Lab Notes

Electronic switching — using the 4066B

There are many applications where mechanical switches and relays just won't do the job you want. The answer? — an electronic switch. The most popular and versatile is the 4066B quad bilateral switch — a CMOS package containing four electronically actuated single-pole single-throw (SPST) switches.

Ray Marston

THE 4066B CMOS IC is described in the manufacturer's literature as a 'quad bilateral switch', a pretty fair description since the device contains four independent electronic switches, each capable of passing signals in either direction and being controlled (turned on or off) by a single high-impedance terminal. The switches have a very high off impedance, an on impedance of about 90 ohms, and can be used to switch both analogue and digital signals.

Basic 4066B circuits

Figure 1 shows the outline and pin notations of the 4066B, which can be used with any supply voltage in the range 3 to 18 V. Note that, since the switches are of the bilateral type, either switch terminal can be used as the input or output.

Figure 2a shows the basic way of using the bilateral switch; each switch can be turned *off* (open circuit) by taking the control terminal to V_{SS} *or* turned on by taking the control terminal to V_{DD}. In digital switching applications (Figure 2b) the IC can be used with a single-ended supply, with V_{SS} at 0 V and V_{DD} at the desired positive supply. In analogue switching applications (Figure 2c), a split power supply (either true or effective) must be used, with the positive rail to V_{DD} and the negative to V_{SS}; in this case, of course, the maximum supply limits are restricted to ±9 V. Typically, the bilateral switch introduces less than 0.5% signal distortion when used in the analogue mode.

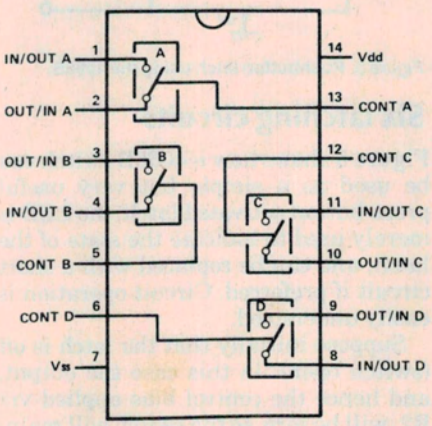


Figure 1. **Outline and pin notations of the 4066B quad bilateral switch.**

Certain simple precautions must be observed when using the 4066B. First, the switch signals must in no circumstances be allowed to rise above the V_{DD} voltage or fall below the V_{SS} voltage. Each unused switch in the 4066B package must be disabled (see Figure 3) either by taking its control terminal to V_{DD} or V_{SS} (as most convenient), or by taking all three terminals to V_{SS}. ▶

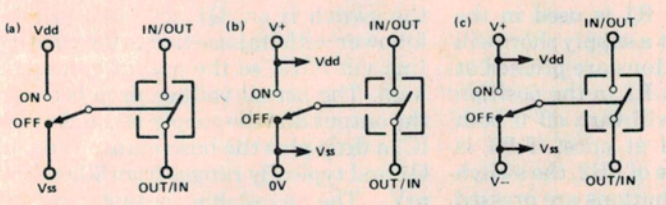


Figure 2. **(a) The basic bilateral switch is turned off by taking the control terminal to V_{SS} and turned on by taking the control to V_{DD}. (b) In digital switching applications, V_{DD} is V+ and V_{SS} is 0 V. (c) In analogue switching applications where a split power supply is used, V_{DD} must go to V+ and V_{SS} to V−.**

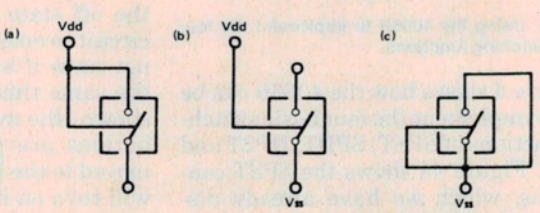


Figure 3. **Unused bilateral switches must be disabled, either by taking the control terminal to V_{DD} and one of the switch terminals to V_{DD} (a) or V_{SS} (b), or by taking all three terminals to V_{SS}.**

