Part 66 Cat. B1 Module 4

ELECTRONIC FUNDAMENTALS

Vilnius-2017

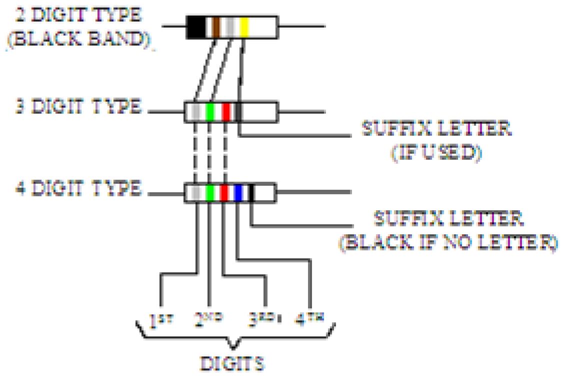

Figure 1-4. Standard diode color code system

Color	***Digit***	***Diode suffix letter***	***Color***	***Digit***	***Diode suffix letter***
Black	*0*	-	Green	*5*	E
Brown	*1*	A	Blue	*6*	F
Red	*2*	B	Violet	*7*	G
Orange	*3*	C	Gray	*8*	H
Yellow	*4*	D	White	*9*	I

Figure 1-5. Standard diode color code system

Diode Characteristics and Properties

First compare the properties of diode to those of resistor. A resistor is a linear device (as the voltage across a resistor changes, the current changes at the same rate). The current flow through resistor is determined by Ohms Law. **Fig. 1-6** shows the result of plotting voltage against current for a 200-ohm resistor.

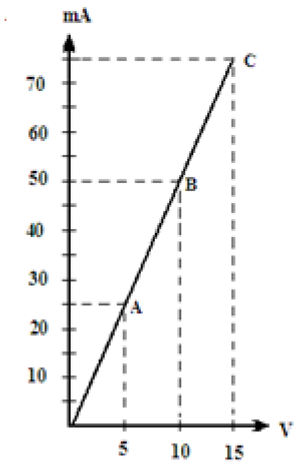

Figure 1-6. I-E dependence for 200Ω resistor

At point A, the voltage applied to the resistor is 5 volts, resulting in 25 mA of current. At point B, the voltage is 10V, resulting in 50mA. At point C, the voltage is 15V, resulting in 75mA of current. For every 5V increase, there is a 25mA increase in current.

The diode is something different. If resistor allows current flow in both directions, the diode does not. When switched in direct mode of operation called “forward bias” (the source of electric current is connected by “+” potential to anode) it first shows non-linearity in current-field dependence, than the changes in current along with applied voltage changes satisfy Ohms law as resistor does.

When connected in reverse mode of operation called “reverse bias” (the source of electric current is connected by “-” potential to anode), the diode shows maximum resistance. For this reason, diode is commonly used to convert AC to DC.

Current Graph

The voltage-current relationship in a diode is represented on **Fig. 1-7**. At point A, with 1V of bias, and a current of 5mA, the resistance is 200 ohms. At point B, with 3V of bias, and a current of 50mA, the resistance is 60 ohms.

