40 PROJECTS Using COSMOS Digital IC's

This is part III in a series of articles describing COSMOS IC's, the latest in solid-state technology. Monostable and astable multivibrator circuits are described here, along with simple circuits you can build.

by R. M. MARSTON

IN PART II OF THIS SERIES WE LOOKED AT the operating principles of COS/MOS digital IC's, and explored a number of practical ways of using the CD4001 IC in inverter, gate, and logic applications. We went on to discuss bistable multivibrator applications.

In this third part of the series, we go on to look at monostable and astable multivibrator applications.

Monostable multivibrator projects

A basic monostable or one-shot multivibrator can be made from two NOT or NOR logic gates by direct-coupling the output of one gate to the input of the other, and by coupling the output of the second gate to the input of the first via a simple R-C time constant network. Figure 21 shows a practical way of making a basic monostable multivibrator, or pulse stretcher, from one half of a CD4001 COS/MOS IC. You can also use the KD4001.

Here, gate A is used as a NOR logic element, and gate B is used as an inverter or NOT gate. The circuit action follows:

Normally, when the circuit is in its quiescent state, the input to gate B is held high via R1, so the output at gate B is low: Both input terminals of gate A are thus low, so the output of gate A is high. Consequently, since both ends of C1 are high, C1 is fully discharged.

Suppose now that a brief positive trigger pulse is applied to the input of gate A. As soon as this pulse is applied, it drives the output of gate A to ground and drags the input of gate B with it via discharged capacitor C1: Consequently, the output of gate B immediately goes high, and thus holds the output of gate A in the low state even when the input trigger pulse is subsequently removed.

As soon as the output of gate A goes low as the result of the applied trigger pulse, C1 starts to charge via R1, and an exponential rising voltage is applied to the input of gate B via the R1-C1 junction. Eventually, after a delay determined by the R1 and C1 values, this exponential voltage rises to the transfer voltage of gate B, and at this point, the output of gate B switches sharply back into the low state. As the output of gate B goes low it causes the output of gate A to go high: C1 then discharges rapidly via the output of gate A and input protection diode D1 (see Fig. 7-b, September 1974 issue) of gate B, and the operating sequence is then complete.

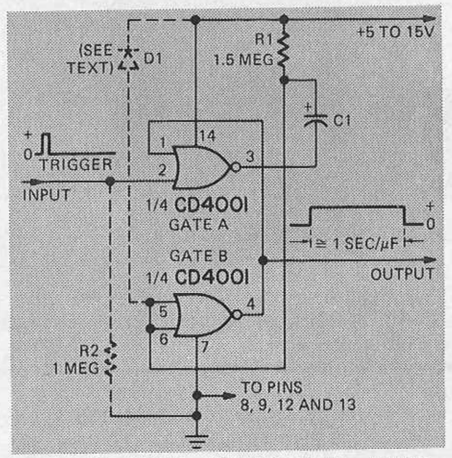


FIG. 21—BASIC MONOSTABLE MULTIVIBRATOR or pulse stretcher.

Thus, the output of the Fig. 21 circuit is normally low, but goes high as soon as a brief positive trigger pulse is applied to the input: The output then remains high for a certain period, and then switches abruptly back to the low state again: The precise period of the output pulse is determined by the R-C time constant, and by the value of the transfer voltage of the individual CD4001 IC that is used.

Three points should be noted about this particular circuit. The first point is that, since the period of the circuit is dependent on the transfer voltage of the particular CD4001 that is used, the period that is obtained using a particular set of R-C values can vary considerably between one CD4001 and another. The CD4001 in fact has a production transfer voltage spread of 30% to 70% of the supply voltage.

In practice, the transfer voltage of any particular CD4001 is almost constant over a wide range of temperature and supply voltages, so the Fig. 21 circuit has excellent stability, but must have its time constant values individually adjusted to give a particular timing period. The Fig. 21 circuit in fact gives a period of roughly 1 second per μF of C1 value when R1 has a value of 1.5 megohms. C1 can have any value between a few pF and hundreds of μF: The value of R1 can range from a few thousand ohms to thousands of megohms, if required.

