THE FUNDAMENTALS & FLEXIBILITY OF INTEGRATED CIRCUITS

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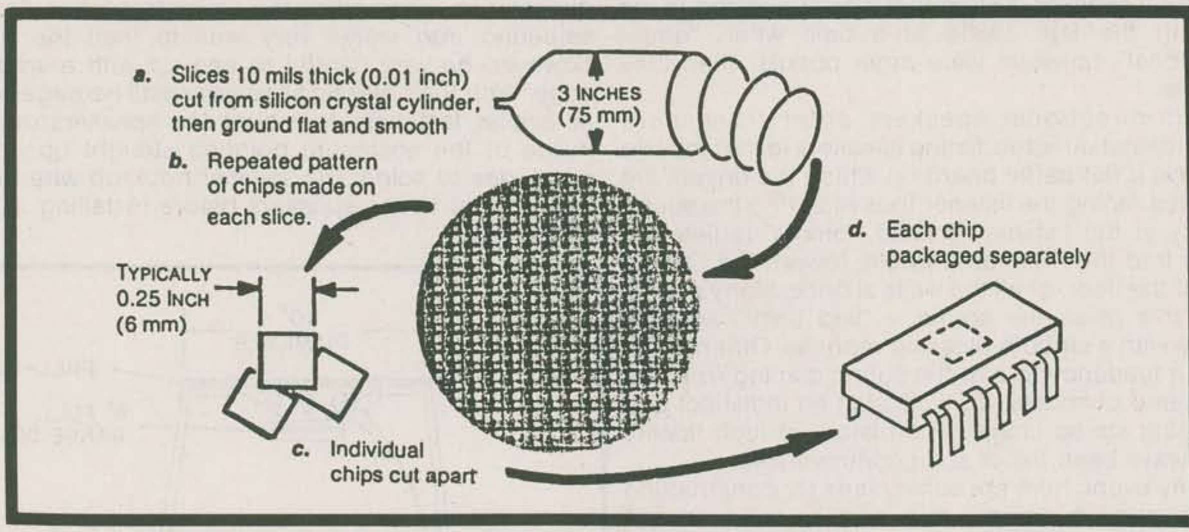
Integrated Circuits, The Brains of Today's Electronics



Four major steps in the creation of an Integrated Circuit chip. In (a) the silicon, made of carefully- controlled impurities (using chemical dopants) is grown as a cylinder which is typically about three inches in diameter. The cylinder is then sliced into thin slices (about 10 mils). This material is etched photographically in (b), into microscopic pattern(s) Typical slice has between 150 and 200 identical chips. These chips are then separated into individual chips. about a quarter of an inch square (c). After cutting apart each chip is wired and sealed into its own flat plastic IC package (d) along with the tiny wires which connect it to the two rows of terminals on the sides. (Courtesy of Radio Shack)

What is an integrated circuit? It is not just a bunch of transistors tucked inside a metal or plastic case. It is a complete "circuit", consisting of both active and passive elements connected in a unique configuration, housed in a container about the size of a transistor or postage stamp. The "active" elements are transistors and diodes. The "passive" components are resistor and capacitors. The elements in an IC are not discrete components wired together in a miniature circuit. Rather the IC is a complete circuit, formed on a silicon chip no larger than the head of a pin. The IC circuit "road map" can be seen only under very high magnification.

ICs are fabricated on a silicon disk approximately one inch in diameter and about the thickness of a piece of paper. The disk is altered in a series of individual steps. The top of the disk is first oxidized, then covered with photosensitive lacquer, called a "resist." Circuit patterns are etched into the oxide by a microphotolithographic process. After heating, minute quantities of "impurities" or dopants, such as boron or arsenic, are diffused into the silicon to form the "P" (electron deficient) and "N" (electron surplus) islands on the disk. The process is repeated many times until all the circuit elements, (transistors, diodes resistors and capacitors), are created on the disk. The various elements are connected by depositing vaporized aluminum in the desired pattern to form the proper circuitry. The completed disk may have as many as 200 ICs on it. These are then diced, separated, tested, and mounted on ceramic or metal bases. Then aluminum wires, about one-third the thickness of a human hair, are bonded between the IC contacts and the pinout connections. The package is then sealed.

ICs come in several different case styles. Some are packaged in small round metal cases with the leads arranged in a circular pattern on the bottom of the case. This is the familiar TO-5 case. Other ICs come in another very common package known as a DIP (Dual In-line Package). The IC leads are arranged in two (dual) parallel sections along the sides (in-line) of the package. ICs are available in DIP packages with 6, 8, 14, 16, 24, 32 and 40 pinouts or leads.