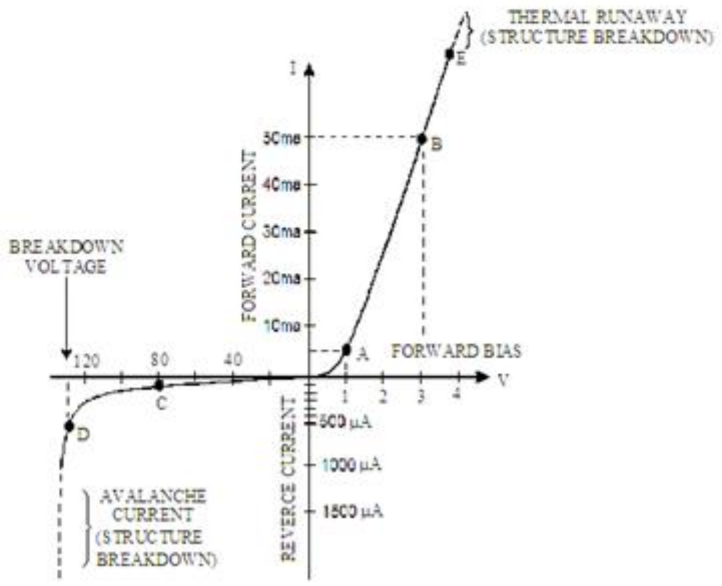

Figure 1-7. Voltage-current relationship in a diode

That means when the forward bias voltage is multiplied by three, the current increases ten times (a non-linear relationship between voltage and current). So when the forward bias was increased, resistance decreased.

This curve also shows than when we reverse bias a diode, it allows very little current flow. At point C, with 80V of reverse bias there is only 200µA of current (and a resistance of 400KΩ).

At point D of the curve, the current increases rapidly. This rapid increase in reverse current is called avalanche current. When the applied voltage is large enough more heat is generated, causing the diode to be destroyed.

Diode also could be destroyed if too much forward bias is applied (more current, more heat). This is called thermal runaway (the heat that is generated by excessive current will cause structure breakdown).

4.1.2A TRANSISTORS

Introduction

A transistor is a semiconductor device that uses a small amount of voltage or electrical current to control a larger change in voltage or current. For a long the individual-package transistor (**Fig. 1-29**) was the fundamental building block of the circuitry that governed the operation of former computers and radios. Combined in integral circuits with other components, now they are fundamental building blocks for cellular phones, and all other modern electronics.

Figure 1-29. Various types of individual transistors

The transistor is different from diode not only that it has one more element than the diode, but it can amplify as well. In some types they have more than three elements.

The term transistor was derived from the words transfer and resistor. This term was adopted because it best describes the operation of the transistor - the transfer of an input signal current from a low resistance circuit to a high-resistance circuit. Basically, the transistor is a solid-state device that amplifies by controlling the flow of current carriers through its semiconductor materials.

The three elements of the two-junction transistor are:

- The emitter, which gives off, or “emits” current carriers (electrons or holes);
- The base, which controls the flow of current carriers; and
- The collector, which collects the current carriers.

The basic purposes of a transistor are:

- Act as a variable resistance;
- Provide a variable voltage;
- Act as a switch or amplifier.

Transistor Symbols, Component Description and Orientation

Transistors are classified as either N-P-N (NPN) or P-N-P (PNP) according to the arrangement of their N- and P-materials. That is, an NPN transistor is formed by introducing a very thin lightly doped region of P-type material between two regions of N-type material (**Fig. 1-30**). On the other hand, a

PNP transistor is formed by introducing a very thin lightly doped region of N-type material between two regions of P-type material. Such transistors have two PN-junctions. One PN-junction called emitter-base junction is between the emitter and the base; the other PN-junction called collector-base junction is between the collector and the base. The two junctions share one section of semiconductor material so that the transistor actually consists of three elements.

Figure 1-30. Transistor classification into NPN and PNP types

Since the majority and minority current carriers are different for N- and P-materials, it stands to reason that the internal operation of the NPN and PNP transistors will also be different.

Fig. 1-31 presents the symbols for NPN and PNP transistors in use along with graphical explanation. The horizontal line represents the base, the angular with the arrow on it represents the emitter, and the other angular line represents the collector. The direction of the arrow on the emitter distinguishes the NPN from the PNP transistor. If the arrow points in, (Points iN) the transistor is a PNP. On the other hand if the arrow points out, the transistor is an NPN (Not Pointing iN).

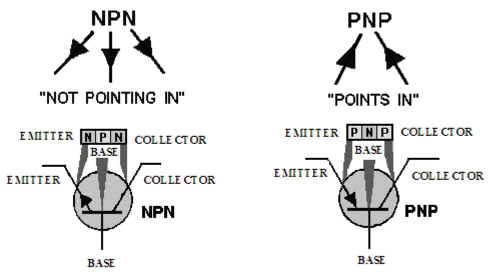

Figure 1-31. Transistor representations

The arrow always points in the direction of hole flow, or from the P to N sections, no matter whether the P section is the emitter or base. On the other hand, electron flow is always toward or against the arrow, just like in the junction diode.