Lab Notes

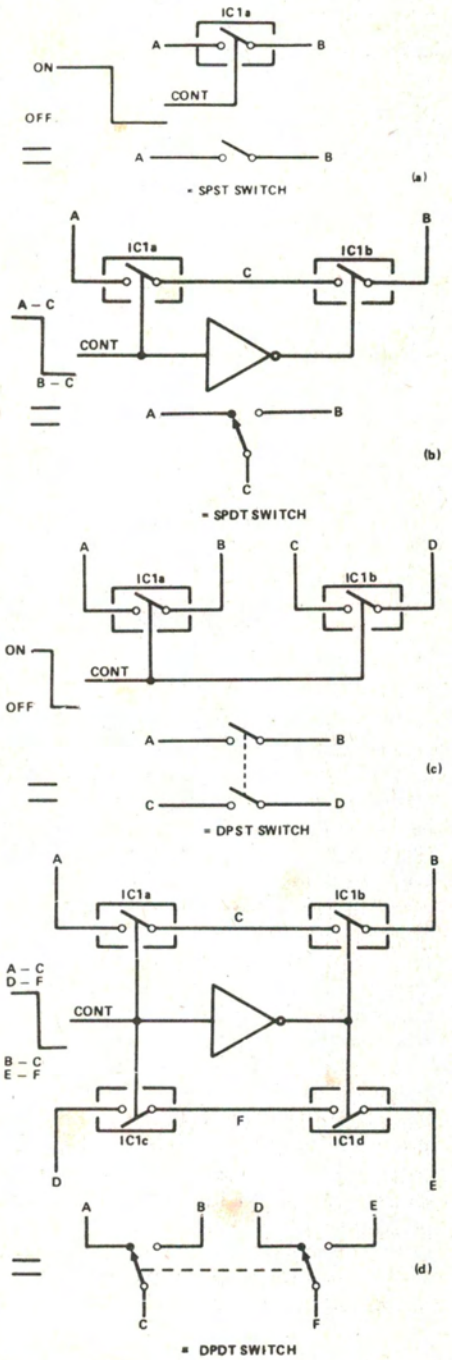


Figure 4. **Using the 4066B to implement the four basic switching functions.**

Figure 4 shows how the 4066B can be used to implement the four basic switching functions of SPST, SPDT, DPST and DPDT. Figure 4a shows the SPST connections, which we have already discussed. The SPDT function is implemented by wiring an inverter stage (a 4001 or 4011, etc) between the IC1a and IC1b control terminals as shown. The DPST switch (Figure 4c) is simply two SPST switches sharing a common control terminal, and the DPDT switch (Figure 4d) is two SPDT switches sharing a common inverter stage in the control line.

Note that the basic switching functions of Figure 4 can be expanded or combined in any desired way by simply adding extra switches/4066B packages, as appropriate. Thus, a 10-pole double-throw switch can, for example, be made by using five of the Figure 4d circuits and joining their control inputs together.

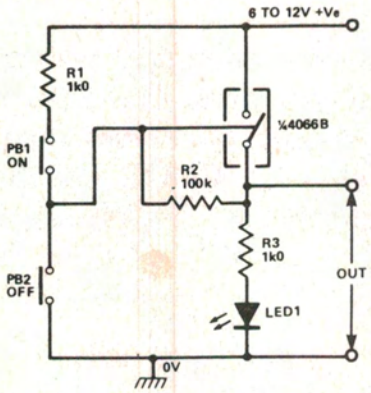


Figure 5. **Pushbutton latch using the 4066B.**

Six latching circuits

Figure 5 shows how a 4066B switch can be used as a simple but very useful press-button activated latch; the LED is merely used to indicate the state of the latch, and can be replaced with a short circuit if preferred. Circuit operation is easily understood.