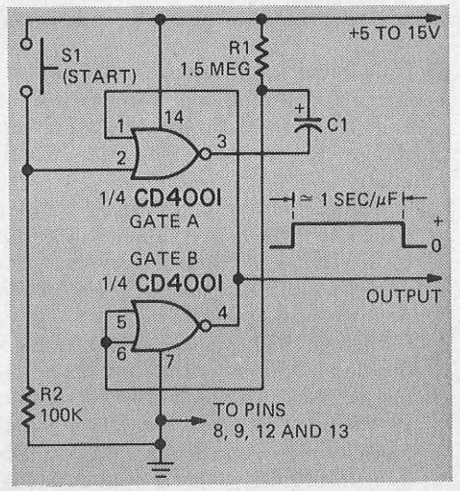
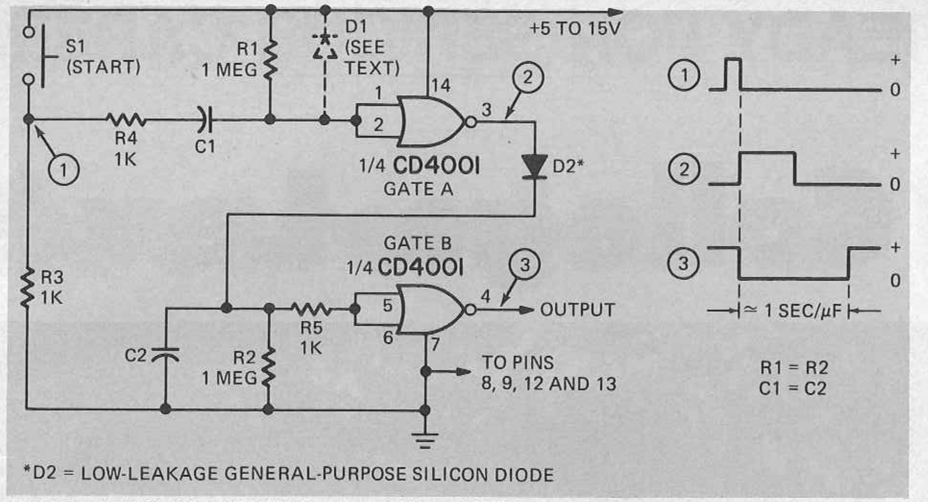
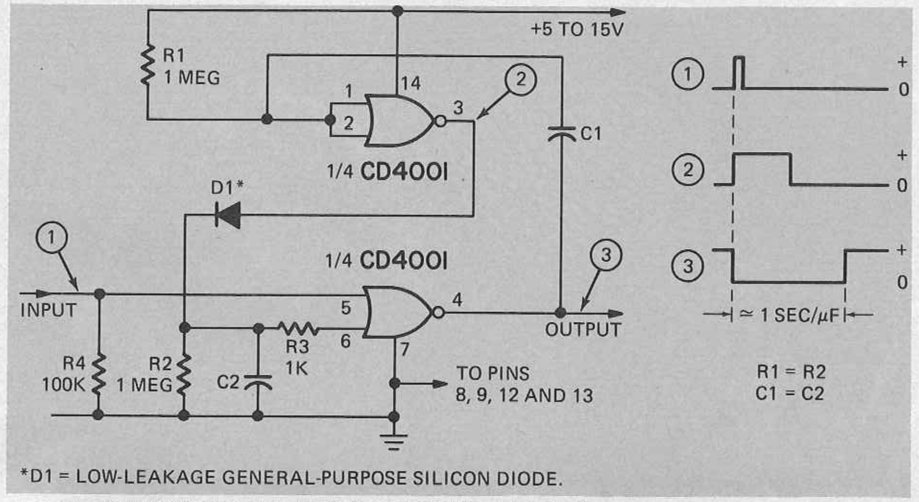


FIG. 22—"NOISELESS" PUSH BUTTON or manually-triggered monostable.



*D2 = LOW-LEAKAGE GENERAL-PURPOSE SILICON DIODE

FIG. 23—BASIC COMPENSATED monostable multivibrator.



*D1 = LOW-LEAKAGE GENERAL-PURPOSE SILICON DIODE.

FIG. 24—IMPROVED COMPENSATED monostable multivibrator.

The second point to note about the circuit is that its input must always be tied to ground in the absence of the positive trigger pulse: This requirement can be met by applying the input from a permanently connected dc source, or by strapping the input terminal to ground via a 1-megohm resistor, as shown dotted by R2 in the diagram.

