BASIC ELECTRONICS GUIDE

REV. 1

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SECTION I

Digital Electronics

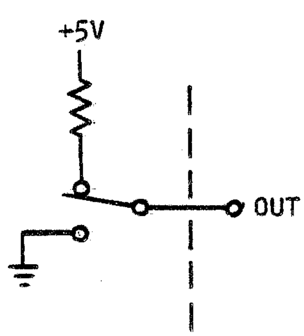
SECTION I - DIGITAL ELECTRONICS

By far, the majority of computer electronic circuitry can be categorized into that branch of electronics known as digital electronics or logic. Digital electronics is the science of switching circuitry, for just as switches can be either on or off, digital signals are confined to one of two possible conditions or states.

LOGIC LEVELS

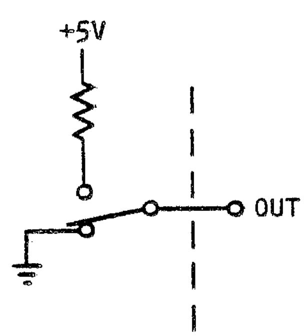
In the digital circuitry used within Dataproducts Line Printers, a signal will be recognized to be in an "on", "high", or "one" state if it measures between +2 and +5.5 volts (see Fig. 1). A signal is in the "off," "low," or "zero" state if it measures between ground and +0.8 volts (see Fig. 2). Some devices (generally outputting to shared bus lines) can operate in a third condition, a "tri-state", in which device outputs are driven through a high device impedance effectively removing them from the circuit (see Fig. 3).

FIG. 1



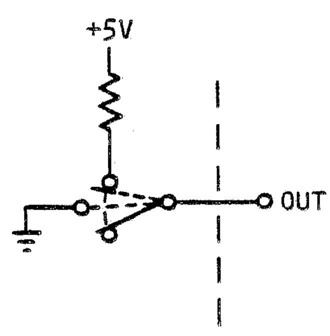
HIGH
'1'

Fig. 2



LOW
'0'

FIG. 3



TRI-STATE

Number Systems

If you were building a machine which was to keep track of numbers by lights, one method you might employ would be to have each number represented by an individual light. So you might use a light for number 1, number 2, number 3, and so on up to the last number that you wanted to designate (see Fig. 4). Let's say, however, that you wanted to use the least number of lights possible to represent the numbers. You would still need a light for number 1 and number 2, but why not activate lights 1 and 2 when you wanted to represent a count of 3. You would need a light for 4 but 5 could be represented by lights 4 and 1, 6 could be represented by lights 4 and 2, and 7 could be represented by lights 4 and 2 and 1. (See Fig. 5)

Fig. 4

Fig. 5

Like the on and off condition of lights, computer electronic signals have only two distinguishable states. To count, computers employ the binary system. The difference between the binary system and the decimal system (our every day system of counting) is that while each column in a decimal number can employ ten uniquely distinguishable numercial characters (0,1,2,3,4,5,6,7,8,9) there are only two numerical characters (0,1) in the binary system. The least significant place or column in a computer binary number is the one's column, the next the two's column, the next the four's column, the next the

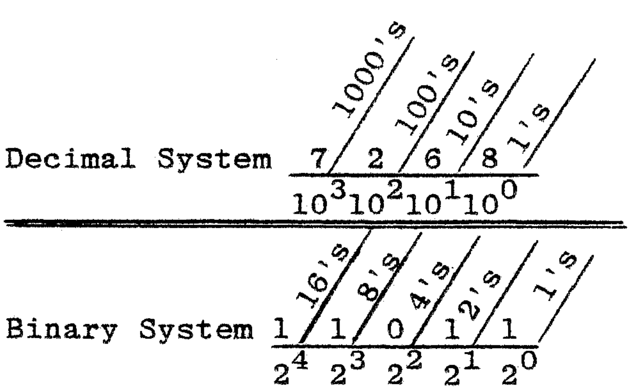


Fig. 6

eight's column, 16, 32, 64, and so on doubling in value with each additional column (see Fig. 6).Though more cumbersome, given enough room, the binary system is equally capable of representing numbers. To aid in communicating computer number values, binary numbers are often grouped together to form octal or hexadecimal numbers. Binary numbers grouped in "three's" form octal numbers. The octal system is composed of eight numerical characters (0,1,2,3 4,5,6,7). Binary 001/000/101 is 105 in the octal system (written 105_8). Each digit in an octal number represents a set of three binary numbers. Binary numbers grouped in sets of four form hexadecimal numbers. The hexadecimal system consist of sixteen numerical characters (0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F). Binary 0011/1010/0111 is 3A7 in the hexadecimal system (written $3A7_{16}$). Each digit in a hexadecimal number represents four binary numbers. Fig. 7 compares various counting systems.

BINARY	OCTAL	DECIMAL	HEXADECIMAL
0	0	0	0
1	1	1	1
10	2	2	2
11	3	3	3
100	4	4	4
101	5	5	5
110	6	6	6
111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A
1011	13	11	B
1100	14	12	C
1101	15	13	D
1110	16	14	E
1111	17	15	F
10000	20	16	10

NUMBER SYSTEMS

Fig. 7

Number System Conversion

To convert a binary number to an octal or hexadecimal number, group the individual digits into groups of three or four respectively and convert each set's value into its octal or hexadecimal equivalent.

EXAMPLE: 1101111101_2 = 001/101/111/101 = 1575_8

11011001000_2 = 0110/1100/1000 = $6C8_{16}$

To convert octal or hexadecimal numbers to binary numbers represent each digit in the number with three (for octal) or four (for hexadecimal) binary numbers of the same value.

EXAMPLE: 727_8 = 111/010/111 = 111010111_2

$7B48_{16}$ = 0111/1011/0100/1000 = 111101101001000_2

To convert a binary number to decimal number, multiply each digit in the binary number by the numerical value of its position and add the results together.

EXAMPLE:

$$10101_2 = (1X16)+(0X8)+(1X4)+(0X2)+(1X1)$$
$$= 16+4+1 = 21_{10}$$

To convert a decimal to a binary number, find the greatest exponential function of two that is less then the decimal number and add lesser exponential functions of two until the sum equals the decimal number. Write a one in each of the binary columns that represent each exponential function of two used to arrive at the decimal number.

EXAMPLE: Convert 44_{10} to Binary.
The greatest exponential function of 2 that is less then 44 is $32(2^5)$. The 12 left over is equal to $8(2^3)+4(2^2)$.

$$\frac{1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 0}{2^5 \; 2^4 \; 2^3 \; 2^2 \; 2^1 \; 2^0} \quad \text{so } 44_{10} = 101100_2$$

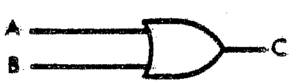
To convert between hexadecimal, octal, and decimal, convert first to binary and then to the required number system.

LOGIC DIAGRAMS

Any machine which is designed to respond in a different and specific manner to each of a number of different input conditions, must incorporate a means of defining which response is appropriate to which input condition. A Logic diagram (taking the place of the electronic schematic) charts the conditions which activate different printer responses. Signals which activate a printer response when they are in a low level are marked with an asterisk while "high-level" activating signals lack the asterisk. Unlike an analog circuit, the symbols used to represent the components of a digital circuit describe the logical function of the device rather than the electronic characteristics or composition of that device.

GATES

A logic "gate" provides a method of conditionalizing a digital signal by outputting a specific logic level in response to a given combination of inputs. The 2-INPUT "OR" gate, for example, (see Fig. 8), joins two signal lines at its inputs. The output of an "OR" gate will go to a high state (approximately +5 volts) if any or all of its inputs are in the high state. Thus, if input A OR input B are high, output C will be high. But if both input A and input B are low, then output C will be low (approximately 0 volts). The table to the right of the symbol for the OR gate is called a truth table. It shows all of the possible input combinations and what state the output will be in when the gate is inputted with those combinations.



A INPUT	B INPUT	C OUTPUT
LOW	LOW	LOW
LOW	HIGH	HIGH
HIGH	LOW	HIGH
HIGH	HIGH	HIGH

THE "OR" GATE

Fig. 8

GATES Continued

Circuit designers attach a small circle to the end of a gate to "invert" its function. A small circle attached to the end of the "OR" gate, for example, creates the "NOT-OR" or "NOR" gate (see Fig. 9). The "NOR" gate output will be low (rather than high like the OR gate) if any or all of its inputs are high.

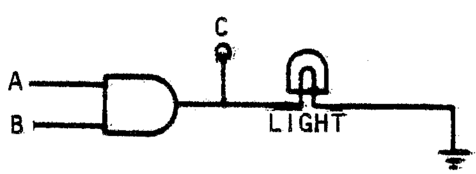
A	B	C
INPUT	INPUT	OUTPUT
LOW	LOW	HIGH
LOW	HIGH	LOW
HIGH	LOW	LOW
HIGH	HIGH	LOW

THE "NOR" GATE

Fig. 9

Many logical functions can be represented in more than one way. The 2-input "AND" gate, for example, is normally defined as a device allowing a high at its output when both its input "A" and its input "B" are high. The "AND" gate, however, could be as validly defined as a gate which allowed a low at its output when its input A or its input B were low. Fig. 10 depicts the 2 different ways that an "AND" gate can be diagrammed; 10A emphasizing that both inputs high will give a high out and 10B emphasizing that if either input A or B is low, the "AND" gate output will be low. Dataproducts manuals use the gate symbology which most simply conveys the total circuit function allowing the signal to be traced with the greatest ease. Fig. 11 diagrams basic gating circuitry.

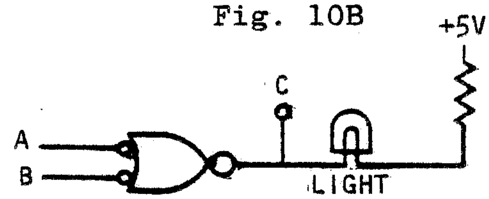
Fig. 10A



THE LIGHT GOES ON IF A AND B ARE HIGH

A	B	C out	LIGHT
LOW	LOW	LOW	OFF
LOW	HIGH	LOW	OFF
HIGH	LOW	LOW	OFF
HIGH	HIGH	HIGH	ON

Fig. 10B

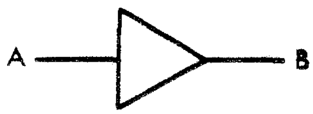


THE LIGHT GOES ON IF A OR B ARE LOW

A	B	C out	LIGHT
LOW	LOW	LOW	ON
LOW	HIGH	LOW	ON
HIGH	LOW	LOW	ON
HIGH	HIGH	HIGH	OFF

FIG. 11
GATES

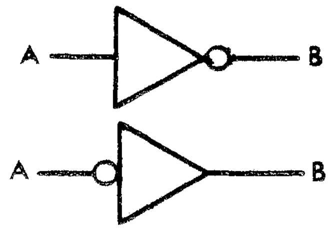
BUFFER



A	B
LOW	LOW
HIGH	HIGH

BUFFERS ARE USED FOR NON-INVERTING SIGNAL AMPLIFICATION

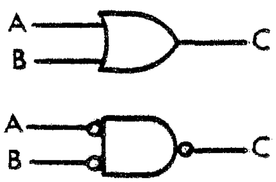
INVERTER



A	B
LOW	HIGH
HIGH	LOW

INVERTERS CHANGE SIGNALS TO THEIR OPPOSITE STATE

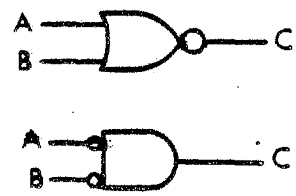
OR



A	B	C
LOW	LOW	LOW
LOW	HIGH	HIGH
HIGH	LOW	HIGH
HIGH	HIGH	HIGH

THE OUTPUT OF AN OR GATE IS HIGH IF ANY INPUT IS HIGH

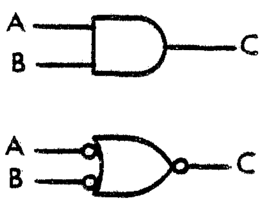
NOR



A	B	C
LOW	LOW	HIGH
LOW	HIGH	LOW
HIGH	LOW	LOW
HIGH	HIGH	LOW

THE OUTPUT OF A NOR GATE IS LOW IF ANY INPUT IS HIGH

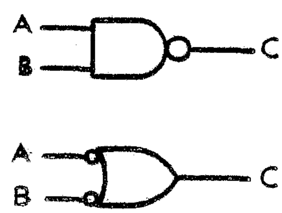
AND



A	B	C
LOW	LOW	LOW
LOW	HIGH	LOW
HIGH	LOW	LOW
HIGH	HIGH	HIGH

THE OUTPUT OF AN AND GATE IS HIGH OF ALL IF ITS INPUTS ARE HIGH

NAND



A	B	C
LOW	LOW	HIGH
LOW	HIGH	HIGH
HIGH	LOW	HIGH
HIGH	HIGH	LOW

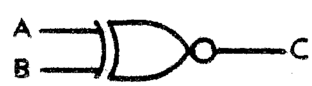
THE OUTPUT OF A NAND GATE IS LOW IF ALL OF ITS INPUTS ARE HIGH

EXCLUSIVE OR

A	B	C
LOW	LOW	LOW
LOW	HIGH	HIGH
HIGH	LOW	HIGH
HIGH	HIGH	LOW

THE OUTPUT OF AN EXCLUSIVE OR GATE IS HIGH, IF ONE BUT NOT BOTH OF ITS INPUTS ARE HIGH.

EXCLUSIVE NOR



A	B	C
LOW	LOW	HIGH
LOW	HIGH	LOW
HIGH	LOW	LOW
HIGH	HIGH	HIGH

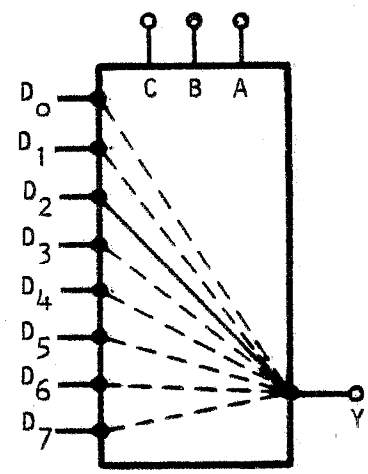
THE OUTPUT OF AN EXCLUSIVE NOR GATE IS LOW IF ONE BUT NOT BOTH, OF ITS INPUTS ARE HIGH.