Suppose initially that the latch is off (switch open). In this case the output, and hence the control bias applied via R2, will be zero, so the switch will maintain its off state. If PB1 is now momentarily closed the control voltage will go high and turn the switch on, thus driving the output high and maintaining the control drive high (switch on) once PB1 is released. This new state will be maintained until PB2 is closed, at which point the switch will latch into the off state again. R1 is used in the circuit to ensure that a supply short will not occur if both buttons are pressed at the same time; with R1 in the position shown, the switch will turn off if both buttons are pressed at once; if R1 is moved to the low side of PB2, the switch will turn on if both buttons are pressed at once.

The Figure 5 circuit has a couple of interesting characteristics. First, the control bias resistor can be given any desired value up to practical limits.

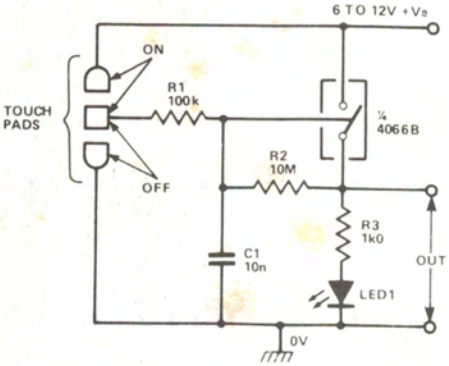


Figure 6. **A latching touch switch.**

Figure 6, for example, shows how the value can be increased to 10M to make a latching touch switch that can be activated by placing a finger across the upper or lower set of touch contacts. R1 and C1 are used to suppress hum signals and ensure positive switching.

Another useful feature is that, since the on resistance of the switch is only 90 ohms or so, the voltage loss across the switch can be quite low (90 mV at 1 mA); in practice, the on current should be limited to 10 mA maximum. Figure 7

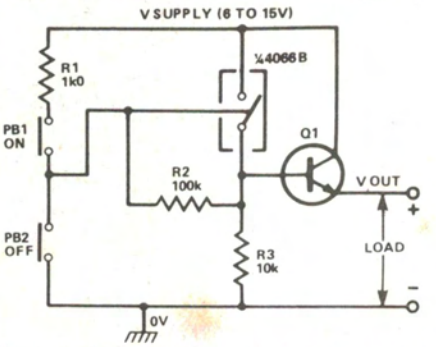


Figure 7. **This pushbutton activated power switch can be used to replace a conventional slide or toggle switch.**

shows how this low-loss effect can be used to connect or disconnect the power supply to a piece of electronic equipment (amplifier, test gear, etc).

When the switch is off, Q1 is cut off and the circuit consumes a typical standby current of less than 1 uA. When the switch is on, Q1 acts as a voltage follower with its base tied to the positive line via IC1a, so the output voltage is high. The actual voltage drop between the output and the supply is equal to the IC1a drop plus the base-emitter drop of Q1 and typically ranges from 600 to 800 mV. The available output current depends on the gain and current rating of Q1, but currents of a few hundred milliamps are readily available from a single transistor.

A slightly more efficient version of

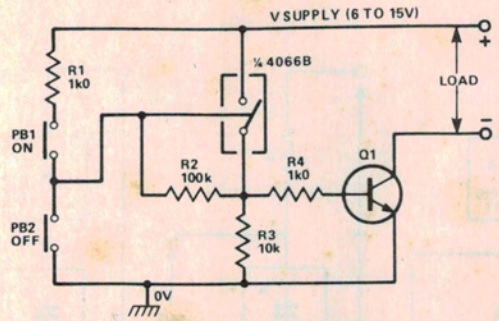


Figure 8. **An alternative version of the pushbutton power switch.**

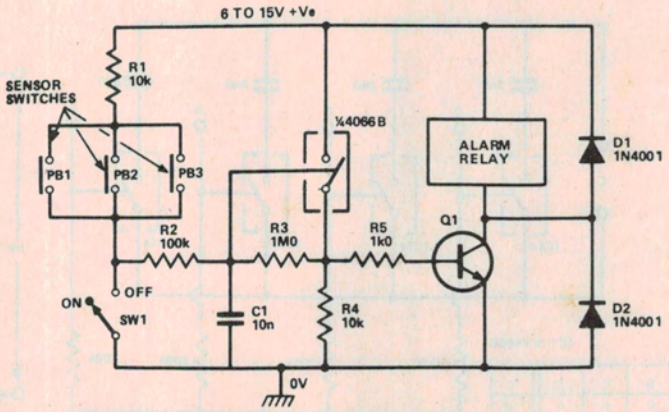


Figure 9. **A close-to-activate burglar/panic/fire alarm.**

the pushbutton power switch is shown in Figure 8. In this case the load is wired between the collector of Q1 and the positive supply rail. The voltage drop in this circuit is determined only by the saturation characteristics of Q1 and may typically be in the range 200 to 600 mV.