The NPN transistor can be compared to two diodes, connected anode-to-anode (**Fig. 1-32A**), and the PNP transistor can be compared to two diodes, connected cathode-to-cathode (**Fig. 1-32B**).

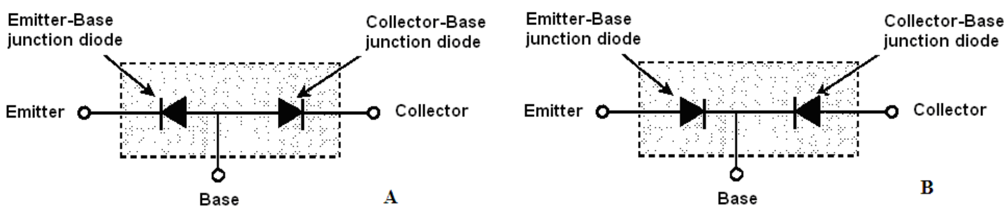

Figure 1-32. NPN (A) and PNP (B) transistors as two-diode combination

4.1.3A. INTEGRATED CIRCUITS

Integrated circuit is an assembly of electronic components, fabricated as a single unit, in which miniaturized active devices (e.g., transistors and diodes) and passive devices (e.g., capacitors and resistors) and their interconnections are built up on a thin substrate of semiconductor material (typically silicon). The resulting circuit is thus a small monolithic "chip," which may be as small as a few square centimetres or only a few square millimetres. The individual circuit components are generally microscopic in size.

Integrated circuits have their origin in the invention of the transistor in 1947 by William B. Shockley and his team at the American Telephone and Telegraph Company's Bell Laboratories. Solid-state devices proved to be much sturdier, easier to work with, more reliable, much smaller, and less expensive than vacuum tubes. Using the same principles and materials, engineers soon learned to create other electrical components, such as resistors and capacitors. Now that electrical devices could be made so small, the largest part of a circuit was the awkward wiring between the devices.

In 1958 Jack Kilby of Texas Instruments, Inc., and Robert Noyce of Fairchild Semiconductor Corporation independently thought of a way to reduce circuit size further. They laid very thin paths of metal (usually aluminum or copper) directly on the same piece of material as their devices. These small paths acted as wires. With this technique an entire circuit could be "integrated" on a single piece of solid material and an integrated circuit (IC) thus created. ICs can contain hundreds of thousands of individual transistors on a single piece of material the size of a pea. Some ICs are shown on **Fig. 1-38**.

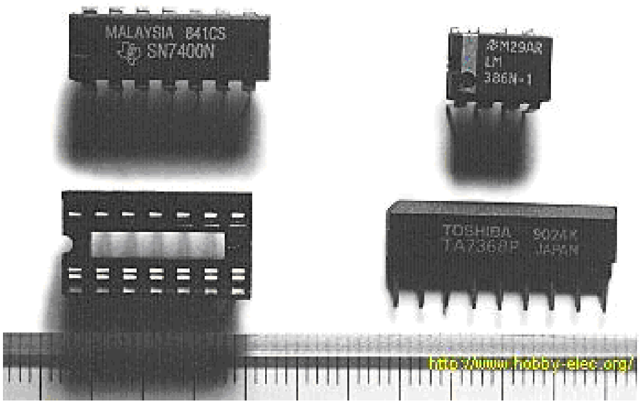

Figure 1-38. ICs packages

The top left device in **Fig. 1-38** is an SN7400. It contains 4 separate "2 input NAND" circuits. The „NOT“ function of these circuits is provided by inverter shown as a „circle“ on the output of each gate. There are 7 pins on each side, 14 pins total. ICs in this form are called Dual In line Package (DIP). When an IC has only one row of pins, it is called a Single In line Package (SIP). The number of pins changes depending on the function of IC.