The final point to note is that, since an exponential voltage is applied to the input of one of the gates during the operating cycle, the gate is driven into its linear region during each operating cycle. A measurable current thus flows in the circuit during the operating period. All COS/MOS monostable and astable multivibrator circuits in fact pass a measurable current when they are in their functional modes.

Figure 22 shows how the circuit in Fig. 21 can be used as a 'noiseless' push-button or manually-triggered monostable by simply using the push-button to apply the positive trigger pulse to the circuit.

It has already been pointed out that a snag with the basic monostable circuit of Fig. 21 is that its period depends on the transfer voltage of the individual CD4001, and is not dictated solely by the R and C values. Figure 23 shows the basic circuit of a compensated monostable multivibrator that does not suffer from this snag. The diagram also shows the basic waveforms of the circuit. Note that the circuit uses two sets of R-C time-constant components. Circuit operation is as follows:

When the circuit is in its quiescent state the S1 side of C1 is grounded via R3, but the R1 side is held positive: C1 is thus fully charged under this condition, and the input of gate A is high. The output of gate A is thus low, so C2 is fully discharged at this time, and the output of gate B is high.

Suppose now that START button S1 is briefly closed and then released. As S1 is closed, the S1 end of C1 is connected to the positive supply line, and C1 discharges rapidly via R4 and D1 (which is one of the input protection diodes built into the CD4001): This action has no effect on the circuit. When S1 is released, however, C1 is fully discharged, so as soon as S1 is released, C1 starts to recharge via R1, R3, and R4, thus pulling the input of gate A low and making the output of gate A go high: As the output of gate A goes high, it charges C2 rapidly via D2, and thus causes the output at gate B to go low.

As soon as S1 is released, C1 starts to charge up, and a rising exponential voltage is applied to the input of gate A. After a time determined by the R1 and C1 values, this voltage RISES to the transfer voltage of gate A, and at this point the output of gate A switches sharply into the low state and removes the charging voltage from C2 as D2 becomes reverse biased. C2 then starts to discharge via R2, and after a time determined by the R2 and C2 values, the C2 voltage FALLS to the transfer voltage of gate B, and at this point the output of gate B switches sharply into the high state. The operating sequence of the circuit is then complete. Note that R4 and R5 are used purely as safety resistors, and prevent heavy capacitor discharge currents from flowing into the IC gates if power is removed from the circuit during the operating sequence.

Now, this particular circuit uses two identical R-C time constant networks, and its final output period is equal to the sum of the two individual time constants. The important point to note, however, is that one of these time constants causes a circuit action when its exponential voltage RISES to the transfer voltage of gate A, and the other causes a circuit action when its voltage FALLS to the transfer voltage of gate B. Consequently, if both gates have identical transfer voltages, the transfer voltage values effectively cancel out, and have no effect on the actual period of the circuit.

For example, if both gates have transfer voltages of 30%, C1 will have to charge to 30% of the supply voltage to cause gate A to change state, and C2 will discharge by 70% of the supply voltage to cause gate B to change state, thus giving a total voltage change of 100%. If, on the other hand, both gates have transfer voltages of 40%, C1 will charge to 40% and C2 will discharge by 60% during the operating sequence, again giving a total voltage swing of 100%. The total period of the circuit is thus independent of the transfer voltage value of the IC, providing that both gates have identical transfer voltage values.

Now, although transfer voltage values can vary over wide limits between individual COS/MOS IC's, the individual transfer voltage values of a set of gates within a single CD4001 are always virtually identical, since the gates are all formed on the same semiconductor chip at the same time. Consequently, the total timing period of the Fig. 23 circuit is dictated purely by the values of R1-C1 and R2-C2, and is independent of variations in the parameters of individual CD4001 IC's.

The Fig. 23 circuit is shown as being manually triggered. The circuit can be modified for electronic triggering by simply eliminating S1 and applying the positive trigger pulse across R3. In either case, a practical disadvantage of the circuit in Fig. 23 is that the actual monostable action is initiated by the end, rather than the start, of the input trigger pulse. This snag can be overcome by modifying the circuit as shown in Fig. 24.

This circuit gives an output that is normally high (positive), but which goes low (to zero volts) for a preset period when a trigger pulse is applied. If required, the polarity of the output signal can be reversed, so that it is normally low but goes high for the duration of the output pulse, by simply wiring an inverter into the output of the circuit in Fig. 24, as shown in the positive-output compensated monostable circuit of Fig. 25.

