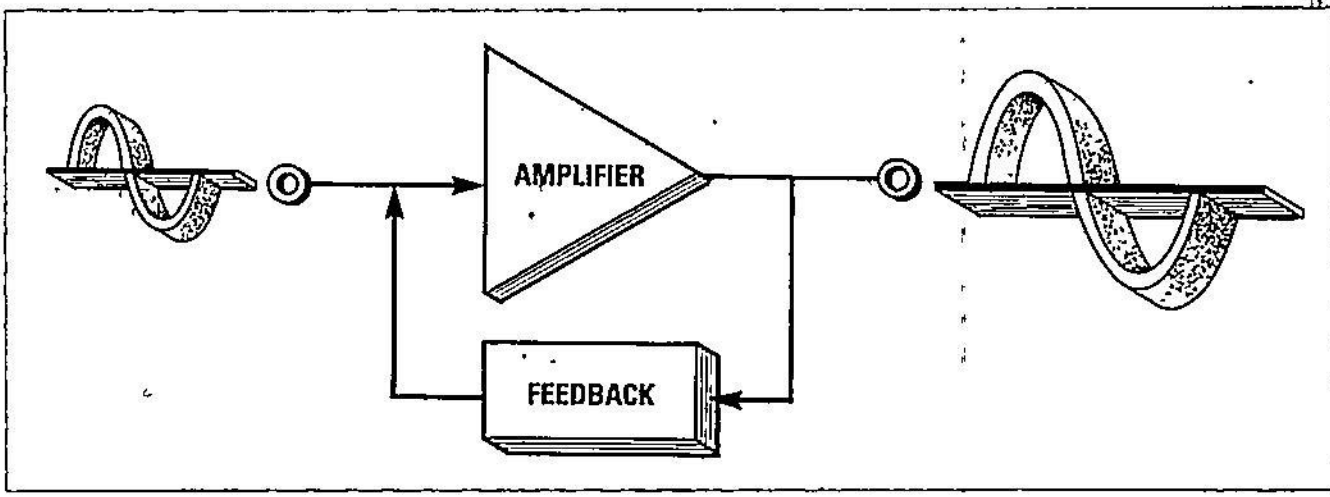
How to



Design OSCILLATOR Circuits

Digital clock circuits using TTL IC's.

Part 6 THIS TIME WE'LL DIScuss digital clocks We don't mean time-of-day clocks, but circuits that create pulse trains for synchronizing digital circuits Digital clocks usually produce either a squarewave or a trapezoidal wave In this article we'll discuss digital-clock circuits based on TTL IC's

TTL basics

The TTL logic family was probably the first really successful family of integrated digital devices Previous families (e g , RTL and DTL) never really attained the widespread popularity enjoyed by TTL devices One reason for TTL's popularity is that it uses standard input and output circuits, and standard logic levels.

A digital circuit is binary in nature; that is, it permits only two possible states Those states, 1 and 0, can be represented by the digits of the binary (base 2) number system Those two states are often called high and low (respectively)

Figure 1 shows the standard logic levels for TTL devices The high condition is attained when the input or output voltage is greater than +2 4, but less than +5 The low condition is represented by any voltage between 0 0 and 0 8. Voltages above +5 (the groan zone) and below ground (the zap zone) must be avoided In addition, an inappropriately connected capacitor or inductor can also feed too much (or incorrectly polarized) voltage to TTL devices.

The members of any logic family work together because inputs and outputs can be interconnected with only a conductor—no impedance-matching or other devices are necessary Figure 2-*a* shows a standard TTL output, and Fig 2-*b* shows a standard TTL input The TTL input acts as a 1 6-mA current source, and the TTL output acts as a 16-mA current sink

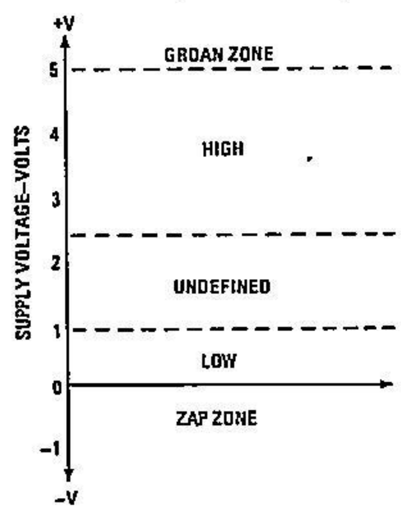


FIG. 1—VOLTAGE LEVELS OF A TTL IC determine logic state. Any voltage below 0.8 is a logical low; any voltage above 2.4 is a logical high. Signals in the groan and zap zones may destroy a TTL device.