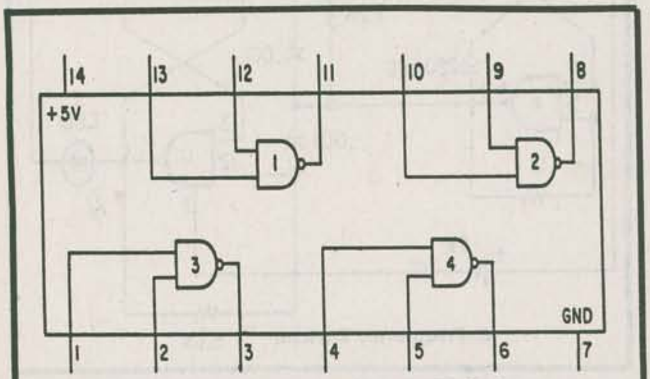


Figure 1. Quad 2 input NAND Gate

The concept of integrated circuits was an outgrowth of printed-circuit techniques. It was only natural, at the start of IC technology, to attempt to develope ICs in the image of conventional transistor circuits, and so early IC circuit design closely resembled transistor circuits using discrete components. However, as the body of knowledge and experience grew, IC circuits took on a character all their own. Anyone knowledgeable in conventional transistor circuitry, upon seeing an IC circuit arrangement for the first time, might be rather startled and find it hard to relate the circuit design to the specific function.

The reason IC circuitry is uniquely different from conventional circuitry is closely related to the methods and economics of the fabrication process and to the size of the chip. In conventional circuit design employing discrete components, the "active" elements (transistors and diodes) are more costly than resistors and capacitors. In IC technology, transistors and diodes are less costly than resistor and capacitors. The reason is that transistors and diodes take up very little space on the chip, whereas, resistors and capacitors require a relatively large amount of room. For this reason, IC designers make extensive use of "active" elements and use the "passive elements" sparingly.

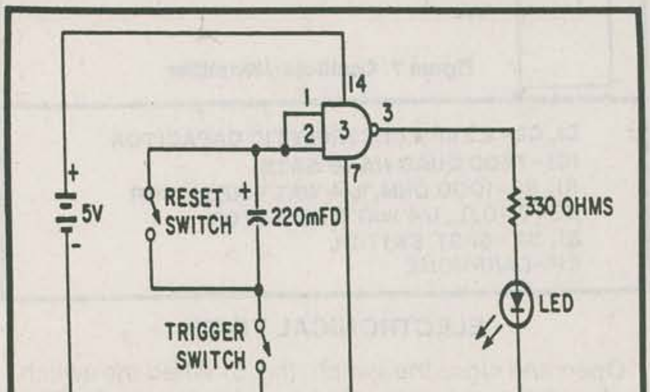


Figure 2. Positive Pulse Generator

An important consideration in the creation of IC chips is flexibility. Chips are designed to be used in more than one circuit configuration. This interchangeability is made possible by rearranging various discrete external components. For example, the same chip with different external circuit arrangements may be used as a positive pulse generator, as a negative pulse generator, as a continuity tester, as an electronic timer, as a frequency divider, or as an oscillator/amplifier circuit. Chip Flexibility is made possible by the fact that circuit leads on the body of the IC make it possible to break into the circuit arrangement at critical points within the IC configuration.

To prove the statement that ICs are flexible, let's use one chip, and by rearranging the various external components, build the circuits listed above. The integrated circuit chip used in these demonstration projects is a 14-pin DIP. It is an SN7400 quad 2 input NAND gate (fig.1). The Sn7400 can be purchased at Radio Shack for a very modest price. This chip is the basic building block for the entire TTL (transistor-transistor logic) family. It is very easy to use and has