Astable multivibrator circuits

The most widely used type of multivibrator circuit is the astable, or square-wave generator. Figure 26 shows how one half of a CD4001 COS/MOS IC can be used to make a basic 1-kHz astable multivibrator. Note that both gates of the circuit are connected as simple inverters, and that the circuit uses only a single set of R-C time constant components. The action of the circuit is as follows:

Suppose initially that a stage has been reached in the circuit operation where the output of gate B has just switched into the high state and the output of gate A has just switched into the low state, and that C1 is fully discharged at this moment.

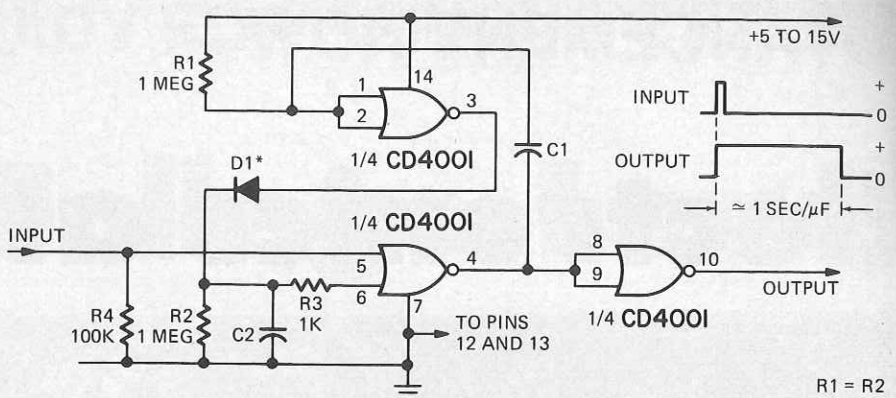
Since C1 is discharged at this time, the input of gate A is effectively shorted to the output of gate B, and is high. As soon as the above stage of operation is obtained, C1 starts to charge up via R1 and the low (effectively grounded) output of gate A (which is derived from the R1-C1 junction) starts to decay exponentially towards zero.

Eventually, after a delay determined by R1 and C1, the input voltage of gate A falls to the transfer voltage point of gate A and at this instant, the output of gate A switches into the high state and drives the output of gate B into the low state: As the output of gate B switches to the low state, it forces the positive end of C1 downwards, and thus forces the gate A input end of C1 to attempt to swing negative with respect to the zero volts line: As the input of gate A goes negative to the zero volts line, input protection diode D3 (see Fig. 7-b, September 1974 issue) conducts and removes the charge from C1.

Thus, at the end of this switching cycle, C1 is again fully discharged, the output of gate B and the input of gate A are low, and the output of gate A and the input of gate B are high.

As soon as this new stage of the operation is obtained, C1 starts to recharge in in the reverse direction via R1 and the low (grounded) output of gate B, and the voltage at the input of gate A (which is derived from the R1-C1 junction) starts to rise exponentially towards the positive voltage. Eventually, after another delay determined by R1 and C1, the input voltage of gate A rises to the transfer voltage of the gate and at this instant, the output of gate A switches into the low state and drives the output of gate B into the high state.

At this moment, C1 discharges rapidly via input protection diode D1 of gate A as the R1-C1 junction end of the capacitor attempts to go positive relative to the positive supply line, and the operating sequence is then complete. The switching sequence then repeats ad infinitum, and a series of approximately square waves are generated at the two outputs of the circuit: Outputs A and B are 180° out of phase.



*D1 = LOW-LEAKAGE GENERAL PURPOSE SILICON DIODE

R1 = R2
C1 = C2

FIG. 25—POSITIVE-OUTPUT compensated monostable multivibrator.

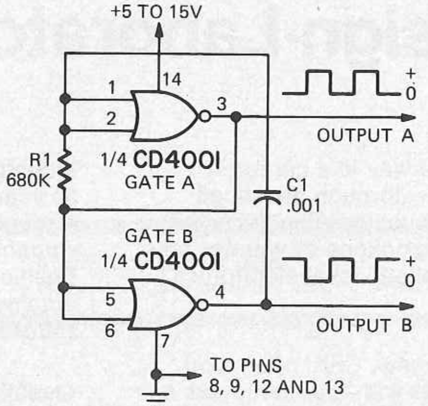


FIG. 26—BASIC 1-KHZ ASTABLE multivibrator or square-wave generator.