MULTIPLE POSITION SWITCHING CIRCUITRY

Gating circuitry controls the logic level of a signal path in a digital circuit. However, there are occasions in which it is necessary to be able to change the path of a signal rather than its logical state. The roles of multiple position switches are assumed in the digital electronic circuit by Multiplexers, Demultiplexers, and selectors.

The Multiplexer

A multiplexer is a device which performs the function of a rotary switch in a digital electronic circuit. Fig. 12 depicts a multiplexer with select terms A, B, and C, inputs DO through D7 and output Y. With three select terms each of which can be in two different states, there are 2^3 or 8 possible input select combinations. The input combination at A, B, and C will select one of the eight data inputs (DO-D7) and connect it to output Y (see truth table in Fig. 12. Multiplexers are an essential component in printer vertical format units.



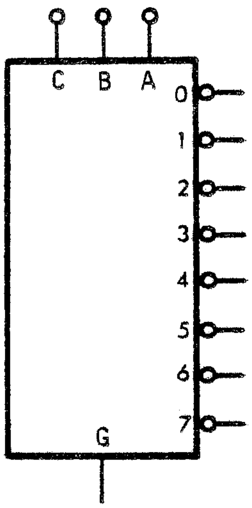
A	B	C	Y
L	L	L	DO
L	L	H	D1
L	H	L	D2
L	H	H	D3
H	L	L	D4
H	L	H	D5
H	H	L	D6
H	H	H	D7

THE MULTIPLEXER
Fig. 12

The Demultiplexer

A demultiplexer is a device which allows one of a number of outputs to be selected by a fewer number of inputs. These devices are often used to decode printer commands in order to activate a particular device or event. Fig. 13 depicts a demultiplexer with inputs A, B, and C, outputs 0-7, and enable term G.

The Demultiplexer Continued



INPUTS				OUTPUTS							
G	C	B	A	0	1	2	3	4	5	6	7
L	X	X	X	H	H	H	H	H	H	H	H
H	L	L	L	L	H	H	H	H	H	H	H
H	L	L	H	H	L	H	H	H	H	H	H
H	L	H	L	H	H	L	H	H	H	H	H
H	L	H	H	H	H	H	L	H	H	H	H
H	H	L	L	H	H	H	H	L	H	H	H
H	H	L	H	H	H	H	H	H	L	H	H
H	H	H	L	H	H	H	H	H	H	L	H
H	H	H	H	H	H	H	H	H	H	H	L

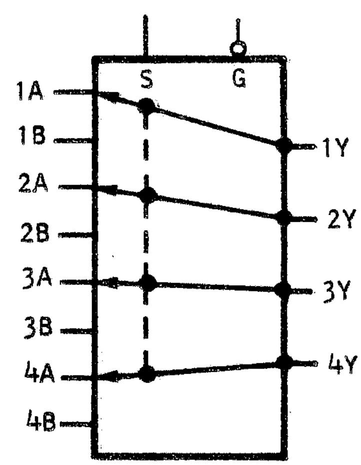
X= IRRELEVENT

When the demultiplexer term is activated by a high level signal at G, then a low will appear on the particular output selected by input terms A, B, and C and all other outputs will be high. When the demultiplexer is deactivated by a low level at G, then all of the outputs will go to a high level.

THE DEMULTIPLEXER
Fig. 13

The Selector

The data selector is a device in an electronic circuit, which performs a function similar to a multipole, single throw switch. (Fig. 14 depicts a selector with inputs 1A, 1B, 2A, 2B, 3A, 3B, 4A, and 4B, outputs 1Y, 2Y, 3Y, 4Y, select term S, and selector enable G. When selector enable (G) is low, then select term S will switch either all of the A or all of the B inputs across to their respective Y outputs. If select term (S) is low, then the "A" inputs will be connected to the Y outputs. If the select term (S) is high, then the "B" inputs will be connected to the Y outputs. When selector enable (G) is deactiviated (high) then all of the outputs will go to a high level.



INPUTS				OUT
G	S	A	B	Y
H	X	X	X	H
L	L	L	X	L
L	L	H	X	H
L	H	X	L	L
L	H	X	H	H

X= IRRELEVENT

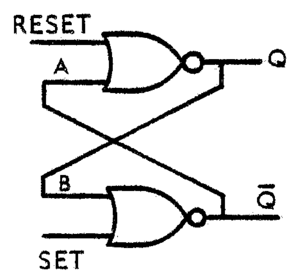
THE SELECTOR
Fig. 14

STORAGE DEVICES

Unlike other digital circuitry in which outputs change in immediate response to input changes, a logic storage device is capable of maintaining an output level even after the input conditions which brought it to that level have been removed. It is this storage capability which allows printers to capture processor generated data at electronic speeds, to edit and manipulate data, and gives printers the power to count.

The Flip Flop

The simplest logic storage device is the bistable multivibrator commonly called the flip flop. Fig. 15 depicts a flip flop in its most basic form. Two cross-coupled nor gates, here, form a Set-Reset flip flop. If the reset input is low and the set input goes high, $\bar{Q}$ will go low as will point A. The two lows at reset and point A will generate a high at Q which will be applied at point B. Now even if the set term returns to a low state, the flip flop will continue to be "set" with Q high and $\bar{Q}$ low because point B will stay high locking $\bar{Q}$ low. The only way to change the state of the flip flop is to apply a high to the reset input. The high at the reset will bring output Q to a low state, the lows at set and point B will force $\bar{Q}$ and point A high locking the flip flop into a reset state. In this manner flip flops store logic states.



S	R	Q	$\bar{Q}$
L	L	Q_0	$\bar{Q}_0$
L	H	L	H
H	L	H	L
H	H	L*	L*

$Q_0, \bar{Q}_0$ = The levels before S and R were both low

* This output is non-stable and may not persist when inputs return to their inactive (low) level.

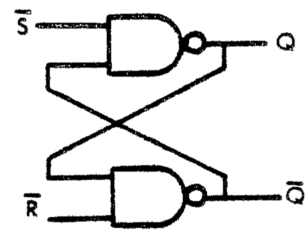
THE S-R FLIP FLOP
Fig. 15

The Latch

The negative version of the Set-Reset Flip Flop is the $\bar{S}$. $\bar{R}$ Latch. The latch operates in much the same way as the S-R Flip Flop, however, a low rather than a high level activates the cross-coupled gating. Fig. 16 depicts the $\bar{S}$-$\bar{R}$ Latch and associated truth table.

The D-C Flip Flop

Preset and clear input terms take the place of the set and reset inputs on the D-C Flip Flop (see Fig. 17). A low at the preset term sets the flip flop; Q goes to a high state, $\bar{Q}$ to a low state (note the small circle signifying preset and clear inputs activate with a low level). A low at the clear term resets the flip flop; Q goes to a low state, $\bar{Q}$ goes to a high state. If both the preset and clear terms are inactive (if both are high) then the Q term will go to the same level as the D input term (and $\bar{Q}$ will go to the inverse of D) when the signal applied to the clock input (ck) changes from a low to a high level.



$\bar{S}$	$\bar{R}$	Q	$\bar{Q}$
L	L	H*	H*
L	H	H	L
H	L	L	H
H	H	Q_0	$\bar{Q}_0$

$Q_0, \bar{Q}_0$ The levels before $\bar{S}$ and $\bar{R}$ were both high

* This output is non-stabl[illegible] and may not persist wher inputs return to their inactive (high) level.

THE LATCH
Fig. 16

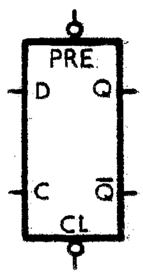
The J-K Flip Flop

J-K Flip Flop operation is similar to the D-C Flip Flop in its treatment of preset and clear terms. However, J-K's such as the 7476 in Fig. 18 differ dramatically in clocked input operation. When the clock input of a J-K is at a high level both the J and the K inputs are sampled. It is at the falling edge of the clock that the sampled data is transferred to the outputs. If at anytime during the period when the clock term was high just the J term was high then at the falling edge of the clock the flip flop would se

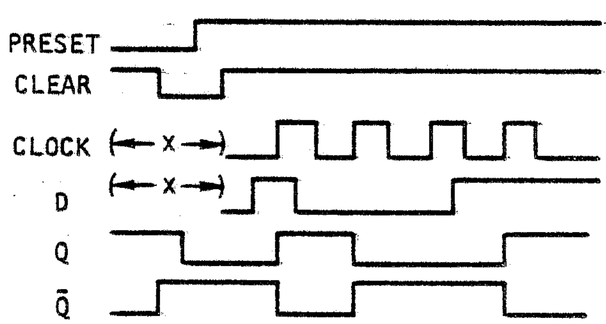
The J-K Flip Flop Continued

If at anytime during the period when the clock term was high just the K term was high, then at the falling edge of the clock, the flip flop would reset. If both inputs J and K stay low during the period that the clock is high, then the flip flop would be unchanged from the period prior to the clock's transitions. If both inputs had gone high anytime during the high period of the clock term, then when the clock goes to a low level, the flip flop would toggle. If set, it would reset. If it were reset, it would set.

THE D-C FLIP FLOP



INPUTS				OUTPUTS	
PRESET	CLEAR	C	D	Q	Q̄
L	H	X	X	H	L
H	L	X	X	L	H
L	L	X	X	H*	H*
H	H	↑	H	H	L
H	H	↑	L	L	H



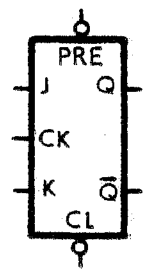
* This output is non-stable and may not persist when preset and clear return to their inactive (high) level

X = Irrelevent

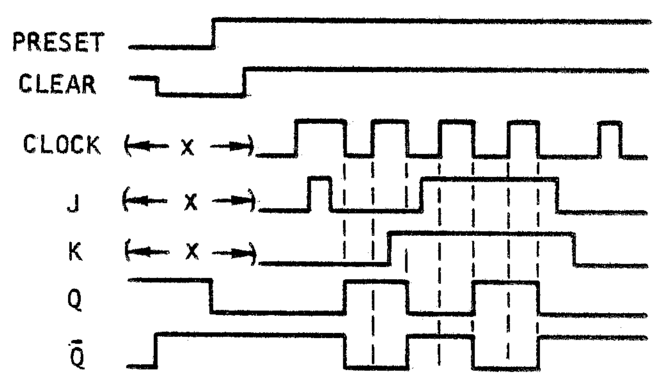
↑ = Rising edge of clock

FIG. 17

THE J-K FLIP FLOP



INPUTS					OUTPUTS	
PRESET	CLEAR	CLOCK	J	K	Q	Q̄
L	H	X	X	X	H	L
H	L	X	X	X	L	H
L	L	X	X	X	H*	H*
H	H		L	L	Q_0	$\bar{Q}_0$
H	H		H	L	H	L
H	H		L	H	L	H
H	H		H	H	Toggle	



* This output is non-stable and may not persist when preset and clear return to their inactive (high) level

Q_0 = The level of Q before the inverted conditions

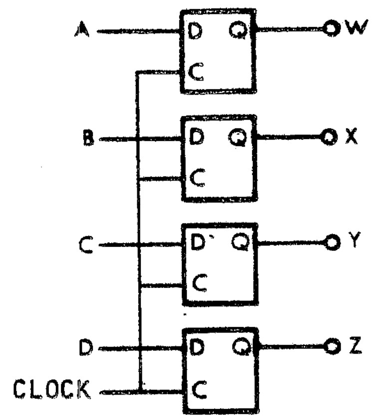
X = Irrelevent

Toggle = Each output will change to its complement

FIG. 18

Storage Registers, Shift Registers, and Counters

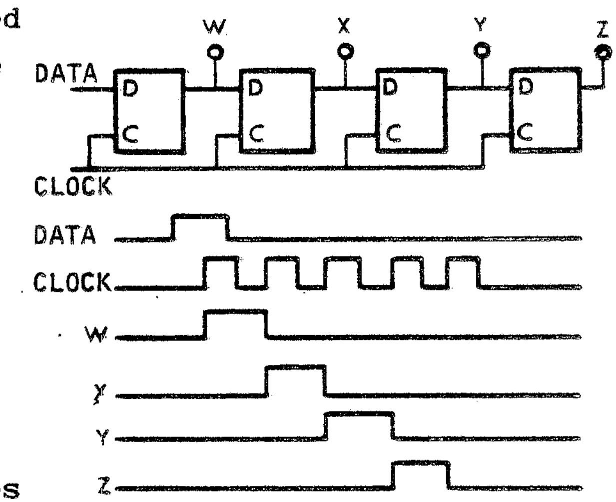
Flip Flops can be combined to form devices capable of storing, shifting, and counting data. A Storage Register is a number of flip flops loaded in parallel by a common clock (see Fig. 19). At the rising edge of the clock, all data at the D inputs is loaded into the flip flops. In this way multiples of individual data bits can be stored as a common unit called a word.