Figure 9 shows how the above circuit can be modified for use as a 'close-to-activate' burglar, panic or fire alarm, in which Q1 output feeds directly to a heavy duty 'alarm' relay which, in turn, actuates an external bell or siren. Any number of normally open sensors/switches can be wired in parallel in the 'PB' positions. The circuit consumes only a microamp or so when in the 'ready' or off mode.

Figure 10 shows the 4066 used in a multiplexer application where two inputs to a LED display (a pair of LM3915s) are switched alternately to provide a readout of 'average' and 'peak' signal levels. This was employed in our ETI-458 LED Level Meter, which featured 'twin-dot' display — the 'upper' dot showing peak signal level, the 'lower' one showing average. As the 4066 toggles between the two inputs the dot-mode display changes in like fashion. Because the toggling speed is so rapid (a few hundred Hertz), the persistence of vision makes the display seem to have two dots rather than one dot at a time. Two gates act as the multiplexing switches and two gates are arranged as an oscillator to drive them.

Digital control

The 4066B can be used to digitally control or vary resistance, capacitance, impedance, amplifier gain or oscillator frequency in any desired number of discrete steps. Figure 11 shows how the four switches of a single 4066B can be used to vary the effective value of a resistance in 16 digitally controlled steps of 10k each. In practice, of course, the step magnitudes can be given any desired value (determined by the value of the smallest resistor) so long as the four resistors are kept in the ratio 1-2-4-8, and that the on-resistance of 90 ohms is kept in mind. ▶

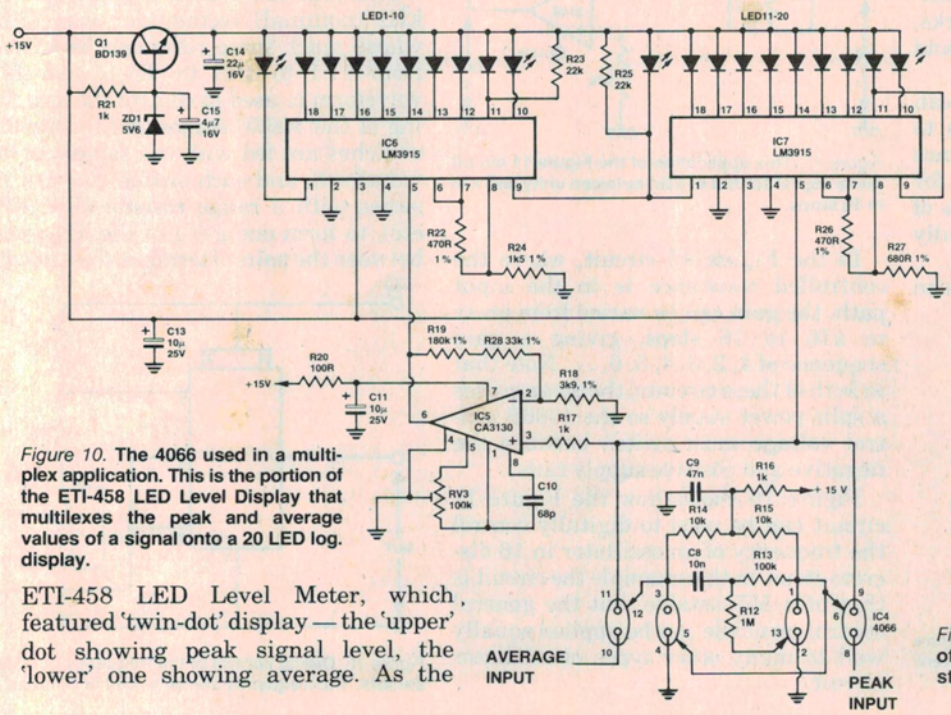
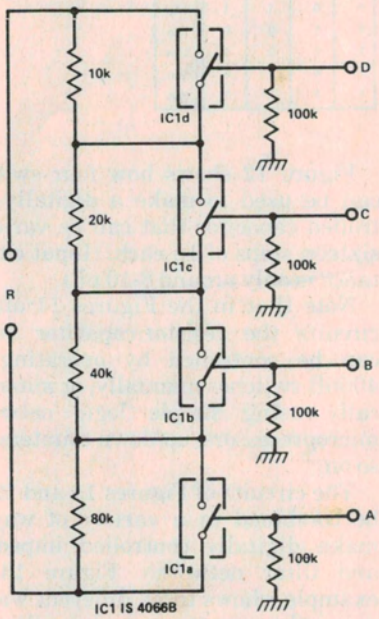