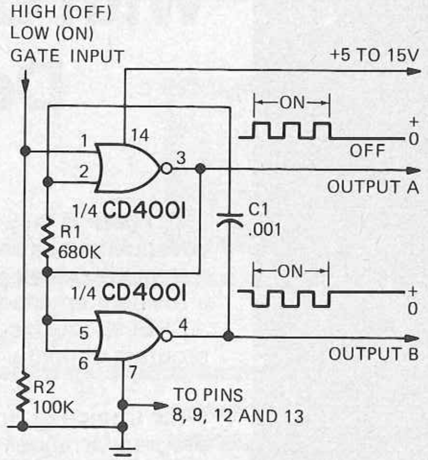


FIG. 28—GATED 1-KHZ ASTABLE multivibrator.

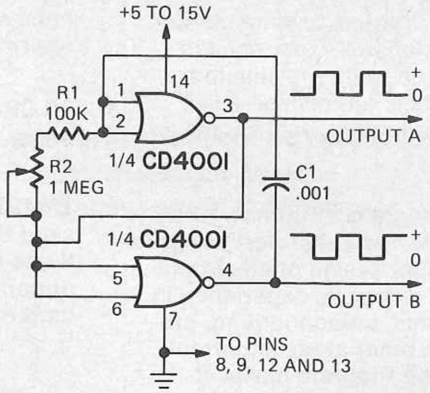


FIG. 27—VARIABLE FREQUENCY (600 Hz-6 kHz) astable multivibrator.

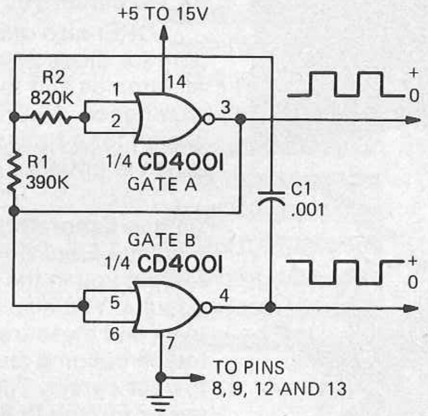


FIG. 29—COMPENSATED 1-KHZ astable multivibrator.

An outstanding feature of the basic astable multivibrator circuit of Fig. 26 is that it uses only two time constant components (R1 and C1), and the values of both of these components can be varied over wide ranges to give required operating frequencies. The value of R1 can be varied from a few thousand ohms to thousands of megohms, and C1 (which must be a non-polarized capacitor) can be varied from a few pF to several µF. The operating frequency is inversely proportional to the R1 and C1 values, and can be varied from less than one cycle per hour to several MHz.

The operating frequency of this circuit can be made variable, if required, by wiring a variable resistor in series with limiting resistor R1, as shown in the circuit of Fig. 27. With the component values shown, this circuit covers the approximate frequency range 600 Hz to 6 kHz.

If required, the basic astable multivibrator of Fig. 26 can be gated on or off via an external pulse signal by connecting gate A as a NOR gate and applying the gating signal to one of the NOR gate inputs, as shown in Fig. 28. The multivibrator is cut off when the gate input signal is high, and is operative when the gate input signal is low.

The basic astable multivibrator of Fig. 26 acts as a simple and very useful circuit, but suffers from several disadvantages. The first of these is that, since the

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new FTC ratings for audio amplifier power

are they any good?

There are some potential loopholes in the newly imposed FTC rules. Here's a look at how they work and where the problems may lie

by LEN FELDMAN
CONTRIBUTING HI-FI EDITOR

BY THE TIME YOU READ THIS, MANY manufacturers of home entertainment audio products will be busily printing new advertising literature, specification sheets and even the outside of packing cartons. No, the industry has not suddenly redesigned its entire product line—the amplifiers haven't changed that much. But they are changing the statements regarding their power output capability to bring them into line with a new trade regulation promulgated on May 3, 1974 by the Federal Trade Commission. The new rule becomes effective November 4, 1974 and the FTC will consider violations after that date to be "an unfair method of competition and an unfair or deceptive act or practice within the meaning of Section 5 (a) (1) of the Federal Trade Commission Act 15 U.S.C. S 45 (a) (1) to violate any applicable provision of this rule."