To interface TTL devices, all we must do is make sure that current-drive requirements are met. Those requirements are simple to calculate because of standardization. A single 1.6-mA input is said to have a "fan-in" of 1. A single 16-mA output has a fan-out of 10. In other words, a standard TTL output can drive 10 standard (fan-in-of-1) devices

There are several sub-families of TTL devices. For example, low-power TTL devices are signified by an "L" in the part number (e g., 74L00) L-type devices have lower drive capacity than regular TTL There is also high-speed TTL, which contains an "H" in the part number (e.g., 74H00). There is also low-power Schottky That is probably the most commonly used type of TTL IC, it contains "LS" in the part number (e g , 74LS00).

The LS type of TTL device has Schottky diodes at its inputs, those diodes are somewhat sensitive to static electricity. Therefore, it is recommended that you handle LS-series TTL devices almost as gingerly as you would handle CMOS devices. The various sub-families have differing drive capacities, consult a data book for details

Using TTL

Figure 3 shows a circuit that converts

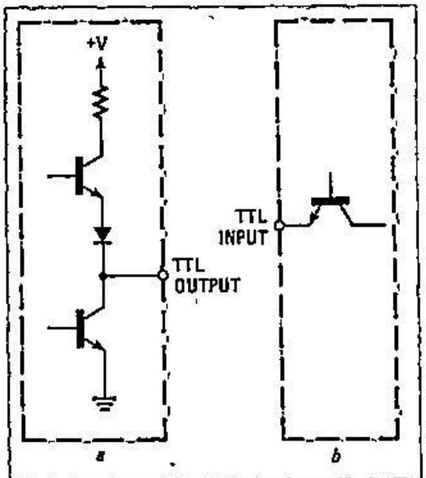


FIG 2—STANDARD INPUT (*a*) and output (*b*) circuits make it easy to interconnect various TTL devices

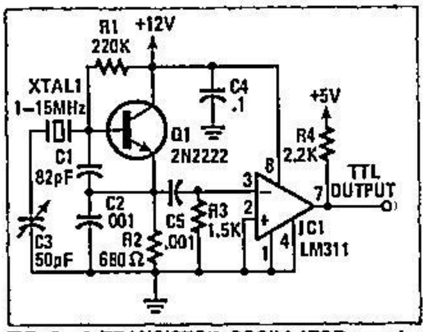


FIG 3—A TRANSISTOR OSCILLATOR may be made TTL-compatible by following the output with a comparator.

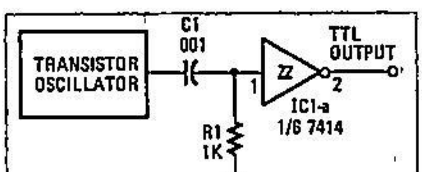


FIG. 4—A SCHMITT TRIGGER may also be used to make a transistor oscillator TTL-compatible

the output of a transistor-based Colpitts oscillator circuit to TTL levels As we saw in Part 5, which appeared in the November issue, the feedback level in a Colpitts oscillator is set by the capacitive voltage divider composed of C1 and C2 The oscillator's frequency is set by XTAL1, a piezoelectric crystal Variable capacitor C3 allows fine control of frequency

The output stage is an LM311 comparator. A comparator is basically a differential amplifier with too much gain In any differential amplifier, the output voltage is a function of the difference between the two input voltages When the input voltages are equal, the difference is zero, so the output voltage will be zero But when those voltages differ by even a few millivolts, the output voltage will be non-zero The gain of a typical comparator is 10,000 to 100,000, so the output will saturate any time that the differential input voltage is non-zero.

In Fig 3, the non-inverting input is grounded, so it sees a zero potential Hence, whenever the signal applied to the inverting input (pin 3) exceeds zero volts, the output will go low

The LM311 has what is called an "open-collector" output stage That means that it requires a pull-up resistor (R4) in order to supply current The 2 2K resistor shown can supply only about two mA of current at five volts, so the LM311's output is not truly TTL-compatible

Another way to accomplish the same trick is to use a TTL IC called a Schmitt trigger The operation of the Schmitt trigger follows this simple rule The output will snap high when a positive-going input signal crosses a certain threshold (1 7 volts), and it will snap low when the input signal crosses a lower threshold (0 9 volts) in a negative-going direction If the transistor oscillator shown in Fig. 3 is used to drive a Schmitt trigger, as shown in Fig 4, the sinewave output of the oscillator will produce a train of squarewaves at the output of the Schmitt trigger.

