RCA
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Application Note
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Astable and Monostable Oscillators Using RCA COS/MOS Digital Integrated Circuits

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COS/MOS integrated logic circuits are being widely used in digital and other applications because of their inherent advantages of high noise immunity, extremely low power dissipation, and tolerance to wide variations in power-supply voltages and operating-temperature ranges. In addition to these features, COS/MOS gates can provide cost and size reductions in multivibrator circuits because their high input impedance makes it possible to obtain large time constants without the use of large capacitors. This Note describes several techniques which may be used to compensate for the normal threshold variation of MOS devices in the design of stable multivibrator circuits for operation at frequencies up to 1 MHz. The circuits shown can be formed by use of COS/MOS Inverters or by use of COS/MOS NAND or NOR gates connected in an inverter configuration. NAND and NOR gates perform the inverter function when all of the gate inputs are tied together. This Note also describes various applications for COS/MOS multivibrator circuits, (i.e., voltage-controlled oscillators, voltage controlled pulse-width circuits, phased-locked voltage controlled oscillators, frequency multipliers, and modulator/demodulator (envelope detectors).

ASTABLE CIRCUITS

Fig. 1(a) shows an astable multivibrator circuit that uses two COS/MOS inverters, and Fig. 1(b) shows the related waveforms. This simple circuit requires only one resistor and one capacitor, and operates in the following manner. When the waveform 1 at the output of inverter B is in a high or "one" state, capacitor C_{tc} becomes charged positive. As a result, the input to inverter A is high and its output is low or "zero".

Resistor R_{tc} is returned to the output of inverter A to provide a path to ground for discharge of capacitor C_{tc}.

As long as the output of A is low, the output of inverter B is high. As capacitor C_{tc} discharges, however, the voltage generated [waveform 2 in Fig. 1(b)] approaches and passes through the transfer voltage point of inverter A. At the instant that this crossover occurs, the output of A becomes high; as a result, the output of B becomes low and the capacitor C_{tc} is charged negative (or low). The resistor R_{tc} connected to the output of A then provides a charge path to a supply voltage. Capacitor C_{tc} begins to charge to this voltage, and again the voltage approaches and passes through the transfer voltage point of inverter A. At that instant, the circuit again changes state (the output of A becomes low and that of B high) and the cycle repeats.

Because of the input-diode protection circuits included in the COS/MOS IC, shown in Fig. 2, the generated drive waveform

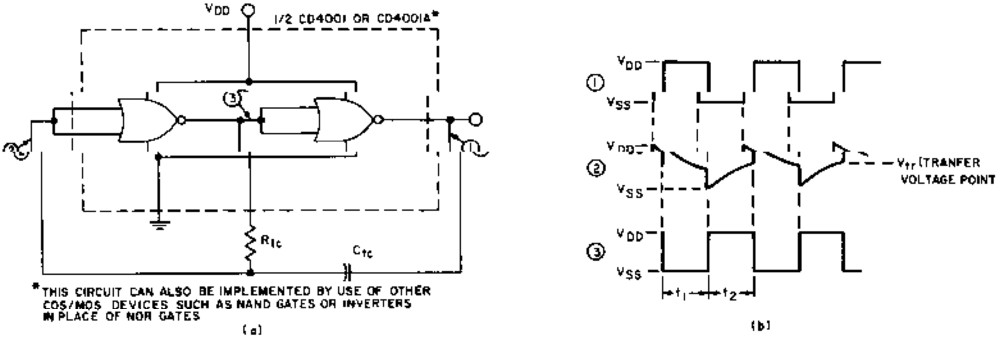

Fig. 1 - Astable multivibrator circuit that uses two COS/MOS inverters: (a) circuit diagram; (b) voltage waveforms.