Reasons for the FTC action

Over the past few years, some segments of the audio industry have been engaged in a quasi-technical semantic race to devise power output statements for audio amplifiers which would yield higher and higher numbers of "watts of output" for their products. About the only thing these assorted specifications had in common was their use of the word "watts" as a measure of power. But what "kind" of watts were used? There were "continuous watts" —the amount of power that an amplifier would deliver on a continuous basis into a fixed, resistive load.

This measurement, the most conservative of all, became known as rms power, a term which in itself is semantically meaningless. The letters rms stand for "root-mean-square." Many ac voltmeters are calibrated to read 0.707 of peak sinusoidal ac voltage applied to their terminals. In the case of a *sine wave*, power developed across a load is defined by the Formula $(E_{rms})^2/R = P$, where E_{rms} is the root-mean-square voltage, R is the resistive component of the load impedance across which the output voltage is applied and P is the resulting power in watts. Power itself cannot be termed rms because musical waveforms are seldom, if ever sinusoidal and as an amplifier is driven into clipping or overload, even a pure sinusoidal waveform changes shape so that voltmeter readings no longer correspond to 0.707 of peak voltage values. Nevertheless, the term "rms power" persists and for our purposes can be considered identical to "continuous power"—the more appropriate term.

Another term "music power" (also known as "dynamic power, IHF Dynamic Power or IHF Music Power") has been used to describe amplifier power output at somewhat higher numerical values of wattage. The numbers are based upon the fact that for short periods of time, most amplifiers can deliver somewhat more power than they can on a continuous basis. Since musical waveforms contain relatively short bursts of higher energy, many experts felt that "music power" represented a more meaningful way to describe an amplifier's power output capability.

Unfortunately, "music power" quickly became corrupted and gave way to such meaningless terms as "peak power," "peak music power," instantaneous peak power (IPP) and even "instantaneous peak music power." Each of these successive manipulations of terms gave rise to higher and higher wattage figures. It was not uncommon to find products rated at 100 watts "IPP" which actually produced 5 watts or less of "continuous power." Small wonder that the FTC stepped in and tried to bring some order into these chaotic audio specs.

A summary of the FTC rule

To begin with, the new FTC regulation requires that all audio products that deliver more than a 2-watt output must specify, in boldest advertising type, the following with regard to power output:

1. "The minimum sine-wave continuous average power output, in watts, per channel —
    a. for **each** load impedance for which the equipment was designed
    b. measured with **all** channels driven
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COSMOS PROJECTS

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voltage swing of C1 is clamped to the limits of the power supply voltage by the input protection diodes of the COS/MOS gates, the operating frequency is influenced by variations in the supply voltage: Typically, a 40% variation in supply voltage causes a 5% variation in frequency. Another disadvantage is that the frequency of operation is influenced by the transition voltage values of the CD4001 gates and in practice, the actual frequency of operation may vary by 10% over the production spread of the CD-4001 when using identical R1 and C1 values.