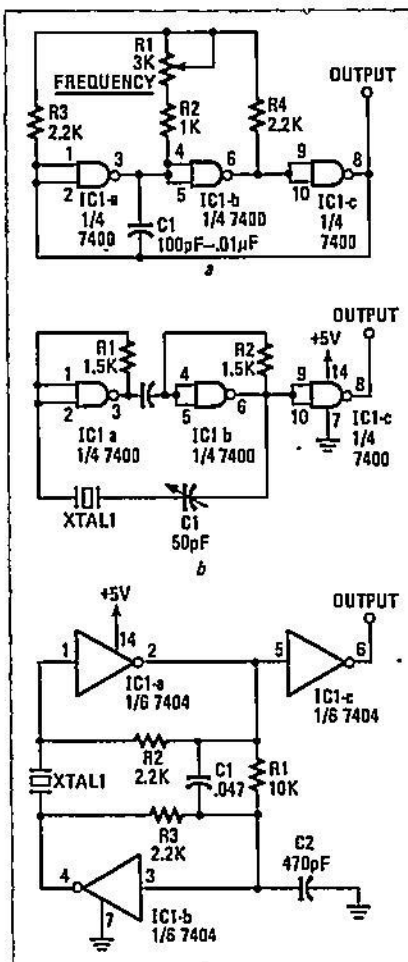


FIG 5—AN RC OSCILLATOR (*a*) can be built with three gates and several discrete components For better stability and accuracy a crystal oscillator may be used. Two popular configurations are shown in (*b*) and (*c*).

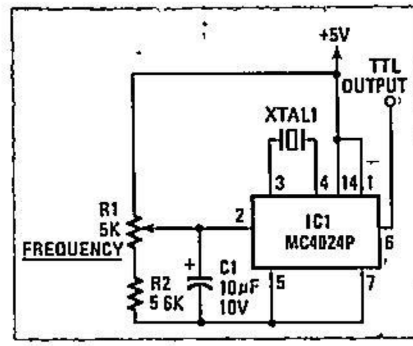


FIG. 6—A TTL-COMPATIBLE VCO requires just a crystal and a few discrete components to be a very stable oscillator.

Pure TTL clocks

Several TTL oscillators are shown in Figure 5 The circuits shown in Fig 5-*a* and Fig 5-*b* use NAND gates configured as inverters, the circuit in Fig 5-*c* uses three standard inverters The frequency at which the circuit in Fig 5-*a* oscillates is determined by capacitor C1 and resistors R1 and R2 Potentiometer R1 allows you to vary the operating frequency over a small range If only a single fixed frequency is needed for your application, replace R1 and R2 with a single fixed resistor

One disadvantage of any RC oscillator is that its operating frequency is neither stable nor accurate The effects of both problems can be reduced by using a piezoelectric crystal, as in Fig 5-*b* and Fig. 5-*c* Two of the NAND gates are used for the oscillator (IC1-a and IC1-b); the third functions as a buffer stage Operating frequency is set by crystal XTAL1, and may be varied with capacitor C1

The circuit shown in Fig 5-*c* is similar to the one shown in Fig 5-*b*, and is based on TTL inverters Again, one stage (IC1-c) is used as an output buffer, and the oscillating stages are self-biased

Special TTL oscillators

There are several all-in-one TTL oscillators on the market, Fig. 6 shows the diagram of a circuit based on the MC4024P dual voltage-controlled oscillator Only one oscillator is used in that circuit By the way, don't confuse the MC4024P with the 4000-series CMOS device called the 4024

The center frequency of oscillation can be controlled in two ways: with a capacitor or with a crystal. For non-critical applications, a capacitor is used, it will have a value of approximately 300/*f* (Hz) picofarads Potentiometer R1 gives you some control over the circuit's frequency

TTL clocks are easy to build and to operate, especially in applications where a great deal of frequency stability is unnecessary In the next and final installment of this series we will examine clock circuits made from CMOS IC's **R-E**