At the bottom left of **Fig. 1-38** is an IC socket for use with 14 pin DIP ICs. ICs can be attached directly to the printed circuit board with solder, but it's better to use an IC socket, because you can easily exchange it should the IC fail.

On the top right of **Fig. 1-38** is an LM386N audio amplifier. It can be used for amplification of low frequency, low power signals. IT has 8 pins and the maximum output is 660mW. On the bottom right of **Fig. 1-38** is a TA7368P, which also is for amplification of low frequency electric power. It has a maximum output of 1.1 watts. It is a 9 pin SIP IC.

A separate view of SN7400 is presented on **Fig. 1-39** along with its structure.

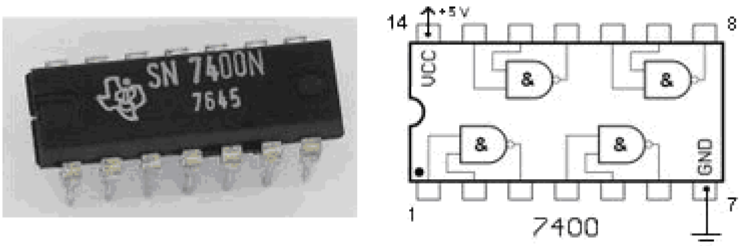

Figure 1-39. SN7400 digital ICs and its internal element's structure

Analog versus Digital Circuits

Analog, or linear, circuits typically use only a few components and are thus some of the simplest types of ICs. Generally, analog circuits are connected to devices that collect signals from the environment or send signals back to the environment. For example, a microphone converts fluctuating vocal sounds into an electrical signal of varying voltage. An analog circuit then modifies the signal in some useful way - such as amplifying it or filtering it of undesirable noise. Such a signal might then be fed back to a loudspeaker, which would reproduce the tones originally picked up by the microphone. Another typical use for an analog circuit is to control some device in response to continual changes in the environment. For example, a temperature sensor sends a varying signal to a thermostat, which can be programmed to turn an air conditioner, heater, or oven on and off once the signal has reached a certain value.

A digital circuit, on the other hand, is designed to accept only voltages of specific given values. A circuit that uses only two states is known as a binary circuit. Circuit design with binary quantities, "on" and "off" representing 1 and 0 (i.e., true and false), uses the logic of Boolean algebra.

Linear Circuit

A *linear circuit* is an electric circuit in which, for a sinusoidal input of frequency *f*, any output of the circuit is also sinusoidal with frequency *f*. The output need not be in phase with the input.

Another way of defining a linear circuit is any electronic circuit whose output is a linear transform of its input, where linear means that

$$f(ax_1+bx_2) = af(x_1) + bf(x_2).$$

4.3A SERVOMECHANISMS

A *servomechanism*, usually shortened to *servo*, is a device used to provide mechanical control at a distance. For example, a servo can be used at a remote location to proportionally follow the angular position of a control knob. The connection between the two devices is not mechanical, but electrical or wireless.

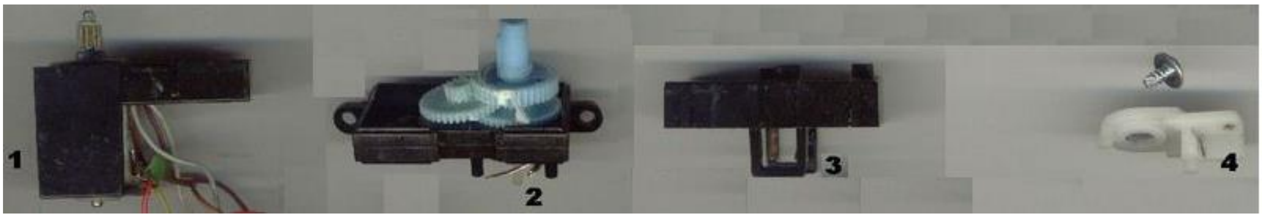

Figure 3-1. Small servo mechanism: 1 - electric motor; 2 - position feedback potentiometer; 3 - reduction gear and 4 - actuator arm

The most common type of servo is the one mentioned above, which gives *positional control*. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force (**Fig. 3-1**). Other types of servos use hydraulics, pneumatics, or magnetic principles. Servos are found in many applications. They operate the throttle of engines that use a cruise control. Fly-by-wire systems in aircraft use servos to actuate the control surfaces that control the aircraft. Radio-controlled airplanes use servos for the same purpose. Many autofocus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus.