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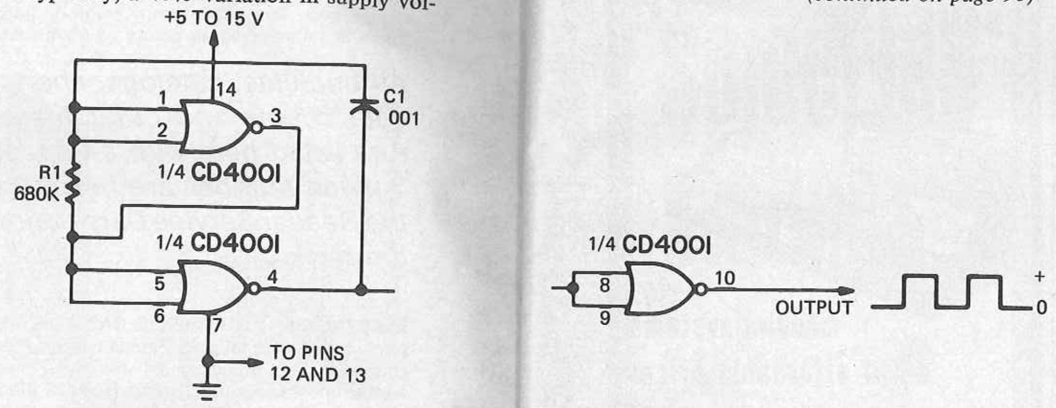
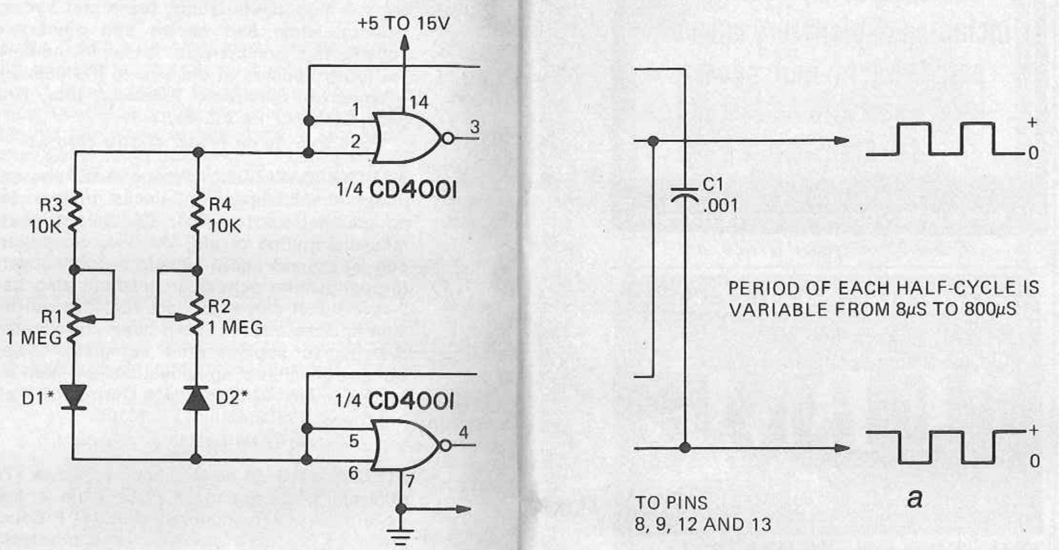
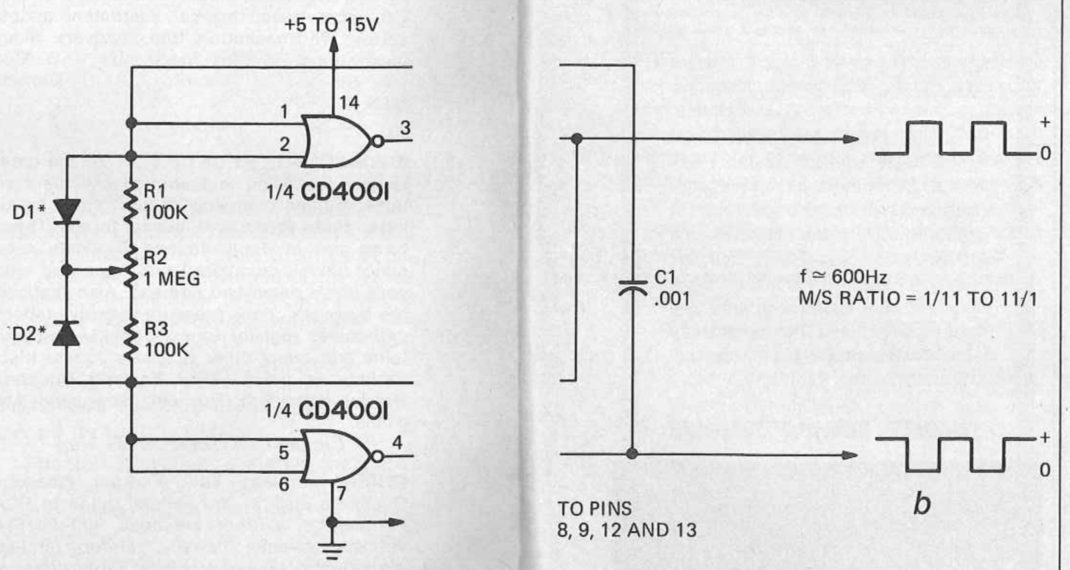


FIG. 30—BUFFERED-OUTPUT 1-KHZ astable multivibrator.