STORAGE REGISTER

Fig. 19

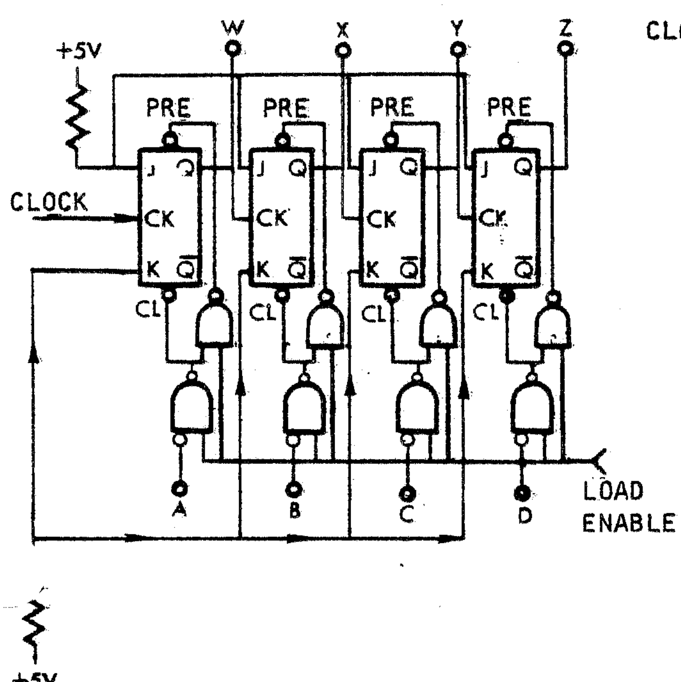
If D-C Flip Flops are cascaded in series with the Q output of one inputting the D input of the next, a shift register is formed. Data loaded into the first flip flop at the first clock will be moved to the second flip flop at the next clock, to the third at the next, and so on. Multi-bit wide shift registers find use in printers as line buffer memories storing an entire line of characters to be printed.



SHIFT REGISTER

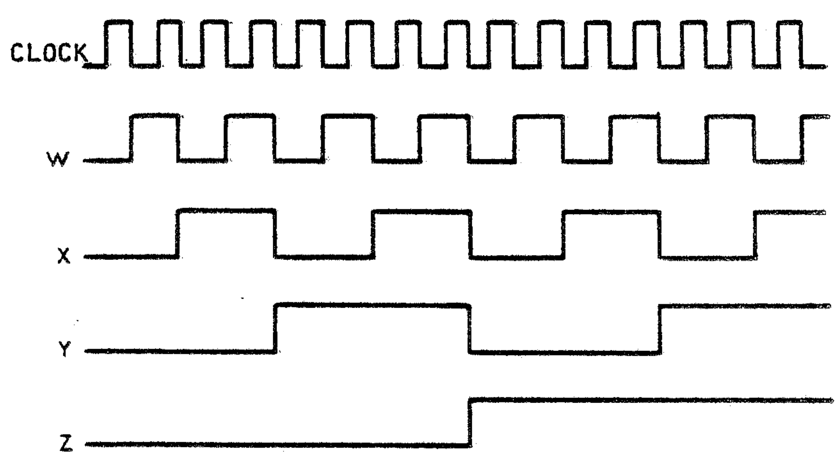
Fig. 20

When J-K Flip Flops are arranged as in Fig. 21. they form a binary counter counting the pulses coming to their clock terms. Arranged in this manner, each flip flop will require twice as many clocks as the previous flip flop to change its state (see Fig. 22). The first flip flop in a binary counter (which stores the least significant bit) represents the count of one, the second represents the count of two, the third the count of four, the fourth the count of eight, and so on doubling in value with each successive flip flop to the last flip flop which stores the most significant bit. To find the count of a binary counter add all the set flip flops together. For instance if the fourth flip flop in the series were set (representing the count of 8) and the second flip flop representing the count of two was set, the count of the binary counter would be ten. Normally counters will have a load enable term which when activated allows the levels at load inputs (here A, B, C, and D) to set the counter to a particular count. Counters are used in line printers to track mechanical positioning, generate synchronoustiming pulses, and create time delays.



THE COUNTER

FIG. 21



BINARY

0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

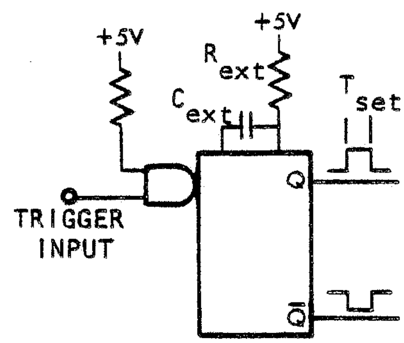
DECIMAL

METHOD OF COUNTING

FIG. 22

The Monostable Multivibrator

A variation of the bistable multivibrator or flip flop is the monostable multivibrator or one-shot. A one-shot will stay in its normally reset condition (Q low $\bar{Q}$ high) until it is triggered (its trigger input changes from a low to a high level). At that time Q will go high and $\bar{Q}$ will go low for a period determined by the externally attached resistor and capacitor. At the end of this period, both Q and $\bar{Q}$ will return to their normal levels. A retriggerable one-shot will stay set in its unstable state (will not time out) if it receives new triggers prior to timing out. A non-retriggerable one-shot cannot be retriggered until it times out. One-shots are useful in standardizing pulses of random widths and in generating time delays.



T_{set}* (Retrig) = 0.31 (R_{ext}) (C_{ext})

T_{set} (non-Ret) = 0.69 (R_{ext}) (C_{ext})

T_{set} = Time Set In Seconds

R_{ext} = External Resistance in Ohms

C_{ext} = External Capacitance in Farads

* Time Set after last trigger pulse

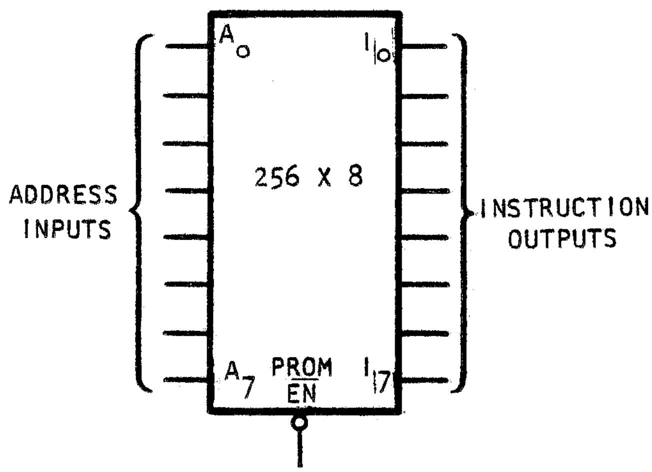
THE ONE-SHOT
Fig. 23

MEMORY DEVICES

Some printers need greater storage capability for storing entire operational programs, large amounts of data, or special character arrangements. Proms and Rams fill this design requirement.

PROMS

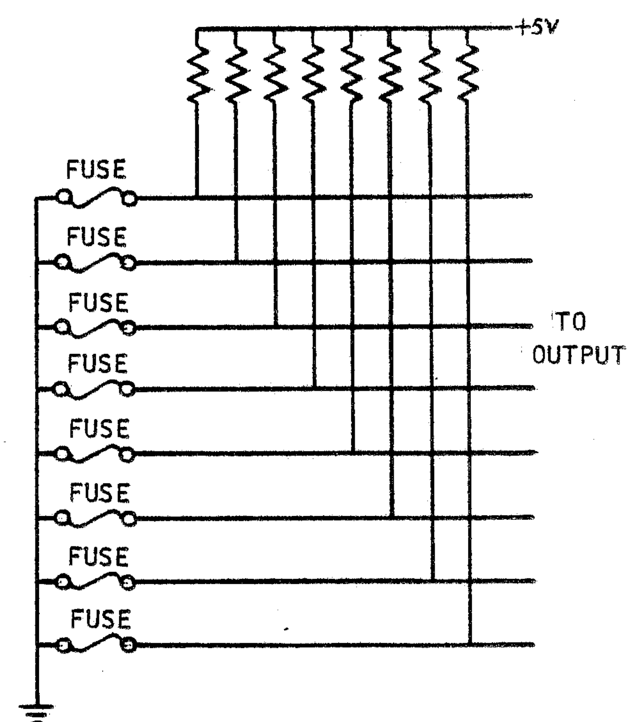
A Prom is a Programmable Read Only Memory. Proms come in a variety of sizes. The prom shown in Fig. 24 is a 2048 bit prom arranged in 256 locations of 8 bits each. Each location in a prom consist of a line of fuses. Each fuse is connected on one side to ground potential. During the programming of a prom these fuses are blown open or left intact forming a line of ones and zeros. A fuse left intact will connect ground to the output when addressed.



THE PROM
Fig. 24

A blown fuse allows +5 volts to move to the output (see Fig. 25). The programming is irreversible. Once a fuse is blown, the output for that bit is one. When the prom is disabled all of the outputs are high.

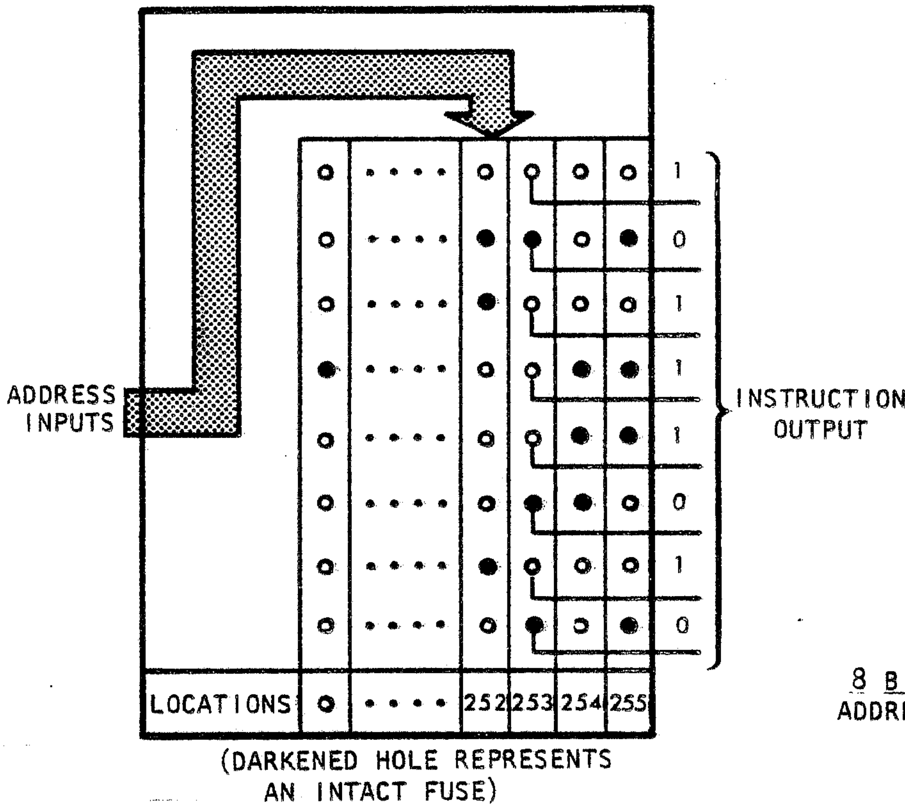
When the prom is enabled the address inputs will access a particular line of fuses and connect them to the prom output pins. In this way a particular pre-programmed instruction will appear at the prom outputs in response to a particular address



ONE 8-BIT PROM LOCATION
Fig. 25

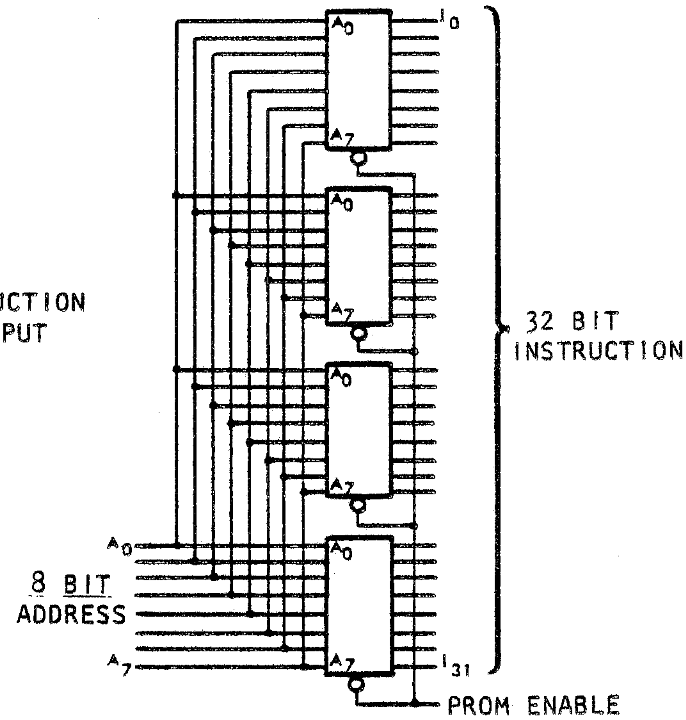
PROMS Continued

input (see Fig. 26). Additional proms can be attached in parallel allowing a particular address to access a line of fuses in each prom giving a wider instruction word out for each address (see Fig. 26).



ADDRESS INPUTS ACCESS A LINE OF FUSES AND CONNECT THEM TO THE INSTRUCTION OUTPUTS OF THE PROM

Fig. 26



PROMS IN PARALLEL

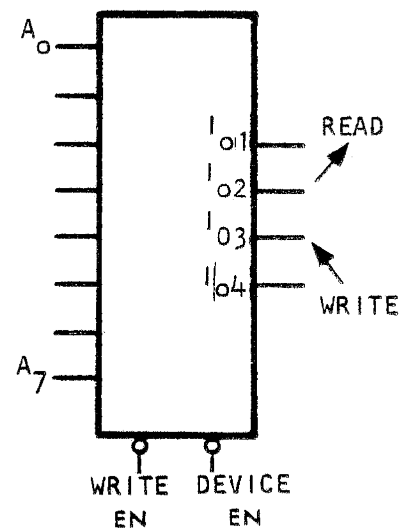
Fig. 27

RAMS

A Ram is a Random Access, read/write memory. In its read mode, a Ram is similar to a Prom in that it utilizes an enable line to activate the device, address inputs which access inner-device locations, and outputs (I/O-1 to I/O-4) to which these inner-device locations can be outputted.

In addition, the device can also be operated in a write mode in which the logic levels on the I/O pins will be programmed into the location selected by the address inputs. A Ram, then, does not need to be pre-programmed and its contents is always alterable.