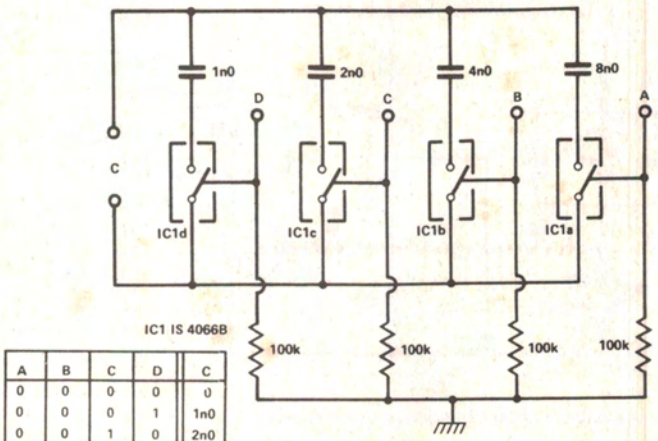
Figure 10. **The 4066 used in a multiplex application. This is the portion of the ETI-458 LED Level Display that multilexes the peak and average values of a signal onto a 20 LED log. display.**



A	B	C	D	R
0	0	0	0	150k
0	0	0	1	140k
0	0	1	0	130k
0	0	1	1	120k
0	1	0	0	110k
0	1	0	1	100k
0	1	1	0	90k
0	1	1	1	80k
1	0	0	0	70k
1	0	0	1	60k
1	0	1	0	50k
1	0	1	1	40k
1	1	0	0	30k
1	1	0	1	20k
1	1	1	0	10k
1	1	1	1	0

Figure 11. **This circuit gives 16-step digital control of resistance. R can be varied from zero to 150k in steps of 10k.**

Lab Notes



A	B	C	D	C
0	0	0	0	0
0	0	0	1	1n0
0	0	1	0	2n0
0	0	1	1	3n0
0	1	0	0	4n0
0	1	0	1	5n0
0	1	1	0	6n0
0	1	1	1	7n0
1	0	0	0	8n0
1	0	0	1	9n0
1	0	1	0	10n
1	0	1	1	11n
1	1	0	0	12n
1	1	0	1	13n
1	1	1	0	14n
1	1	1	1	15n

Figure 12. **A similar circuit to that of Figure 11 gives 16-step digital control of capacitance. C can be varied from zero to 15n in steps of 1n.**

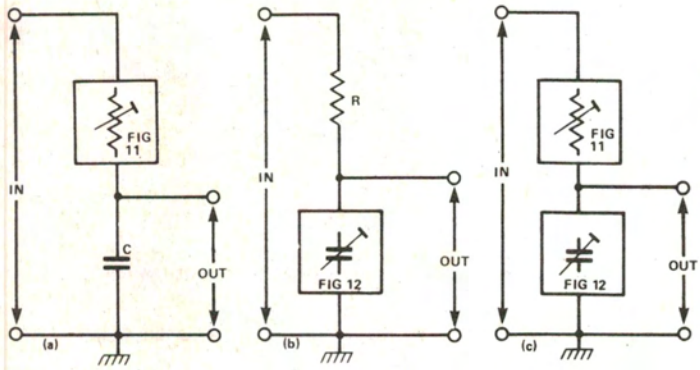


Figure 13. **Three ways of using the circuits of Figure 11 and Figure 12 to make a digitally-controlled first-order low pass filter.**

Figure 12 shows how four switches can be used to make a digitally controlled capacitor that can be varied in sixteen steps of 1n each. (Input capacitance is only around 8-10 pF).