*D1 AND D2 = LOW-LEAKAGE GENERAL-PURPOSE SILICON DIODES



*D1 AND D2 = LOW-LEAKAGE GENERAL-PURPOSE SILICON DIODES

FIG. 31-a—VARIABLE MARK/SPACE RATIO astable multivibrator. b—ASTABLE MULTIVIBRATOR with independently variable on and off times.

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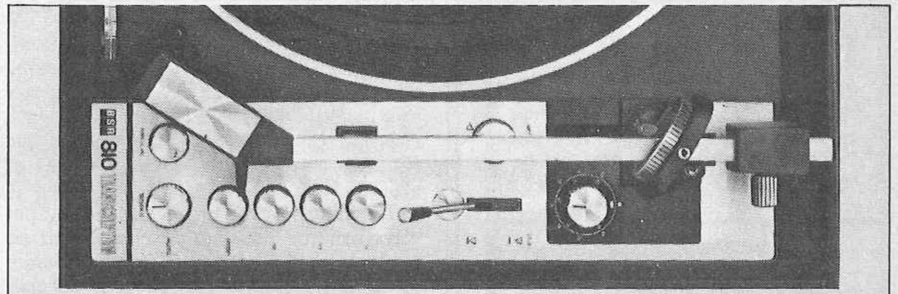

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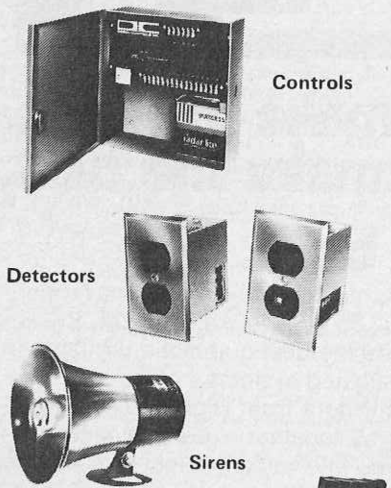

COSMOS PROJECTS

(continued on page 89)

Both of these disadavantages can be largely overcome by simply wiring a high value resistor in series with the input of gate A, as shown in Fig. 29, thus enabling the voltage swing of C1 to exceed the supply voltage. Limiting resistor R2 must have a value at least double that of timing resistor R1.

In practice, the operating frequency of this circuit is subject to a change of less than 5% over the production spread of transfer voltages, and to a frequency shift of less than 2% with a 40% change in supply voltage. Another advantage conferred by the use of R2 in the Fig. 29 circuit is that of excellent thermal stability: The operating frequency typically varies by only 1% over the temperature range –40°C to +85°C.

Minor disadvantages of both the Fig. 26 and Fig. 29 circuits are that the leading and trailing edges of the output waveforms sometimes contain a certain amount of sag and 'mush', and the operating frequency is influenced by variations in the output loading conditions. Both of these disadvantages can be overcome by interposing an inverting buffer stage between the output of the astable multivibrator and the input of the external loading circuit, as shown in Fig. 30.

A final disadvantage of the Fig. 26 circuit, and to a lesser degree of the Fig. 29 circuit, is that the symmetry or mark/space ratio of the output waveform depends on the transition voltage value of the individual CD4001 that is used. An IC with a transition voltage value of 35% gives a mark/space ratio of approximately 35/65, and an IC with a value of 60% gives a mark/space ratio of approximately 60/40. A true square wave (50/50) output is available only if the IC has a transition voltage value of exactly 50%.

The mark/space ratio of the output waveform of the astable circuit can be made variable by using steering diodes to select alternative charge and recharge resistance paths for the time-constant network, as shown in Figs. 31-a and 31-b.

In the Fig. 31-a circuit, the capacitor charges via D1 and the low half of the resistance chain in one half cycle, and via D2 and the top half of the resistance chain in the other half cycle. The mark/space ratio can be varied over the range 1/11 to 11/1 via R2, and the circuit operates at a frequency of roughly 600 Hz.

The Fig. 31-b circuit has independently variable ON and OFF times. In one half cycle, the capacitor charges via D1—R1 and R3, and in the other half cycle, it charges via D2—R2 and R4. The period of each half cycle is variable over the approximate range 8 μs to 800 μs using the component values shown.

In this part of the series we have looked at practical ways of using the CD4001 in monostable and astable multivibrator applications. In the coming part of the series we shall go on to look at sixteen ways of using the CD4001 in lamp flasher, time delay, oscillator, and alarm applications. **R-E**