is clamped between V_{DD} and V_{SS}. Consequently, the time to complete one cycle is approximately 1.4 times the RC time constant because one time constant is used to control the switching of both states of the multivibrator circuit. Switching occurs when the charge or discharge reaches the transfer voltage level, or when the time period reaches 70.7 per cent of its discharge. As shown in waveform 2 of Fig. 1(b), the transfer voltage point V_{tr} is the same for t_1 and t_2. The time period T for one cycle can be computed as follows:

$$T = t_1 + t_2$$

$$t_1 = -RC \ln \frac{(V_{DD} - V_{tr})}{V_{DD}}$$

$$t_2 = -RC \left[\ln \frac{V_{tr}}{V_{DD}} \right]$$

$$T = -RC \left[\ln \frac{(V_{DD} - V_{tr})}{V_{DD}} + \ln \frac{V_{tr}}{V_{DD}} \right] \qquad (1)$$

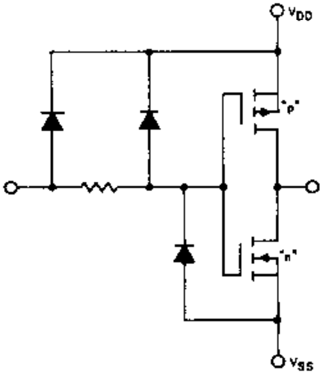

Fig. 2 - Diode protection circuit.

If the time constant is assumed to be 1 x 10^{-6} second and the transfer voltage V_{tr} is allowed to vary from 33 to 67 per cent of V_{DD}, the period T varies from 1.4 microseconds at a value of V_{tr} equal to half of V_{DD} to 1.5 microseconds at either the 33 or 67 per cent value of V_{DD}. Therefore, the maximum variation in the time period T is only 9 per cent with a ±33-per-cent variation in transfer voltage from unit to unit.

The oscillator can be made independent of supply-voltage variations by use of a resistor in series with the input lead to inverter A, as shown in Fig. 3(a). This resistor R_s should be at least twice as large as the resistor R_{tc} of the time constant to allow the voltage waveform generated at the junction of R_s, R_{tc}, and C_{tc} to rise to $V_{DD} + V_{tr}$. The waveform is still clamped at the input between V_{DD} and V_{SS}, as shown by the waveforms in Fig. 3(b). The use of resistor R_s provides several advantages in the circuit. First, because the RC time constant controls the frequency, the over-all maximum variations in the time period are reduced to less than 5 per cent with variations in transfer voltage, as determined by the following equation:

$$T = -RC \ln \left[\frac{V_{tr}}{(V_{DD} + V_{tr})} + \ln \frac{(V_{DD} - V_{tr})}{2V_{DD} - V_{tr}} \right] \qquad (2)$$

The resistor R_s also makes the frequency independent of supply-voltage variations. Table I shows data measured on typical units with and without the resistor.

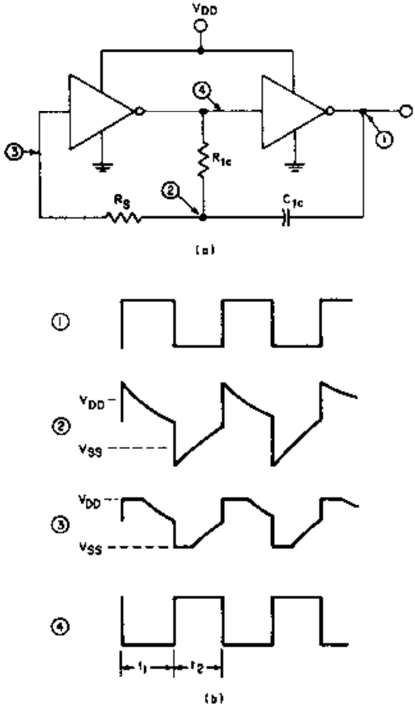

Fig. 3 - Addition of resistor in series with input to one COS/MOS inverter to make oscillator circuit independent of supply-voltage variations: (a) circuit diagram; (b) voltage waveforms.

Fig. 4 shows a typical transfer characteristic as a function of temperature. It can be seen that there is very little change in the characteristic from low to high temperature. Because the oscillator can also tolerate changes in the transfer characteristic without frequency instability, it requires no thermal compensation. The frequency at -55°C is the same as at +125°C. Table II shows data measured on typical units at temperature extremes.