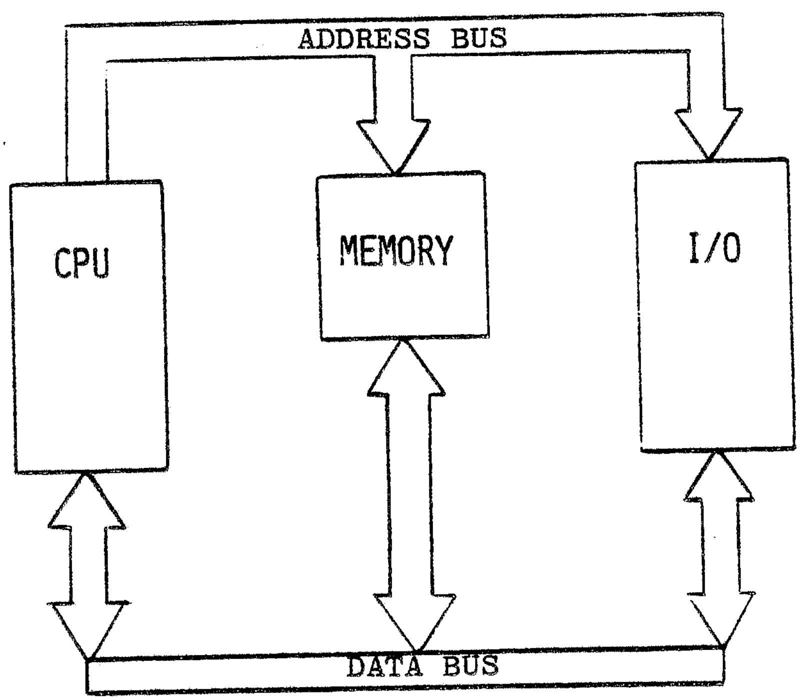
To read programmed data out of a Ram, the device enable must be activated (low), the write enable term is deactivated (high) and the particular location in Ram to be read is addressed by the address inputs and outputted to I/O-1 to I/O-4. To write data into a Ram, the device enable is activated (low), the write enable is activated (low) and data on pins I/O-1 to I/O-4 is inputted into the inner-device location addressed by the address inputs. When the device enable term on a Ram is deactivated (high), the Ram outputs go to a tri-state of operation (reference Fig. 28).



THE RAM
Fig. 28

THE MICROCOMPUTER

A typical computer system consists of a memory, a central processing unit, and I/O (input/output) devices. The power of the computer system is harnessed within the printer when the printer logic elements are arranged to duplicate the functions



MICROCOMPUTER
FIGURE 28-A

of a computer. The resultant microcomputer with hardware designed along general lines yet with it's internal program dedicated to specific requirements tends to be more adaptable to future modification and broad-range application.

Microcomputer circuitry also consists of memory, CPU, and I/O sections. Further, a microcomputer is laced with tri-state buses. These buses function as parallel carriers for data, instructions, and/or activation or control signals transfered from point to point within the microcomputer. In Fig. 28A, an Address bus originating from the CPU is being utilized to activate and address specific components within the microcomputer and a data bus carries the data to or from the device activated.

The memory section of the microcomputer is sub-divided into program memory and memory dedicated to data storage. In the program, the pre-planned reactions of all of the microcomputer components to all anticipated events are charted. The program memory outputs instructions to which the surrounding electronics responds.

The program can be manipulated or controlled by means of a program sequencer control or program counter within the Central Processing Unit. The program sequencing control addresses the program memory fetching the next program address and thus determines the next instruction to be moved out of program memory onto the Data Bus for execution. The Central Processing Unit also performs arithmetic and logical operations on the data inputted into it.

The I/O section of the microcomputer consists of input and output ports. Under program direction, input ports may be activated allowing external data to be moved on to the data bus for storage or processing. Similarly, data can be communicated to the "outside world" through output ports within the I/O.

The power of a microcomputer is it's ability to "time-share" it's constituent components. Thus, at one moment, the address bus may be addressing program memory and the data bus would carry the addressed program instruction to be executed. At the next moment, the address bus might cause an input port to be activated allowing data from it to move on to the data bus. This microcomputer capability allows economy of design and optimizes reliability in microcomputer-based printers.

Digital electronic devices discussed in this section are basic devices chosen to convey a generalized concept of particular circuit functions. Yearly, new and more sophisticated devices are introduced and incorporated into printers. There is a wide variety of common-function devices which differ in their operation, activating levels, and their complexity. Digital electronic devices comprise the "Central Nervous System" of printer control. These devices with switching speeds in billionths of seconds make possible today's print speeds and print quality.

SECTION II

Analog Electronics

SECTION II - ANALOG ELECTRONICS

A digital clock breaks time into steps, increments it, yet time, the thing the digital clock measures is continuous. The sweeping hand of a mechanical clock more accurately measures time for it is more analogous to time. Unlike digital devices, analog devices can be on, off or somewhere in between (partially on). There are many instances in which analog devices must interface with digital devices and so there are devices to digitize analog signals. Both analog and digital/analog devices are discussed in this section.

The Electron

An electron is one of the elementary constituents of matter and energy having both, properties associated with particulate matter such as mass and properties associated with pure energy such as wave motion. Just as air moves from a high pressure area (an area of high molecular density) to a low pressure area (an area of low molecular density), so electrons flow from an area of high electron density to an area of low electron density. Electronic devices harness the power of this "electron wind". Areas of electron abundance are termed negatively "charged". Areas of electron scarity are positively charged.

Ohms Law

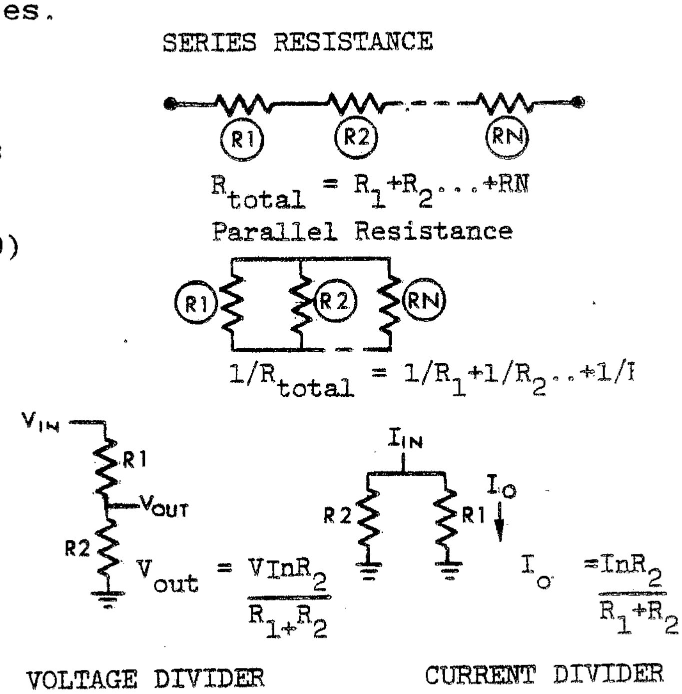
Ohm's Law, the basic law of electronics, describes electron flow. Essentially, it states that the amount of electrons that will flow from one area to another depends on how many more electrons there are at the one area as opposed to the other and how many obstacles there are between the two areas to current flow. Electron current, (I) measured in amperes, is directly proportional to the electron pressure, (E) measured in volts, which arises

Ohms Law Continued

between two areas of different electron densities and inversely proportional to the resistance to current flow, (R) measured in ohms, between them. Thus, I = E/R.

The Resistor

A resistor is an obstacle to electron current flow. For this reason, there are more electrons on one side of a resistor then on the other creating a voltage drop across it. In this way resistors divide voltage. Resistors in series are added to each other representing greater current obstacles. Resistors in parallel create more current paths and so divide current flow. Both voltage divider circuits and current divider circuits are used throughout printers (see Fig.29)



THE RESISTOR

Fig. 29

The Capacitor

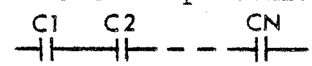
A capacitor is a device consisting of two conductive plates separated by a non-conductive material. Despite the fact that different electron densities exist between the two conductive plates, no electrons are able to cross the non-conductive barrier. However, electrons will build up on a plate in response to the opposite plate's attracting force.

The number of electrons that will build up at a plate depends upon the size of the plate, the attractive force between the plates, and the time allowed for electrons to accumulate. Capacitors in

The Capacitor continued

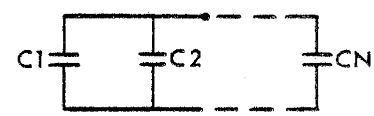
parallel effectively increase plate area and so increase the device's capacity to accumulate electrons (store a charge). Capacitors in series maximize the effect of the intervening non-conductive barriers decreasing the attractive force between plates and, so decrease the device's capacity to store a charge (see Fig. 30). Changes in the number of electrons at one plate alter the attractive force between the plates and so change the number of electrons at the other plate. If the voltage at one plate is held constant and the "capacitive coupling" between two plates is large enough, the second plate will also resist voltage variations. This property allows capacitors to be used for "filtering" voltage variations. Since time is a factor affecting voltage build up at a plate, (and voltage discharge) capacitors also find use in time delay circuits. A capacitor will charge to 63% of the applied voltage in a time period (in seconds) defined by its capacitance (in farads) multipled by the resistance (in Ohms) in the circuit charging path. A capacitor will discharge to 37% of its charged voltage in one time period equal to RC. Capacitors are also used for energy storage.

Series Capacitance



$1/C_{total} = 1/C_1 + 1/C_2 .. +1/C_N$

PARALLEL CAPACITANCE



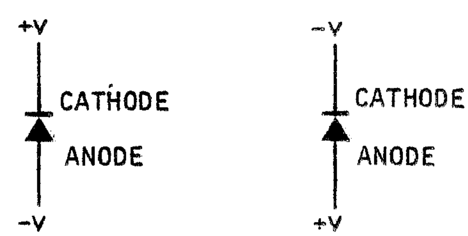
$C_{Total} = C_1 + C_2 .... +C_N$

THE CAPACITOR

Fig. 30

The Diode

A diode is a device which presents a very large resistance to current flow in one direction and a small resistance to current flow in the other. Current flows readily through a diode which is forward biased, that is, which has a more negative voltage on the cathode side of the diode (as opposed to the anode). When the voltage is more negative on the anode side of the diode, the diode shuts off to current flow. Diodes are often used to insure that a point in a circuit does not exceed a certain voltage (a diode clamp) and to convert alternating current to direct current.



No current Flow

Current Flow

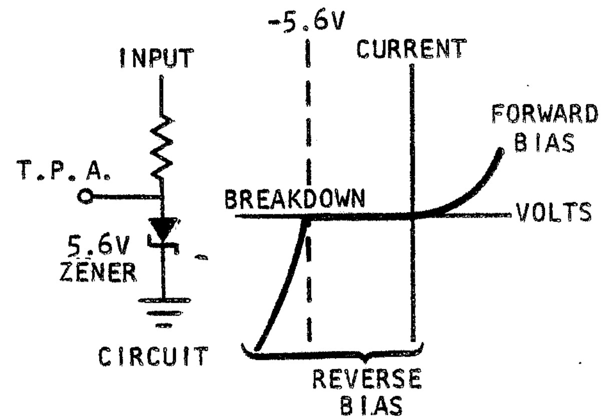
THE DIODE

Fig. 31

The Zener (Breakdown) Diode

Some diodes are specially made to conduct although reverse biased, when a reverse-voltage breakdown threshold is reached. Zener diodes operate on this principle. Below their breakdown threshold, Zener diodes operate as a simple diode allowing current to flow when forward biased and barring current flow when reverse biased. However, when the reverse voltage across the Zener exceeds a certain point, the diode conducts current from the anode to the cathode. After breakdown, the voltage at the input to the diode is essentially constant and is independent of the current (see Fig. 31A). This property makes Zener diodes ideal for use as voltage regulators, voltage references, and over-voltage protectors.

SYMBOL



VOLTAGE/CURRENT PLOT FOR T.P.A APPLICATION

THE ZENER DIODE
FIG. 31A

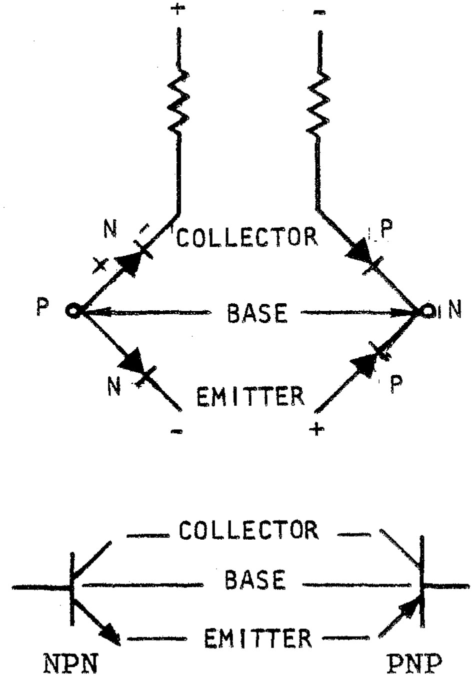
The Transistor

Transistors are devices used for circuit voltage, power, and current control. Transistors are composed of three terminals (emitter, base, and collector) and are functionally comparable, through not totally equivalent, to two diodes placed with like poles toward the base. There are, then, two basic types of transistors which differ as to which poles are turned toward their bases (see Fig. 32). Transistors are connected into a circuit in such a way that the emitter to base connection is able to be forward biased while the base to collector connection is always reverse biased. Thus, when the emitter to base is forward biased a very

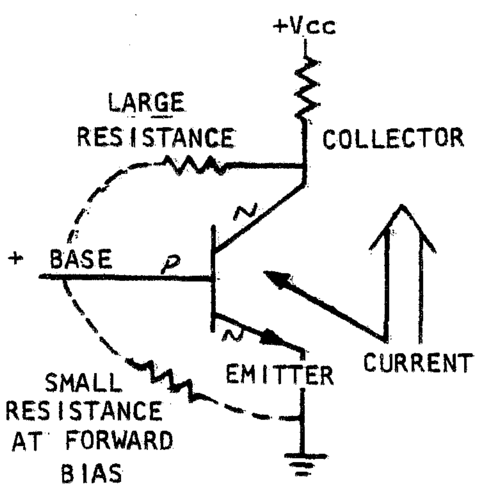
The Transistor Continued

small resistance exists between the base and emitter and a very large resistance exists between the base and collector.