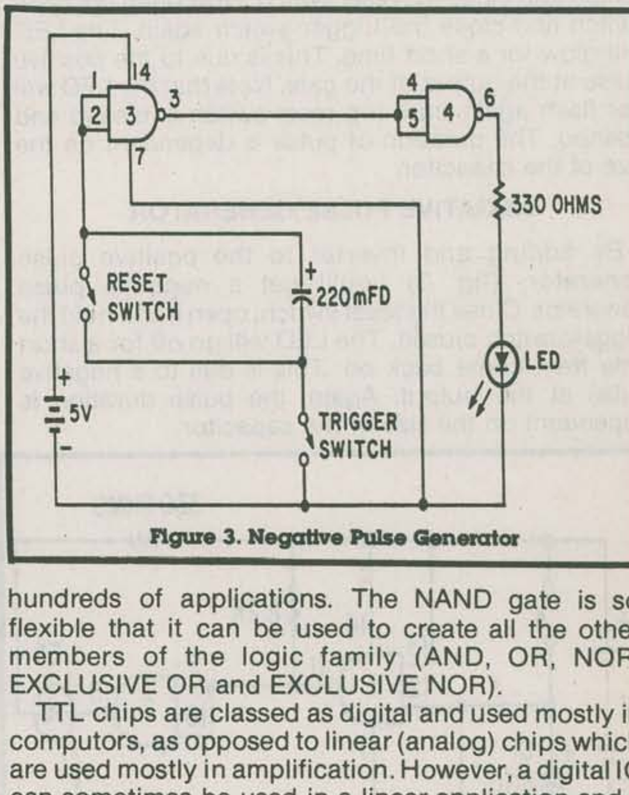


Figure 3. Negative Pulse Generator

hundreds of applications. The NAND gate is so flexible that it can be used to create all the other members of the logic family (AND, OR, NOR, EXCLUSIVE OR and EXCLUSIVE NOR).

TTL chips are classed as digital and used mostly in computors, as opposed to linear (analog) chips which are used mostly in amplification. However, a digital IC can sometimes be used in a linear application and a linear IC can sometimes be used in a digital application. This will be seen in some of the projects where a NAND gate is used as an amplifier.

Before beginning these demonstration projects, keep in mind that the operating voltage for the SN7400 is 5 volts. If you have a 5 volt regulated power supply, fine, but three 1.5 volt AA batteries connected in series will work just as well. If you use batteries disconnect them when you are finished so their power will not be drained. I also recommend using a bread-board from Radio Shack. That way when you are done with one project you can just unplug the discrete external circuitry from the board and start on the next project.

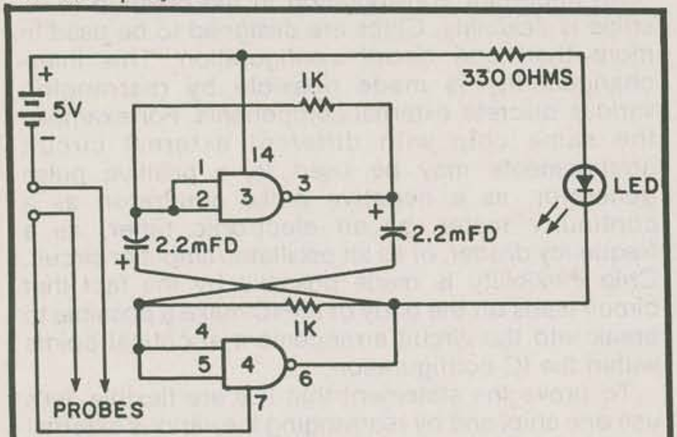


Figure 4. Continuity Tester

POSITIVE PULSE GENERATOR

This positive pulse generator (fig. 2) will generate a positive pulse when the trigger switch is held closed. To get another pulse, you have to release the trigger switch and close the reset switch. Now open the reset switch and close the trigger switch again. The LED will glow for a short time. This is due to the positive pulse at the output of the gate. Note that the LED will not flash again until the reset switch is closed and opened. The duration of pulse is dependent on the size of the capacitor.

NEGATIVE PULSE GENERATOR

By adding and inverter to the positive pulse generator, (fig. 3) you'll get a negative pulse generator. Close the reset switch, open it and hold the trigger switch closed. The LED will go off for a short time then come back on. This is due to a negative pulse at the output. Again, the pulse duration is dependent on the size of the capacitor.

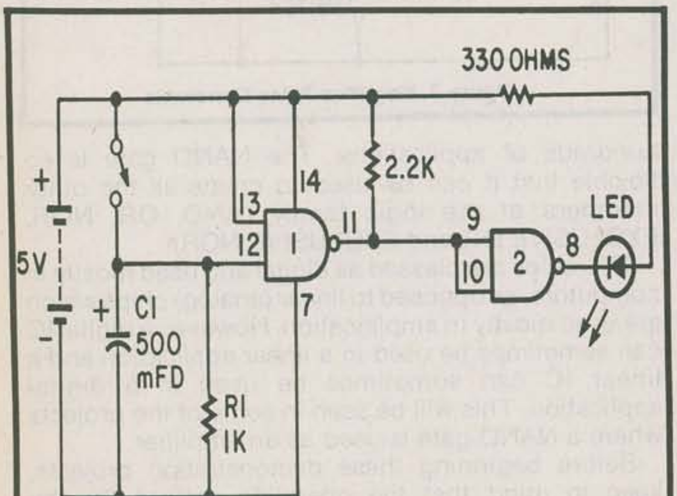
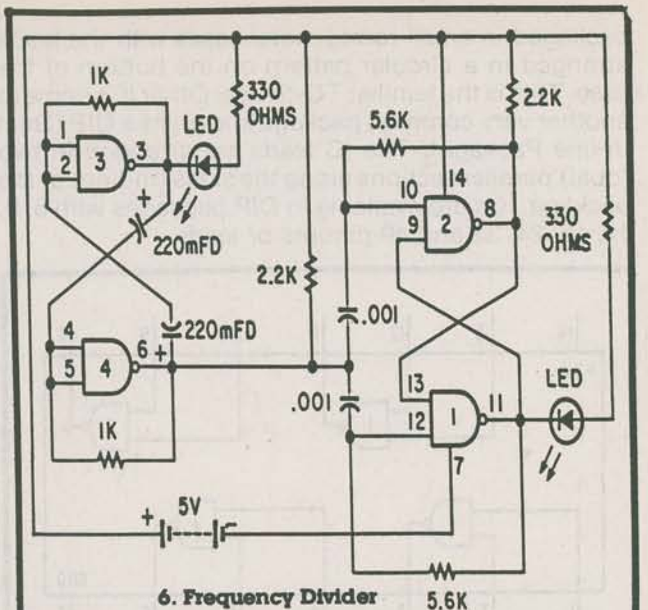


