x	x	x	–
⊐(11)	x	x	x	x	–	–	–
⊔(12)	–	x	–	–	–	x	x
⊆(13)	x	x	–	x	–	x	x
⊑(14)	–	–	x	x	x	x	x
Blank (15)	–	–	–	–	–	–	–

x - lit
– - unlit

Fig 6 Truth table for figure and character displays.

	A	B	C	D	a	b	c	d	e	f	g
0	0	0	0	0	0	0	0	0	0	0	1
1	1	0	0	0	1	0	0	1	1	1	1
2	0	1	0	0	0	0	1	0	0	1	0
3	1	1	0	0	0	0	0	0	1	1	0
4	0	0	1	0	1	0	0	1	1	0	0
5	1	0	1	0	0	1	0	0	1	0	0
6	0	1	1	0	1	1	0	0	0	0	0
7	1	1	1	0	0	0	0	1	1	1	1
8	0	0	0	1	0	0	0	0	0	0	0
9	1	0	0	1	0	0	0	1	1	0	0

Fig 7 Truth table for a common-anode display, figures only.

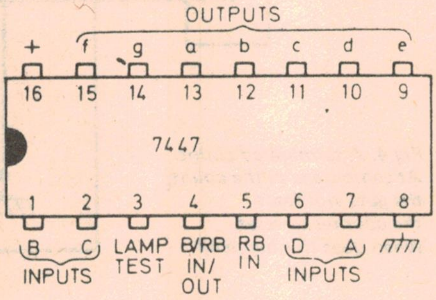


Fig 8. Pinout of the 7447 BCD to 7-segment decoder-driver.

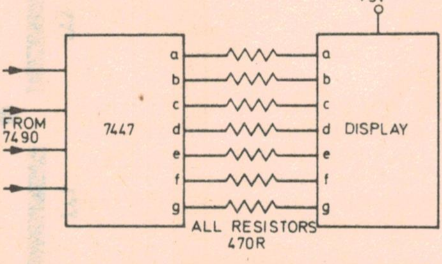


Fig 9. Connection of the 7447 to the display — not that the arrangement on the board is as neat as the drawing would suggest!

The type used here is the 7447 BCD-to-seven segment decoder/driver, which has output stages of transistor collectors with no loads. In this way, the combination of LED and limiting resistor acts as load for the collectors of the output transistors in the 7447.

Care should be taken that the outputs of a 7447 are never connected directly to the +5 V line, as excessive currents could flow if the decoder were operated.

In use, the segment output pins of the 7447 are connected through the limiting resistors to the segment pins of the display. The values of the limiting resistors used will determine the brightness of the display. For the 7447 display we can use 150 R resistors, but 470R resistors have been specified on our board to ensure long life and to cut down current consumption. If other displays are used, 470R should also be suitable — in general the small displays need less current, and so larger values of limiting resistors should be used than with larger displays. If a common cathode display, such as the MAN-3 types, had been used, the 7448 decoder would have been needed.

Now connect up the display and the decoder on your board, noting the connection diagram of Fig. 9. In the prototype boards, the very small resistors used for limiting could be passed under the body of the display, so avoiding long paths around it. The +5 V supply is taken to pin 16 of the 7447, and earth is taken to pin 8. The outputs of the 7447, all on the side facing the display, and marked on the circuit diagram with small letters, are taken through the 470R limiters to the correspondingly lettered pins of the display. The inputs indicated by the capital letters A, B, C and D on pins 1, 2, 7 and 6 of the 7447 are for the BCD input from a 7490 and should be connected to the appropriate Q outputs from the 7490 counter.

Testing and Blanking

Note that pin 3 of the 7447 is labelled "lamp test". Taking this pin to logic 0 illuminates all segments of the display irrespective of what stage the count has reached, and is a useful check on the operation of the display. For example, an operator can check that a steady display of 8 is not just 3 with two segments faulty.

Pins 4 and 5 on the 7447 are for blanking, used mainly when the display is one of a set, to suppress zeros occurring before the first significant figures and after the last one. When pin 4 is low, the display is blanked out, though counting is unaffected.