In an NPN transistor, because of the small emitter to base resistance, a very small voltage between the base and emitter is required to generate a considerable emitter current. The chemistry of the transistor is such that only a few of the emitter electrons move out to the base, the rests of the current moves over to the collector junction (see Fig. 33).



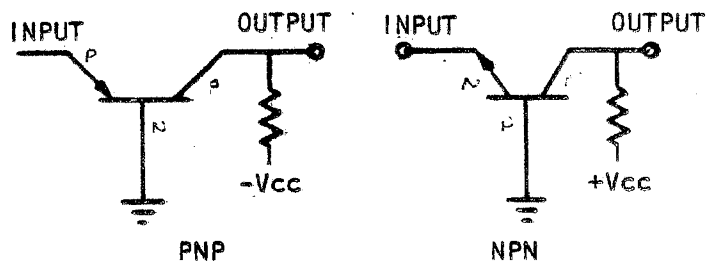
TRANSISTORS
Fig. 32



TRANSISTOR OPERATION
Fig. 33

The current, then, is essentially the same in the emitter as in the collector, but the emitter to base resistance is very small and the base to collector resistance is very large. This inequality allows a very small change in voltage between the base and emitter to effect a very large change in the voltage between the base and collector. As the voltag changes at the collector are proportional, though on a larger scale, to the voltage changes at the base, and if the base is considered the transistor input and the collector is the transistor output, then the transistor is said to amplify its input. An NPN transistor requires a more positive voltage at its base with respect to its emitter to conduct. Of course, how much the transistor conducts depends upon how strongly the emitter base junction is forward biased. Fully forward biased the transistor is driven to saturation creating an equipotential (same voltage) condition between the emitter and collector. A PNP transistor requires a more negative voltage at its base with respect to its emitter in order to conduct.

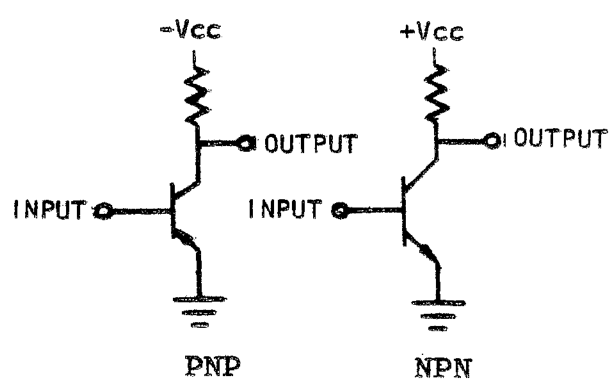
Transistor operation varies according to its method of circuit connection. There are three types of transistor connections. In the common-base amplifier circuit, the base of the transistor is tied to a fixed voltage with input applied to the emitter and output at collector. This circuit provides a low input resistance, a high output resistance, and voltage and power amplification (see Fig.34).



COMMON-BASE

Fig. 34

In the common-emitter circuit (see Fig.35) the emitter is tied to a fixed voltage, the input is applied to the base and the output is at the collector. Its input resistance is higher and its output resistance is lower then the common-base input. This circuit connection provides the highest voltage and power gain of the three configurations. The



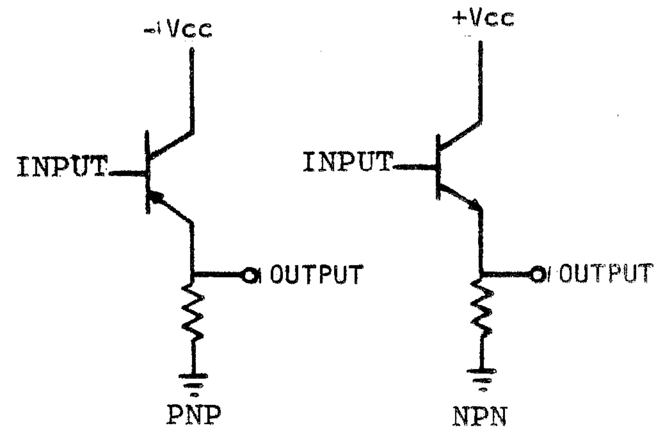
COMMON-EMITTER

Fig. 35

The Transistor Continued

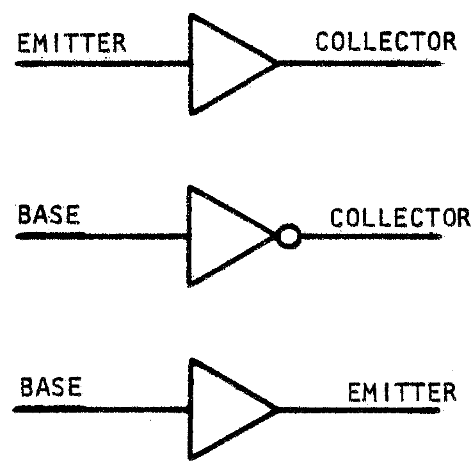
common-emitter connection provides a phase reversal between the input and output.

In the common-collector circuit, the collector is tied to a fixed voltage, the input is applied to the base and the output appears at the emitter. This configuration provides a relatively high input resistance, a low output resistance and provides a voltage gain of less than one. The common-collector amplifier is, often, used as a buffer (see Fig. 36)



COMMON-COLLECTOR
FIG. 36

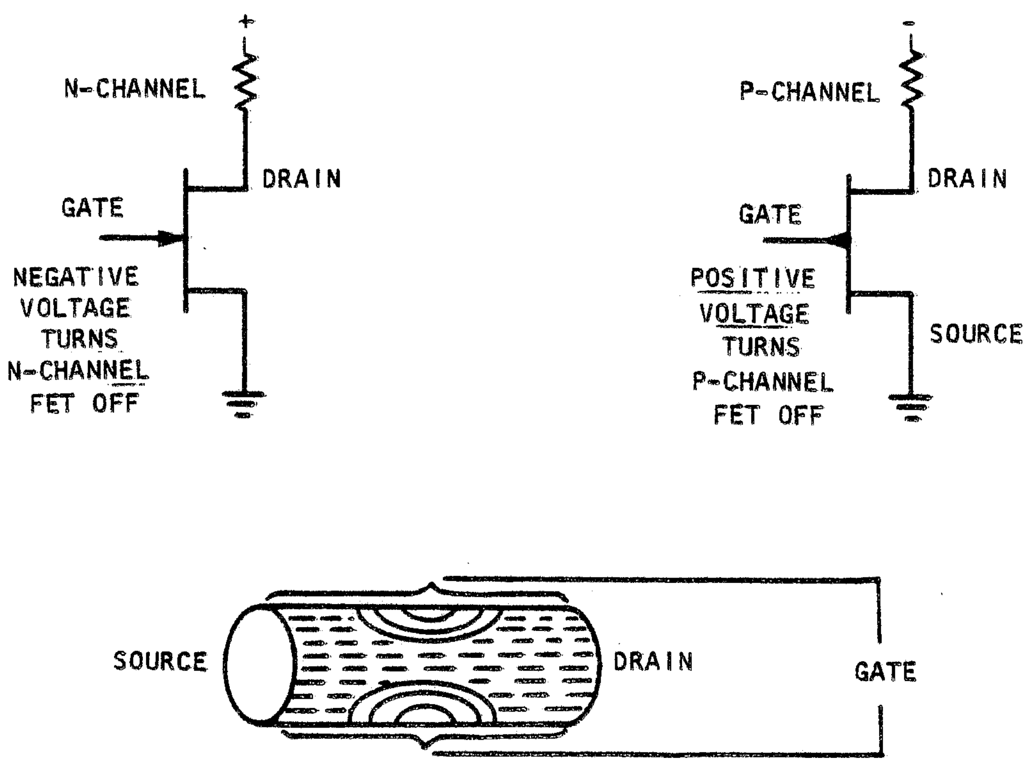
Transistors can be used as switches in digital circuits turning fully on or off. Although in analog circuits, transistors are often only partially on, their operation can be simplified as digital devices operating in the manner as illustrated in Figure 37.



DIGITIZING TRANSISTOR OPERATION
FIG. 37

The FET

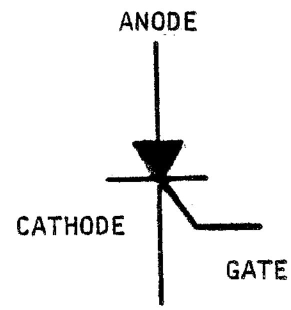
A FET can be conceived as an electron pipeline with source and drain at either end and the gate as a valve in between. Current flow between the source and the drain is dependent upon a field produced by a voltage applied to the gate. A negative voltage at the gate of an N-Channel FET produces a field which expands as a greater negative voltage is applied. Current flow from source to drain will be pinched off when the field has become large enough (in response to a larger negative voltage) finally prohibiting all current flow through the device. A positive voltage at a P-Channel FET produces the field that regulates source to drain current flow. It is a more positive voltage for an N-Channel FET and a more negative voltage for a P-Channel FET which turns the respective devices on allowing current flow. (See Fig. 38).



THE FET
FIG. 38

The SCR

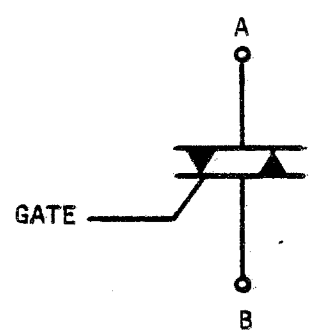
An SCR is a silicon controlled rectifier. In its quiescent state, an SCR blocks current flow. If the cathode and anode are forward biased, the device requires an enabling voltage at its gate to turn on. The polarity of the enabling voltage depends upon the type of SCR used (consult manufacturer's data manuals). Once on the enabling gate voltage can be removed and current will continue to flow until the cathode becomes more positive with respect to the anode. The SCR is a valuable DC power control device (reference Fig. 39).



THE SCR
Fig. 39

The Triac

AC power control in printers is achieved by the Triac. A Triac is formed when two SCR's are connected in anti-parallel, the cathode of each to the anode of each, with their gates connected in common. As with the SCR, an enabling voltage to a Triac gate allows the Triac to turn on. Triacs allow printer Logic to control AC driven devices such as motors. (reference Fig. 40).

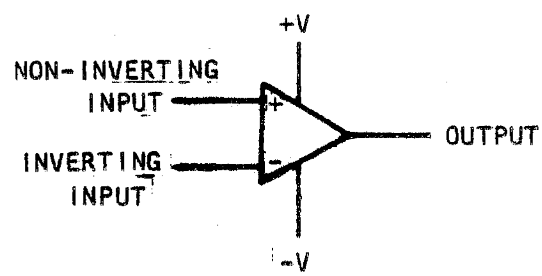


The Triac
Fig. 40

The Operational Amplifier

Operational amplifiers are multipurpose devices. These devices find common use as signal amplifiers and signal comparators. The dual input operational amplifier (see Fig.41) has an inverting input, a non-inverting input, power inputs, and an amplifier output. Operation of an Op-AMP depends largely on the circuit configuration external to it.

An Op-AMP will output a more negative voltage when the voltage at its inverting input is more positive than the voltage at its non-inverting input. An Op-AMP will output a more positive voltage when the voltage at its non-inverting input is more positive than the voltage at its inverting input.

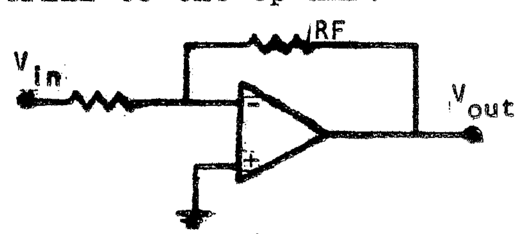


THE OP-AMP
Fig. 41

Signal Amplifiers

When suitable feedback from the output to one of its inputs is applied to an operational amplifier, the Op-AMP will output a voltage of a magnitude great enough to allow neither the inverting input nor the non-inverting input to be more positive, that is the output voltage will increase in one direction until the voltage difference between the two inputs is equal to zero. The gain of the Op-AMP is a function of components external to the Op-AMP.

Figures 42 and 43 diagram typical Op-AMP configurations. In the inverting amplifier configuration (see Fig.42), the non-inverting input is tied to ground. To attain a differential input voltage equal to zero, the inverting input voltage must also equal ground.



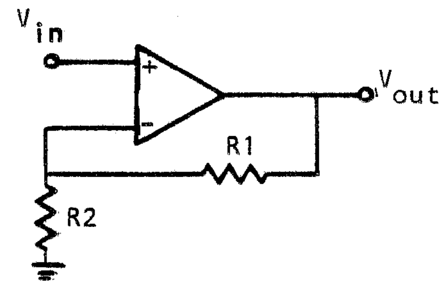
$$A = R_f/R_{In}$$

$$V_{out} = -V_{In}\ (A)$$

INVERTING OP-AMP
Fig. 42

The Op-AMP will output enough voltage (of opposite polarity to its input) to bring the inverting input voltage equal to the non-inverting input voltage. The gain of the Op-AMP(A) is equal to its feedback resistance divided by its input resistance. Its output voltage is equal to the product of its input voltage multiplied by its gain. The output voltage is opposite in polarity to the input voltage.

Figure 43 diagrams a typical non-inverting Op-AMP configuration. Like the inverting Op-AMP, the non-inverting Op-AMP will output enough of a voltage to equalize its inputs. Resistors R_1 and R_2 form a voltage divider. By using the voltage divider formula, presented earlier, the gain of this Op-AMP is calculated to equal 1+R1/R2.