Note that in the Figures 11 and 12 circuits the resistor/capacitor values can be controlled by operating the 4066B switches manually, or automatically using simple logic networks, microprocessors, up/down counters, and so on.

The circuits of Figures 11 and 12 can be combined in a variety of ways to make digitally controlled impedance and filter networks. Figure 13, for example, shows three different ways of using the circuits to make a digitally controlled first-order lowpass filter.

Digital control of amplifier gain can be obtained by hooking the 'resistance' circuit of Figure 11 into the feedback or input path of a standard op-amp inverting circuit, as shown in Figures 14 and 15. The gain of such a circuit is equal to R_F/R_{IN}, where R_F is the feedback resistance and R_{IN} is the input resistance. Thus, in the Figure 14 circuit, where the controlled resistance is in the feedback loop, the gain can be varied from zero to unity in 16 discrete steps of 'one fifteenth' each, i.e: giving a sequence of 0, 1/15, 2/15, 3/15, . . . , 14/15, 15/15.

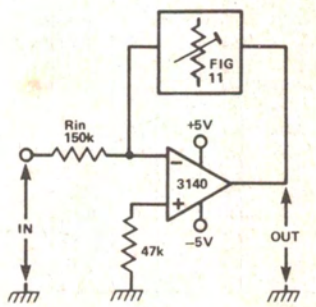


Figure 14. **Digital control of gain using the Figure 11 circuit. The gain can be varied between zero and unity in 16 steps.**

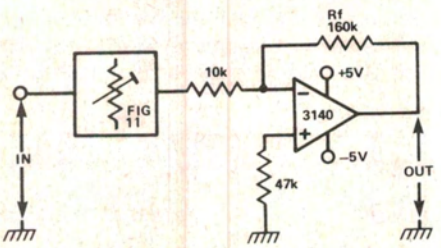


Figure 15. **This application of the Figure 11 circuit gives digital control of gain between unity and x16 in 16 steps.**

In the Figure 15 circuit, where the controlled resistance is in the input path, the gain can be varied from unity to x16 in 16 steps, giving a gain sequence of 1, 2, 3, 4, 5, 6, . . . Note that in both of these circuits, the op-amp uses a split power supply so the 4066B control voltage must switch between the negative and positive supply rails.

Figure 16 shows how the Figure 11 circuit can be used to digitally control the frequency of an oscillator in 16 discrete steps. In this example the circuit is that of a 555 astable, but the general control principle can be applied equally well to many other types of oscillator circuit.

Figure 17 shows how a trio of 4066B switches can be used to implement digital control of the decade range selection of 555 astable. Here, only one of the switches must be turned on at any time. Naturally, the circuits of Figures 16 and 17 can be combined to form a wide-range oscillator that can be digitally controlled by a computer, for example.

Synthesised multi-gang pots

The synthesising principle is quite simple and is illustrated in Figure 18, which shows the circuit of a synthesised four-gang 10k-100k rheostat for use at signal frequencies up to about 15 kHz.

Here, the 555 is used to generate a 50 kHz (nominal) rectangular waveform whose mark/space ratio can be varied from 11:1 to 1:11 by RV1, and this waveform is used to control the switching of the 4066B stages. All the 4066B switches are fed with the same control waveform, and each switch is wired in series with a range resistor (RA, RB, etc), to form one gang of the 'rheostat' between the pairs of terminals, as shown.