Table I - Frequency variations of astable multivibrator with and without series resistor.

Unit No.	V_{tr} @ V_{DD} = 10V (V)	Period Without Rs - (ms)			Period With Rs - (ms)		
		V_{DD} = 6V	V_{DD} = 10V	V_{DD} = 14V	V_{DD} = 6V	V_{CC} = 10V	V_{CC} = 14V
2	4.77	0.735	0.66	0.645	1.04	1.00	1.02
6	5.78	0.715	0.665	0.63	1.06	1.04	1.03
11	5.58	0.695	0.66	0.625	1.03	1.02	1.03
13	5.00	0.70	0.665	0.64	1.03	1.01	1.02
20	5.56	0.70	0.665	0.64	1.04	1.03	1.03

R_{tc} = 0.4 megohm, C_{tc} = 1000pF, R_S = 0.8 megohm

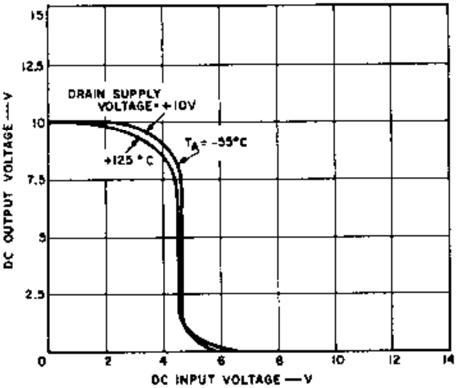

Fig. 4 - Transfer characteristic as a function of temperature.

The astable multivibrator shown in Fig. 1 can be gated on and off by use of a NOR or NAND gate as the first inverter, as shown in Fig. 5.

Table II - Frequency variations of astable multivibrator at temperature extremes.

	Period - (ms)					
	V_{DD} = 6V		V_{DD} = 10V		V_{DD} = 14V	
Unit No.	-55°C	+125°C	-55°C	+125°C	-55°C	+125°C
2	1.04	1.04	1.02	1.01	1.03	1.02
6	1.06	1.07	1.06	1.04	1.04	1.03
11	1.03	1.03	1.04	1.02	1.04	1.01
13	1.02	1.02	1.02	1.02	1.03	1.01
20	1.04	1.03	1.04	1.03	1.04	1.02

R_{tc} = 0.4 megohm, C_{tc} =1000pF, R_S = 0.8 megohm

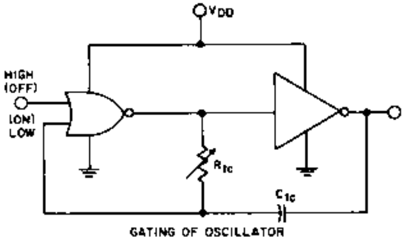

Fig. 5 - Astable multivibrator in which a NOR or NAND gate is used as the first inverter to permit gating of the multivibrator.

COMPENSATION FOR 50-PER-CENT DUTY CYCLES

The variation in transfer voltage described above affects the output-pulse duty cycle, as shown in Fig. 6. A true square-wave pulse is obtained only when the transfer voltage occurs at the 50-per-cent point. However, the duty cycle can be controlled if part of the resistance in the RC time constant is shunted out with a diode, as shown in Fig. 7. Because adjustment of this diode shunt to obtain a specific pulse duty factor causes the frequency of the circuit to vary, a frequency control R_3 is added to compensate for this variation. It may also be necessary, to reverse the diode to obtain the desired duty factor. The frequency of any of the circuits shown can be made variable by use of a potentiometer for resistor R_{tc}.

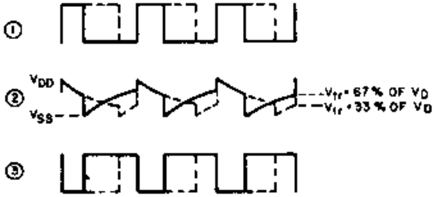

Fig. 6 - Waveforms showning effects of transfer voltage on multivibrator frequency.