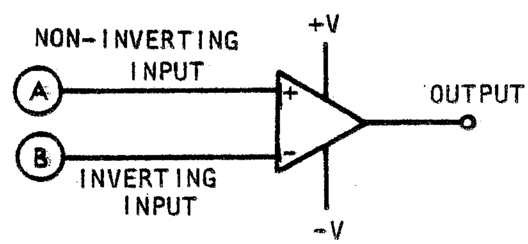
A = 1+R1/R2

$V_{out} = V_{In}$ (A)

NON-INVERTING OP-AMP CONFIGURATION
Fig. 43

Voltage Comparators

If no feedback is provided the Op-AMP becomes an excellent device for comparing voltage magnitudes. If the voltage at the non-inverting input is more positive than the voltage at the inverting input, the Op-AMP, seeking to equalize its inputs, will drive its output fully positive to its positive power supply input voltage. If the voltage at the inverting input is more positive than the voltage at the non-inverting input, the Op-AMP will drive its output fully negative to its negative power supply input voltage. If the positive power supply voltage is +5 volts and the negative power supply voltage is ground, the comparator will give a digital response to an analog voltage comparison.



If $V_A > V_B$, V_{output} = +V
If $V_A < V_B$, V_{output} = -V

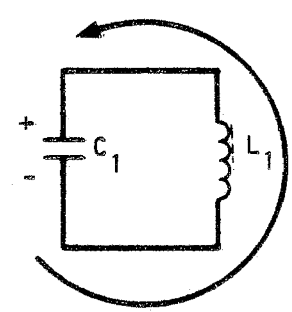
VOLTAGE COMPARATOR
Fig. 44

Inductive Devices

A magnetic field as that produced by an ordinary magnet is produced when an electric current flows through a conductor. The converse of this is also true, when a conductor in a circuit is moved through the lines of magnetic force in a magnetic field an electron current flows. It is this interrelationship of electricity and magnetism which finds a host of applications in printer technology.

The Inductor

An inductor is a coiled wire which, via its electromagnetic properties, opposes any change in the existing current of an analog circuit. The unit of inductance is the Henry. Inductors are used in conjunction with capacitors in oscillator circuits in printers. A typical oscillator operates in the following manner. The capacitor in Fig. 45 is charged. It begins to discharge through the inductor L_1. As soon as the electron current flows through L_1, a magnetic field is established around the coil. As the field builc magnetic lines of force cut across the coil wires inducing a counter voltage which opposes the increasing current flow. This slows the rate of capacitor discharge down. As one plate loses its electrons, the current tends to die down, but is prevented from doing so by the inductor coil which now opposes the decrease in current flow. The originally negatively charged plate of the capacitor loses not only the excess of electrons, but gives up more electrons, becoming positively charged. The originally positively charged plate gains an excess of electrons acquiring a negative charge. Only when the energy of the magnetic field is exhausted does the current stop flowing. Then, the process begins again in the opposite direction.



Freq. $= 1/2\pi\sqrt{LC}$

Freq. In Hertz

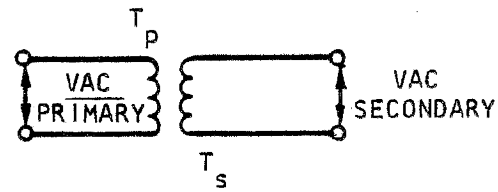
L In Henries

C In Farads

OSCILLATOR CIRCUITRY
Fig. 45

Transformers

A transformer consists of two adjacent coils of wire. The expanding magnetic field generated by current in the first coil cuts the second coil of wire causing current to flow in the second. Transformers are used to change one AC voltage to another and also to provide circuit isolation. The ratio of primary to secondary voltage is equal to the ratio of the number of turns in the primary to the number of turns in the secondary.

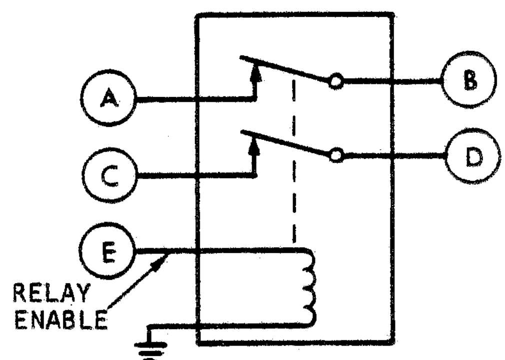


$$\frac{VAC_p}{VAC_s} = \frac{T_p}{T_s}$$

THE TRANSFORMER
Fig. 46

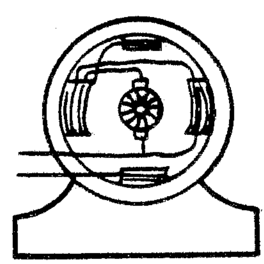
RELAYS AND MOTORS

The magnetic field around a coil of wire, also is used to physically move ferromagnetic material. In the relay, contacts are closed or opened by energizing or de-energizing a coil thereby allowing control of one circuit by another (see Fig. 47). A motor converts electrical energy to mechanical energy. In motors, coiled wire on a central turnable shaft is surrounded by stationary coils of wire. Current flowing in the wire causes the central shaft to rotate. (see Fig. 48).



A=B, C=D if E

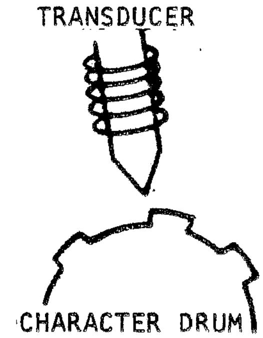
THE RELAY
Fig. 47



THE MOTOR
Fig. 48

THE RELUCTANCE PICKUP TRANSDUCER

A Reluctance Pickup Transducer is a magnet surrounded by a coil of wire. Any metal moving in front of the magnet alters the field of the magnet causing current to flow in the transducer coil. Transducers are used in printers to detect character positions. (see Fig. 49).



THE TRANSDUCER
Fig. 49

Analog devices mechanize digital electronic printer control. They provide the means by which electric energy is converted to the mechanical energy necessary to move paper, move ribbon, and provide impact printing. They provide power to light lights and generate the various voltages used in a printer. They constitute the necessary detection devices of the printer. If digital circuitry is the "central nervous system" of the printer, analog circuitry constitutes the muscle and the senses of the printer. The respective roles of analog and digital devices are essential to today's printer technology.

APPENDICES

APPENDIX A
SEMICONDUCTOR PHYSICS

THE SEMICONDUCTOR

A semiconductor is a material that is not a conductor, yet not an insulator. It lies in the region between these two materials. As an example, Silicon is a semiconductor. In order to understand the semiconductor, an understanding of the electron valence band and conduction band must be understood (see Fig. 1)

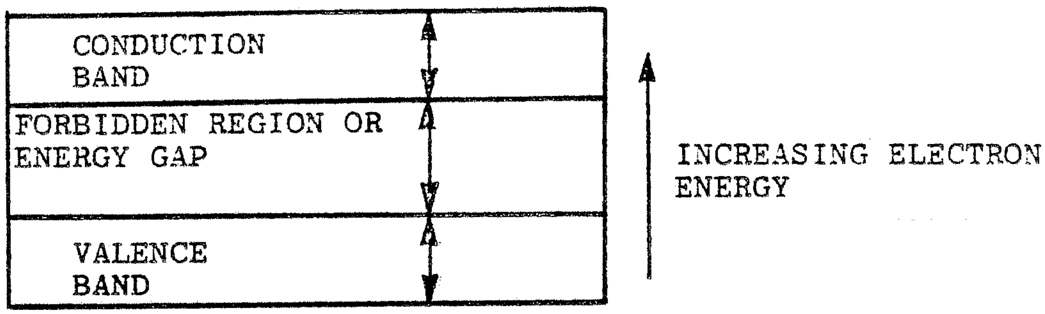


FIGURE 1 ENERGY BANDS

The allowable energy bands for electrons in a semiconductor are the valence and conduction bands. The conduction band represents the permissible energy level for free electrons while the valence band represents energy levels corresponding to outer atomic orbits of the electrons. Note that <u>NO</u> electrons may exist in the energy gap region. At very low temperatures, all electrons in the silicon atom exist in the valence band, thus silicon is a insulator. However, at room temperature some of the electrons in silicon (a very small fraction) are allowed to leave into the conduction band, thus the material is called a SEMICONDUCTOR.

Let us note at this time that conduction is totally dependent on the number of free electrons in the conduction band or holes (absence of electrons) in the valence band. Either of these quantities may be controlled by a process known as doping. By controlling the electron or hole concentration, the overall electrical conductivity of the semiconductor is determined.

Let us also note at this time that silicon resides in column IV in the periodic table. This tells us that silicon has four outer orbiting electrons. Silicon in its normal state forms a crystal lattice structure which is covalently bonded (see Fig. 2). In other words each atom shares another electron.

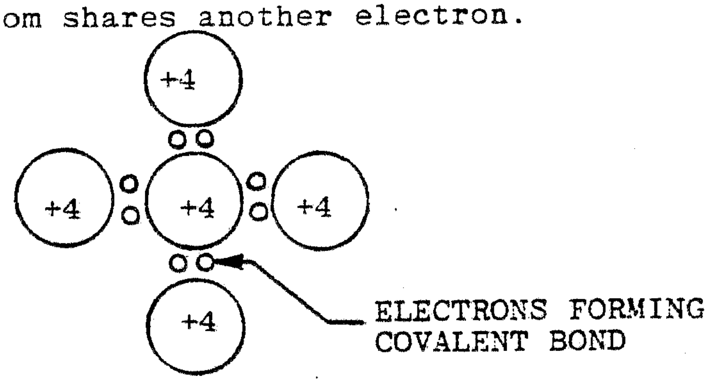


FIGURE 2 THE SILICON LATTICE

If an impurity atom such as phosphorus is added to the lattice from column V in the periodic table, the following configuration results (see Fig.3).

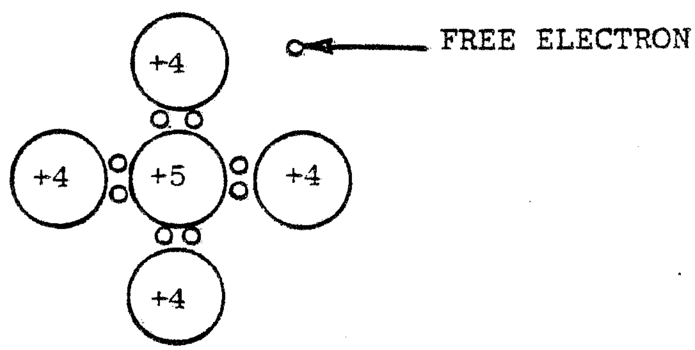


FIGURE 3 DONOR ATOM IN Si LATTICE

Note that a free electron is in the lattice structure at this time which is not being used in the covalent bond between the +4 atoms (Si) and the +5 impurity atoms. This results in the following energy diagram (Fig. 4).

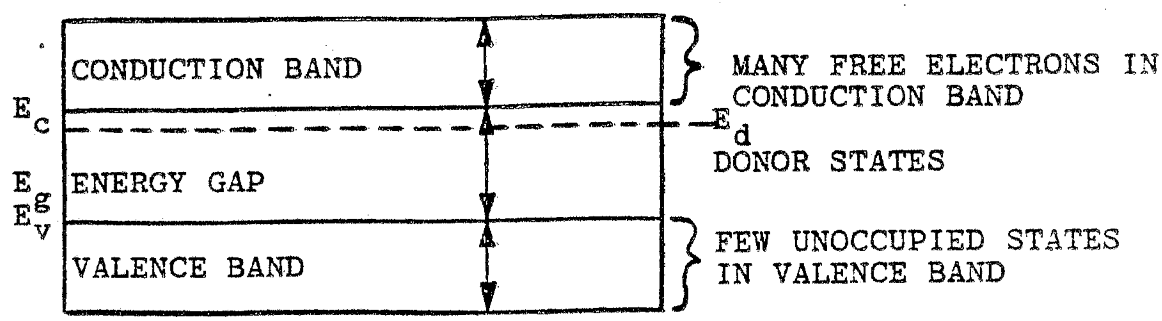


FIGURE 4 ENERGY DIAGRAM FOR N TYPE MATERIAL

We have just formed an "N" type semiconductor. Note that the conduction carriers are electrons in the conduction band.

Now let us see how the hole is formed to produce a "P" type semiconductor material. In this case an acceptor element such as aluminum with a valence of +3 would have to be added to the silicon lattice structure in the following configuration (see Fig. 5).

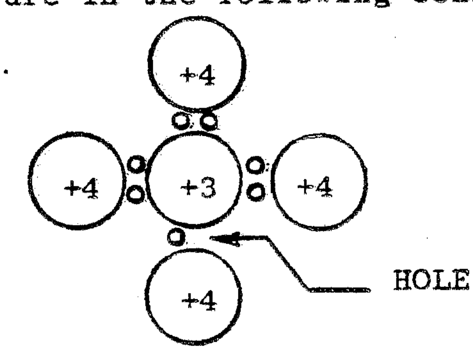


FIGURE 5 ACCEPTOR ATOM IN Si LATTICE

Note that an electron is missing from one of the covalent bonding positions which produces what is referred to as a hole.

The energy diagram for this configuration is seen in figure 6.

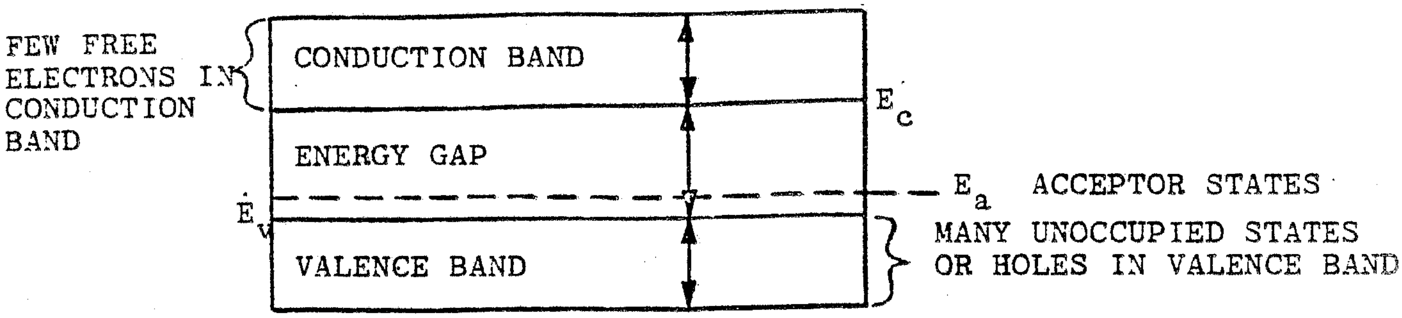


FIGURE 6 ENERGY DIAGRAM FOR P TYPE MATERIAL

We have just formed a "P" type material. Note that the conduction carriers are "HOLES" in the valence band.