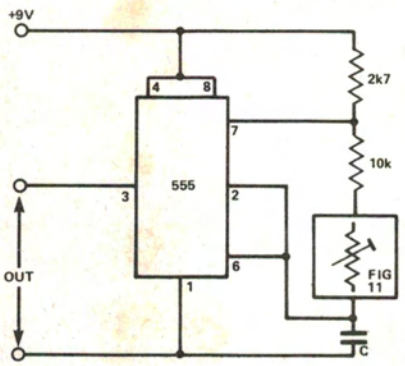


Figure 16. **Digital control of the frequency of a 555 astable. The frequency can be varied in 16 steps.**

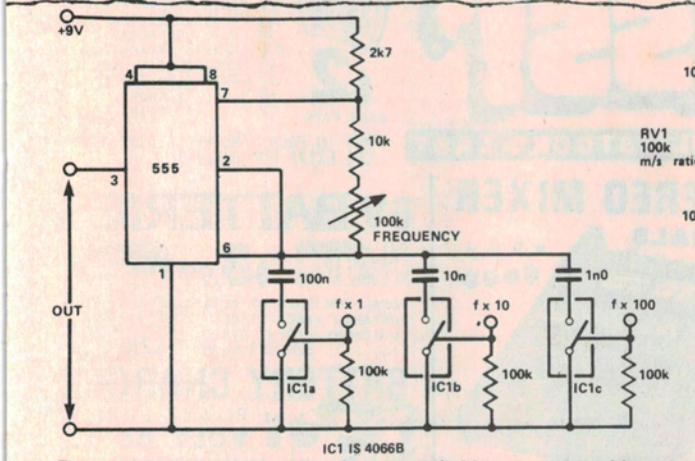


Figure 17. **Digital control of decade range switching of a 555 astable.**

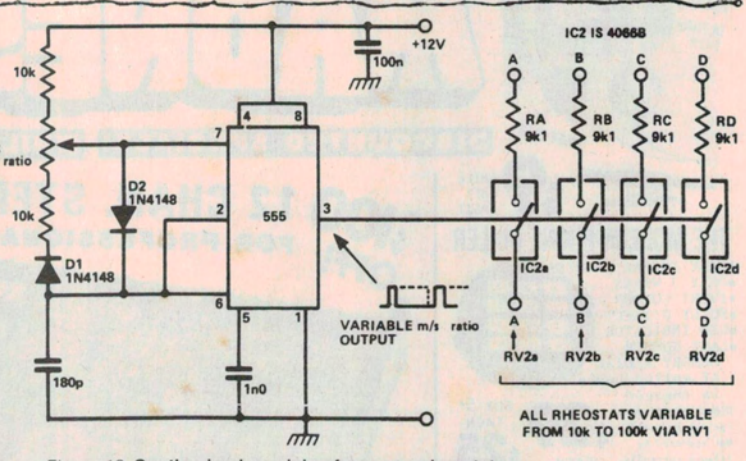


Figure 18. **Synthesised precision four-gang rheostat.**

Remembering that the switching rate of this circuit is very fast (50 kHz) relative to the rheostat's maximum signal frequency (15 kHz), it can be seen that the mean or effective value of the 'rheostat' resistance can be varied with mark/space ratio control RV1. Thus, if IC2a is closed for 90% and open for 10% of each duty cycle (mark/space ratio of 9:1), the apparent (mean) value of the resistance will be 10% greater than RA, i.e: 10k. If the duty cycle is reduced to 50%, the apparent RA value will double, to 18k2. If the duty cycle is further decreased, so that IC2a is closed for only 10% of each duty cycle (mark/space ratio 1:9), the apparent value of RA will increase by a decade, to 91k. Thus, the apparent resistance of each 'gang' of the 'rheostat' can be varied by RV1.

There are some important points to note about the Figure 18 circuit. First, the circuit can be given any desired number of 'gangs' by simply adding an appropriate number of switch stages and range resistors. Since all switches are controlled by the same mark/space ratio waveform, perfect tracking is automatically assured. Individual gangs can be given different ranges, without affecting the tracking, by giving them different range resistor values. The sweep range and the law of the rheostat can be changed by changing the characteristics of the mark/space ratio generator. ●