Figure 5. Electronic Timer Figure

CONTINUITY TESTER

The continuity tester (fig. 4) is a device to check for open circuits in electrical equipment. The LED will



6. Frequency Divider

flash only if the circuit being tested is unbroken. The LED will emit no light if the circuit being tested is open or broken.

CAUTION: BE SURE THAT THE DEVICE BEING TESTED IS NOT CONNECTED TO ANY ELECTRICAL SOURCE.

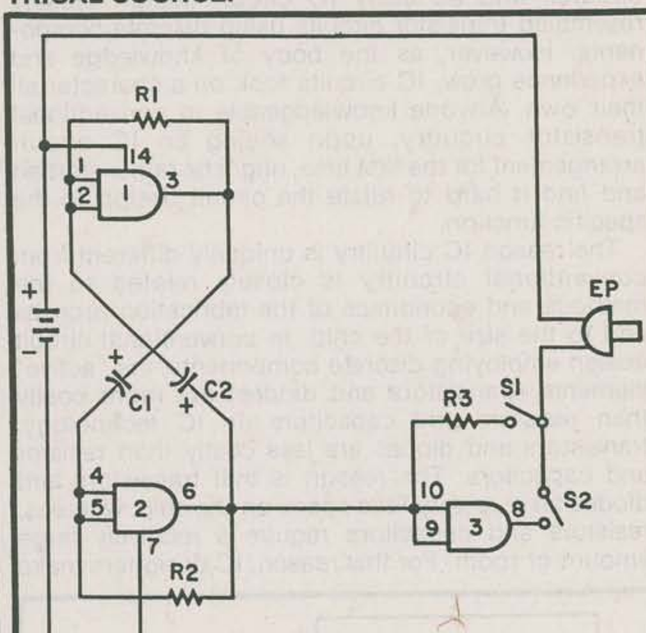


Figure 7. Oscillator/Amplifier

C1, C2 - 2.2 uF ELECTROLYTIC CAPACITOR
IC1 - 7400 QUAD NAND GATE
R1, R2 - 1000 OHM, 1/4 WATT RESISTOR
R3 - 300Ω, 1/4 WATT RESISTOR
S1, S2 - SPST SWITCH
EP - EARPHONE

ELECTRONICAL TIMER

Open and close the switch. (fig. 5) When the switch is closed the capacitor is charged very rapidly. The

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input of the first NAND gate goes high and the output of this gate and the input of the following gate goes low. The output of the second NAND gate goes high and the LED goes out. When the switch is opened the capacitor discharges through the first gate and R1. After the voltage on pin 12 of the first gate is low enough the output of the first gate goes high and the output of the second gate goes low and the LED comes back on. Try different sized capacitors for C1 and different sized resistors for R1 and see how long the LED stays off.

FREQUENCY DIVIDER

The Frequency divider (fig. 6) is often used in digital logic circuits. For example, in digital clocks, frequency counters, digital VOMs and many others. This frequency divider is a divide-by-two circuit. Follow the schematic carefully. If everything is connected correctly, the LEDs should blink on and off. Note that one LED will blink twice as fast as the other LED.

OSCILLATOR/AMPLIFIER

This is a very low frequency oscillator. (fig. 7) The LED is connected in series with a 330 ohm resistor between the output of gate number 2 and pin 14. Gate number 2 is used as a buffer. A buffer is a circuit that helps to isolate one stage from another. In this circuit, gate number 2 not only "buffers" the output of gate number 4 from its load (LED), it also increases the signal strength, so it also acts as an amplifier.

Please keep in mind that the SN7400 has a lot more uses than those shown in these demonstration projects. Don't be afraid to experiment with other circuit arrangements. Just remember not to exceed 5 volts VCC. And above all, enjoy yourself. ■