Now that we have created both the N and P materials, it is time to put them together to form a device called the diode.

THE DIODE

At this time let us examine a bar of N material and a bar of P material (see Fig. 7).

FIGURE 7 P AND N MATERIAL BARS

Note that the P material contains many excess holes, while the

N material contains many excess electrons. When these two bars are are connected together, the semiconductor diode is formed (see Fig. 8).

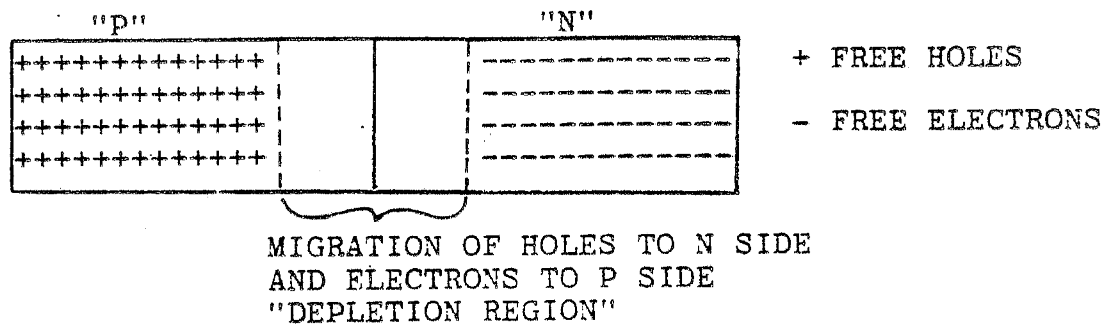


FIGURE 8

Note that some of the holes have migrated to the N region and some of the electrons to the P region, thus recombining and leaving a Depletion region at the junction. At this depletion region a barrier voltage is developed. Note that the wider the region, the larger the barrier potential.

Now let us examine what the effect of an external voltage would be on this junction in the forward biased condition.

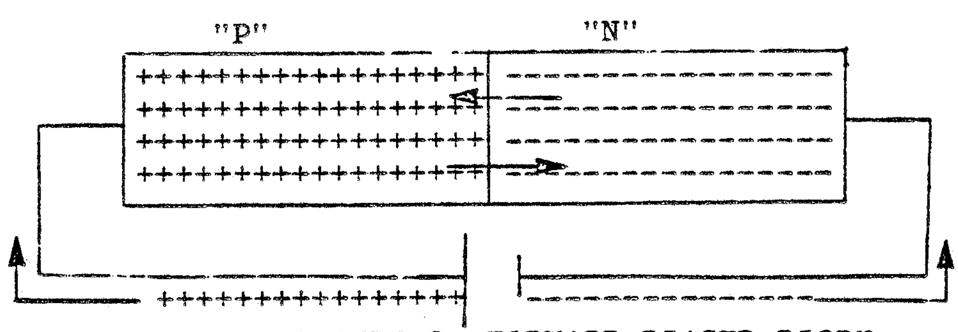


FIGURE 9 FORWARD BIASED DIODE

Note that when an external voltage is connected in such a manner as to supply electrons to the N region or holes to the P region then the excess carriers supplied from the external voltage source will cause the carriers to flow through the junction, thus conduction occurs. Since very little external voltage is required, we can say that the resistance to conduction (current flow) is also very small from the relation E=IR where E is the applied voltage, R is the resistance to conduction and I is the current or conduction flow of carriers.

In the reverse biased condition just the opposite occurs.

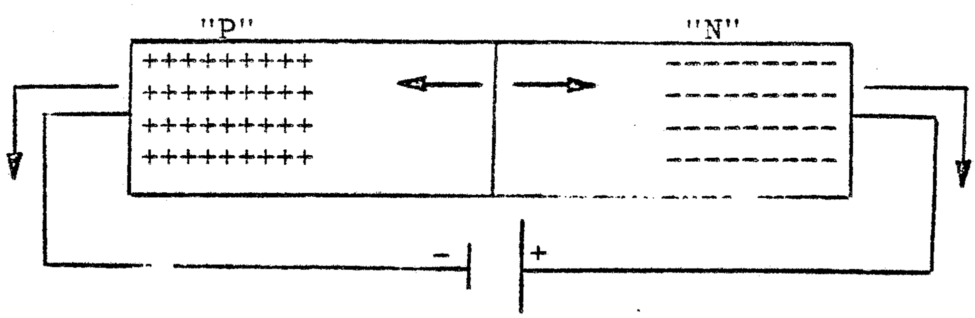


FIGURE 10 REVERSE BIASED DIODE

Note that electrons are drawn from the N region and holes from the P region. The depletion region becomes very large and NO conduction or current flow occurs. In this case we may say that R is very large since I=O and I=E/R therefore, R approaches infinity to keep I=O.

Since current can only flow in one direction though a diode, the diode may be thought of as a one way control valve. In other words, if a rapidly varying voltage is applied to a diode such as in figure 11, the output voltage will appear as seen to the right.

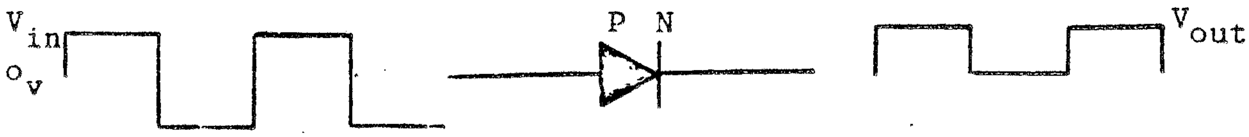


FIGURE 11 THE DIODE AS A ONE WAY CONTROL VALVE

Last, but not least, let us examine the functional operation of the semiconductor transistor.

THE TRANSISTOR

The semiconductor transistor may be thought of as two back to back diodes with a few peculiar characteristics (see Fig. 12).

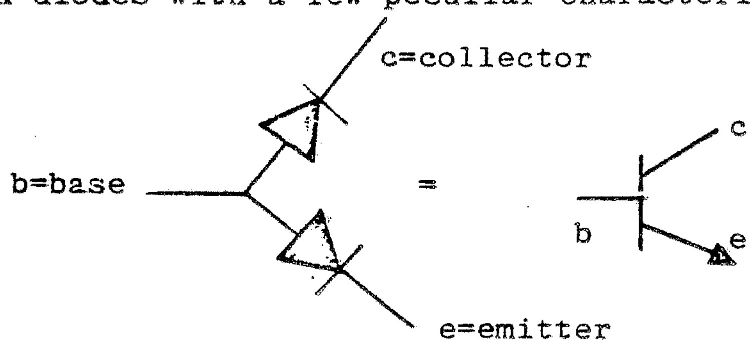


FIGURE 12 THE NPN TRANSISTOR

The three transistor terminals are represented by b=base, e= emitter and c= collector. Let us say at this time that the base to emitter junction is forward biased by an external source and the base to collector junction is reverse biased by an external source as shown in figure 13.

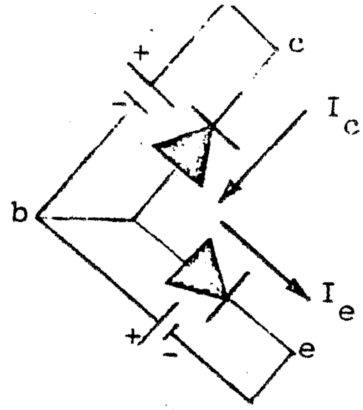


FIGURE 13 TRANSISTOR BIASING

Referring back to the diode biasing diagrams 9 and 10, we note that a diode in the reverse biased direction has a very high equivalent resistance. With the transistor circuit of Fig. 13, we will assume that I_e (emitter current)=I_c(collector current) for simplification purposes (see Fig. 14).

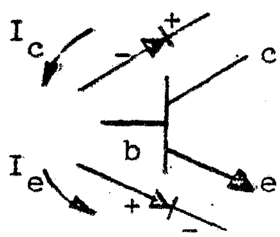


FIGURE 14 TRANSISTOR BIASING

Note that if $I_e=I_c$ then E_{be} (voltage from base to emitter) is very small since R_{be} (resistance from base to emitter) is small and $E_{be}=I_eR_{be}$. Note that E_{bc} (voltage from base to collector) is very large since R_{bc} (resistance from base to collector) is very large and $E_{bc}=I_cR_{bc}$.

Therefore, a very small voltage across the base-emitter junction for a given current I_e results in a very large voltage across the base collector junction for a given current I_c allowing voltage amplification.

APPENDIX B

Metric Prefixes and Component Value

Prefixes such as the ones listed below are commonly placed in front of Electronic terms such as the OHM or Hertz. These prefixes are used to increase or decrease these electronic units by some factor of ten. Below is a list of Metric Prefixes and the amount they multiply a unit's value.

Prefix	Symbol	Exponential Multiplier	Multiply Units By
Tera-	T	10^{12}	1,000,000,000,000
Giga-	G	10^{9}	1,000,000,000
*Mega-	M	10^{6}	1,000,000
*Kilo-	K	10^{3}	1,000
Hecto-	H	10^{2}	100
Deka-	D	10^{1}	10
Units	-	10^{0}	1
Deci-	d	10^{-1}	.1
Centi-	c	10^{-2}	.01
*Milli-	m	10^{-3}	.001
*Micro-		10^{-6}	.000001
*Nano-	n	10^{-9}	.000000001
*Pico-	p	10^{-12}	.000000000001
Femto-	f	10^{-15}	.000000000000001
Atto-	a	10^{-18}	.000000000000000001

* Commonly used prefixes in Printer Electronics

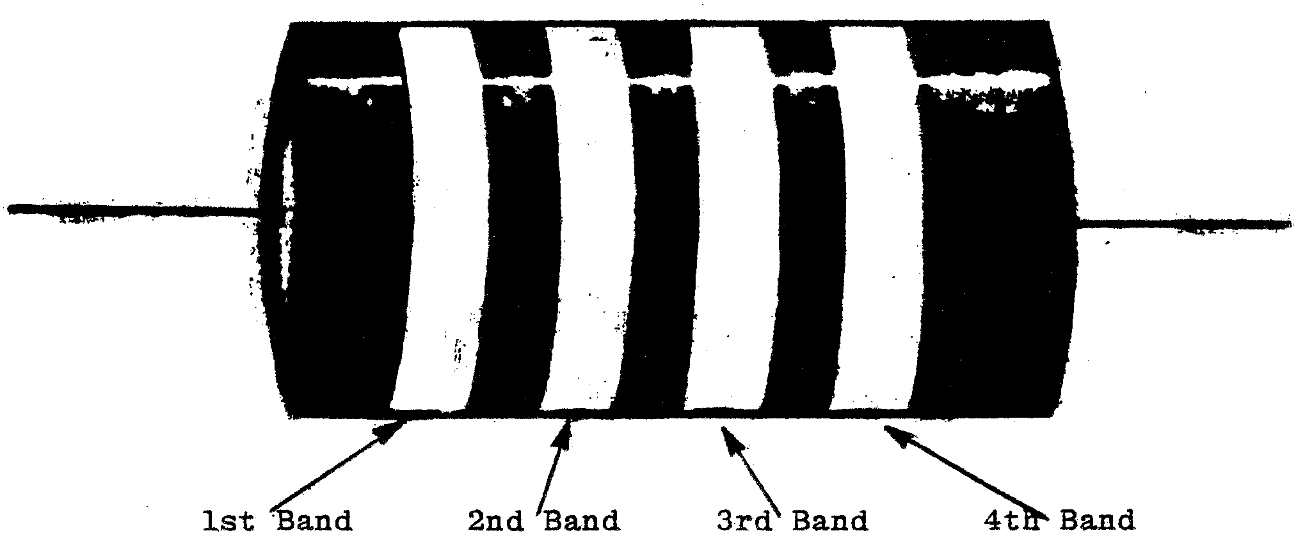
APPENDIX C

Identifying Components

A. Resistors

Resistance value is generally determined by a color code marked on the resistor itself. Some special resistors have their value printed on the resistor.

Resistor Color Code	1st Band Digit	2nd Band Digit	3rd Band Multiplier	4th Band Tolerance
Black	0	0	$10^0=1$	---
Brown	1	1	$10^1=10$	$\pm$ 1%
Red	2	2	10^2	$\pm$ 2%
Orange	3	3	10^3	---
Yellow	4	4	10^4	---
Green	5	5	10^5	$\pm$ 0.5%
Blue	6	6	10^6	$\pm$ 0.25%
Violet	7	7	10^7	$\pm$ 0.1%
Grey	8	8	10^8	---
White	9	9	10^9	---
Gold	-	-	10^{-1}	$\pm$ 5%
Silver	-	-	10^{-2}	$\pm$ 10%
No Color	-	-	-	$\pm$ 20%



APPENDIX C

Identifying Components

B. Capacitors

Many kinds of capacitors are used in Electronics. Common Printer Capacitors include:

Mica Capacitors (in which the intervening non-conducting material is composed of Mica, typically range from 10pF to 0.01 mFd., and are generally molded into a plastic case to protect plates from corrosion).

Paper Capacitors (which are strips of metal foil separated by waxed paper, typically ranging from 250pF to 1 mFd., and are generally sealed in wax).

Molded Paper Capacitors (in appearance similar to a resistor, molded paper capacitors are encased in plastic, have similar capacitive values to paper capacitors, but may operate over a wider temperature range).

Metal-Cased Paper Capacitors (Paper Capacitors for rugged uses are encased in metal with the case serving as one of the capacitor leads).

Ceramic Capacitors (which use film deposits of silver as plates and ceramic material for the intervening non-conductive material as well as the capacitor package. They are constructed in a wide variety of shapes, the most common being disk and tubular and typically range in value between 1pF and 0.01 mFd.)

Electolytic Capacitors (for values of capacitance in excess of 1mFd, Electrolytic capacitors are used. Unlike other capacitors, these are polarized and care must be taken to observe polarity when inserting an electrolytic capacitor in a circuit. A line on one end of the capacitor, a blob on one of the leads, or a + at one of the poles marks the positive terminal).

A line on the end of a non-polarized capacitor denotes the lead attached to the outer foil and, although not often applicable in Printer Electronics, denotes the lead to be grounded for shielding in an RF circuit.

No standardization existsin the industry on coding capacitive values and, if a capacitor is not obviously marked, it is suggested that a manufacturer's specification sheet on the capacitor be referenced.

C. Inductors No standardization existsin the industry on coding inductive values and if an inductor is not obviously marked, it is suggested that a manufacturer's specification sheet be referenced.

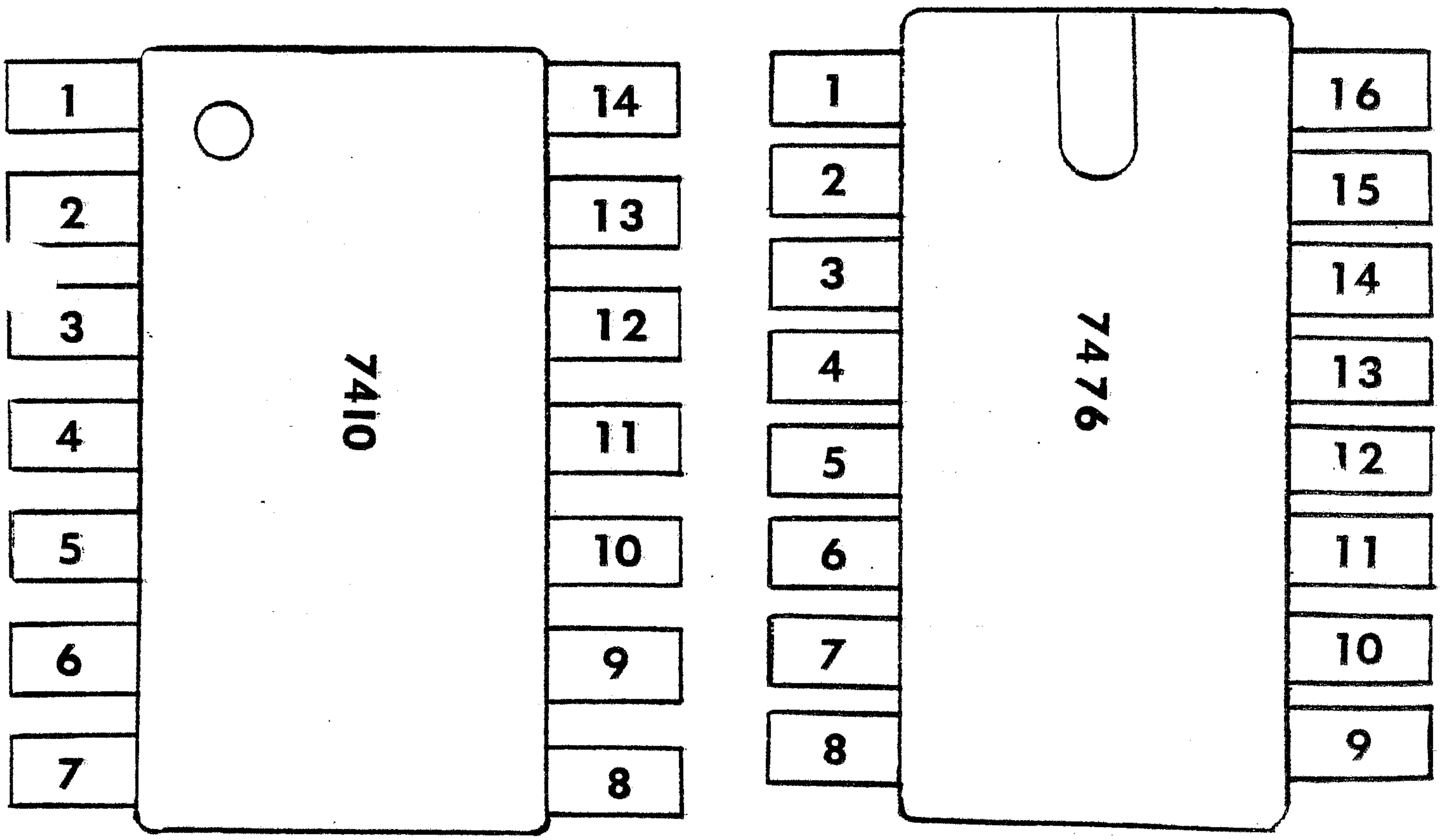
D. Diodes The cathode of a diode is denoted on the diode generally by a line encircling the component on the cathode side.

E. Transistors The emitter of a transistor is generally marked via an E on the underside of the transistor case or a small metal protrusion jutting out adjacent to the emitter lead. Leads are often asymmetrical so that identification of emitter allows proper transistor insertion.

Identifying Components

<u>Transistors Contd.</u> If unsure, a manufacturer's specification sheet for the transistor should be referenced. The transistor type is generally printed on the transistor case.

F. <u>Integrated Circuits</u> A slot or a small circle at one end of an I.C. allows identification of pin 1 of that I.C. Numbering of pins proceeds downward along one side of the I.C. and up the opposite side. I.C. types are generally printed on the top of the I.C. (Reference diagram below).



INTEGRATED CIRCUITS

APPENDIX D
SAMPLE PROBLEMS

1. Calculate set time after last trigger pulse for a retriggerable one-shot with a 4KΩ external resistor and a 25 μF external capacitor.

T_{set} (Retrig.) = .31 (R_{ext})(C_{ext}) (retrig. capacitor formula)

$T_{set} = .31 \times 4 \times 10^3 \Omega \times 25 \times 10^{-6} F$

$T_{set} = .31 \times 4 \times 25 \times 10^{(3)+(-6)}$ (Exponent rule $X^a \cdot X^b = X^{a+b}$)

$T_{set} = .31 \times 100 \times 10^{-3}$

$T_{set} = 31 \times 10^{-3}$ SEC = 31 mSEC

2. Calculate total resistance in circuit A.

R_1, R_2, R_3, R_4 = Parallel Resistors

$1/R_{T_P}$ (Parallel Resistance) = $1/R1 + 1/R2 + 1/R3 + 1/R4$ (Parallel Resistance Formula)

$1/R_{T_P} = 1/10 + 1/20 + 1/40 + 1/40$ (Insert Values)

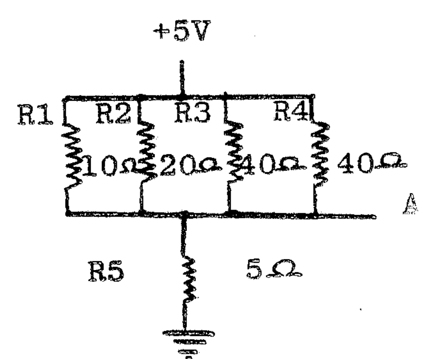
$1/R_{T_P} = 4/40 + 2/40 + 1/40 + 1/40$ (Common Denominators)

$1/R_{T_P} = 8/40 = 1/5$ (Reduced to lowest terms)

$5/R_{T_P} = 1$ (Multiply both sides of Eq. by 5)

$5 = R_{T_P}$ (Multiply both sides of Eq. by R_{T_P})

Total Circuit Resistance = $R_T = R_{T_P} + R5$
$= 5 + 5$
$= 10\Omega$



CIRCUIT A

SAMPLE PROBLEMS

3. What is the voltage at A in circuit A?

Total parallel resistors and R5 form a voltage divider circuit.

$$V_o = \frac{V_{in} \times R5}{\text{R equivalent for total parallel resistors (problem 2)} + R5}$$

$$V_o = \frac{5 \times 5}{5 + 5} = \frac{25}{10} = +2.5V$$

4. What is the current through R5 in circuit A?

Since all of the current that flows through circuit A flows through R5:

$$I_{R5} = I_{\text{Total Circuit}} = \frac{\text{E Total Circuit}}{\text{R Total Circuit}} = \frac{+5V}{10\Omega} = 1/2 \text{ A}$$

5. What is the current through R1 in circuit A?

We've found that a total of 1/2 A flows through circuit A but is divided through the various circuit paths of the parallel resistors. The current divider formula given in the text is for a 2 path current division. Therefore to find the current through R1, we must find the equivalent resistance of R_2, R_3, and R_4, and then use the current divider formula.

R equivalent (R_2, R_3, R_4) : $1/R_T = 1/R_2 + 1/R_3 + 1/R_4 = 1/20 + 1/40 + 1/40$

$$= 2/40 + 1/40 + 1/40 = 4/40 = \frac{1}{10}$$

$$\frac{10}{R_T} = 1 \quad , \quad 10\Omega = R_T = \text{Equiv. Res. of } R_{2,3,4}$$

$$\text{Current } (I_{R_1}) = I_o = \frac{I_{in} \times (\text{Equiv. Res. } R_2, R_3, R_4)}{(\text{Equiv. Res. } R_2, R_3, R_4) + R_1} = \frac{1/2 \times 10}{10 + 10} = \frac{5}{20} = \frac{1}{4} = 250 \text{ mA}$$

SAMPLE PROBLEMS

6. Calculate total capacitance in circuit B neglecting any input/output capacitance of the inverters.

Capacitance in series: $1/C_T = 1/C1 + 1/C2 = 1/30 + 1/30$

$= 2/30 = 1/15$

Therefore: C_T series $= 15pF$

Total capacitance $= C_T$ series $+C_3 = 15pF + 10pF = 25pF$

7. Calculate the frequency at which circuit B oscillates.

$F = 1/2\pi\sqrt{LC} = 1/2\,(3.14)\sqrt{(25X10^{-6})(25\ X10^{-12})}$

$= 1/2\,(3.14)\sqrt{25^2\ X\ 10^{-18}}$ (Exponent Rule: $X^a \cdot X^b = X^{a+b}$

$= 1/2\,(3.14)\,(25\ X\ 10^{-9})$ (Exponent Rule: $\sqrt{X^b} = X^{b/2}$.

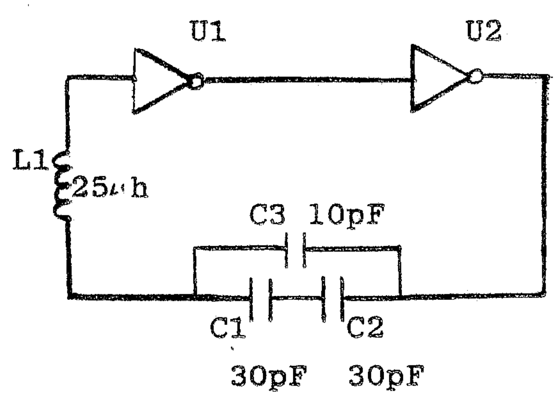
$= \dfrac{1}{6.28\ X\ 25\ X\ 10^{-9}}$

$= \dfrac{1}{157\ X\ 10^{-9}}$

$= .00637\ X\ 10^9$

$= 6.37\ X\ 10^6$ HZ

$=$ 6.37 MHZ



CIRCUIT B

SAMPLE PROBLEMS

8. Approximately how long after a voltage is applied to a capacitor will the capacitor be charged to 99% of the applied voltage?

A capacitor will attain 63% of the applied voltage in a time period determined by RC.

Therefore:

Time Period	Calculation/Comments	% of Applied Voltage to which Capacitor Charged
I	@ Time period I completion (= RC) the capacitor is charged to 63% of the applied voltage	63%
II	After the next time period = RC, the capacitor will increase its charge by an amount equal to 63% of the remaining applied voltage. Therefore Cap. Charge increase = 63% X remaining applied voltage = 63% X (total voltage - Voltage charged in first time period) = 63% X (100% - 63%) = 63% X 37% = 23.31%	86.31% (First time period + 2nd time period increase)
III	In the next time period the capacitor will increase its charge to 63% of the remaining applied voltage Therefore Cap. Charge increase = 63% X remaining applied voltage = 63% X (total voltage - Voltage charged in time period I & II) = 63% (100% - 86.31%) = 63% X 13.69% = 8.62%	94.93% (Time Period I + II + III)

Time Period	Calculation/Comments	% of Applied Voltage to which Capacitor Charged
IV	In the next time period the capacitor will increase its charge to 63% of the remaining applied voltage. Therefore Cap. Charge increase = 63% X (total voltage - Voltage charged in time period I, II, III) = 63% (100% - 94.93%) = 63% (5.07%) = 3.19%	98.12% (Time period I, II, III, IV)
V	In the next time period the capacitor will increase its charge to 63% of the remaining applied voltage. Therefore Cap. Charge increase = 63% (100% - 98.12%) = 63% (1.88%) = 1.18%	99.3% (After Time Periods I, II, III, IV, V

Therefore a capacitor will charge to approximately 99% of the applied voltage in the time = 5 X R X C

9. There are 150 turns of wire in the primary of a transformer and 300 turns of wire in the secondary. If 20 volts AC is applied to the primary, what is the voltage across the secondary?

$$\frac{VAC_p}{VAC_s} = \frac{T_p}{T_s}$$ (Transformer Formula)

$$\frac{20\ VAC}{VAC_s} = \frac{150}{300}$$

$$20\ VAC = \frac{150}{300}\ VAC_s$$ (Multiply both sides of Equation by VAC_s)

$$20\ VAC = \frac{VAC_s}{2}$$ (Reduce to lowest terms)

$$40\ VAC = VAC_s$$ (Multiply both sides of Equation by 2)