Typical servos give an angular output. Linear types are common as well, using a screw thread or a linear motor to give linear motion. There are more convenient terms used in connection with servo mechanisms description. They are transducers and actuators.

Introduction to Synchros

Synchros are found in a lot of communication, detection and navigation systems. The importance of synchros is sometimes taken lightly because of their low failure rate.

The understandin of the theory of operation and the alignment procedures for synchros is well ahead of the problem when a malfunction does occur. The term "synchro" is an abbreviation of the word "synchronous". It is the name given to a variety of rotary, electromechanical, position-sensing devices. **Fig. 3-2** shows a view of typical synchro. A synchro resembles a small electrical motor in size and appearance and operates like a variable transformer. The synchro, like the transformer, uses the principle of electromagnetic induction.

Synchros are used primarily for the rapid and accurate transmission of information between equipment and stations. Examples of such information are changes in course, speed, and range of targets or missiles; angular displacement (position) of the aircraft rudder and ailerons. This

Operation of Servo System basics

The closed-loop servo system is normally made up of electromechanical parts and consists basically of a synchro-control system, servo amplifier, servo motor, and some form of feedback (**Fig. 3-4**).

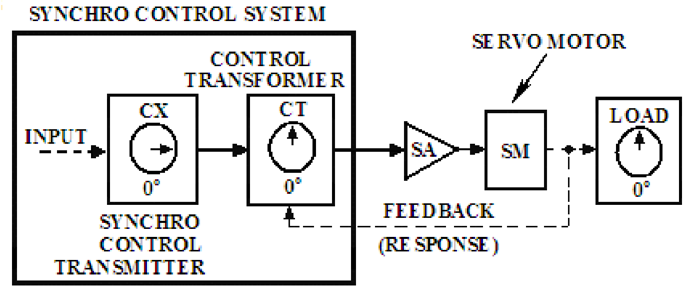

Figure 3-4. A basic closed-loop servo system

The synchro-control system provides a means of controlling the movement of the load, which may be located in a remote space. The servo amplifier and servo motor are the parts of the system in which power is actually developed (to move the load).

The controlling signal from a CT is relatively weak, too weak to drive an electric motor directly. Assume (**Fig. 3-4 – Fig. 3-7**) that the control signal will be initiated by a handcrank input connected to the synchro transmitter (CX). The dials located on the CX and the CT indicates the positions of the synchro's rotors, while the dial on the load indicates the position of the load.

First the dials of both the CX and the load indicate that the load is in the desired position (**Fig. 3-4**). Because the load is where it should be, there will be no error signal present at the servo amplifier and no power to the servo motor.

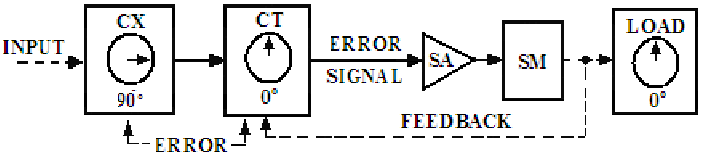

Figure 3-5. Closed-loop servo system

Next (**Fig. 3-5**) the rotor of the CX has been moved by the handcrank to 90º (This indicates that it is ordered to move the load by 90º). At this moment the rotor of the CT is still at 0º. The CT develops a signal, referred as the *error signal*, which is proportional in amplitude to the amount the CT rotor is out of correspondence with the CX rotor. The phase of the error signal indicates the direction the CT rotor must move to reduce the error signal to zero or to "null out." The error signal is sent to the servo amplifier.

Torque Differential Transmitter

In the torque differential transmitter, both the rotor and stator windings consist of three Y-connected coils (**Fig. 3-16**). The stator is normally the primary, and receives its input signal from a synchro transmitter. The voltages appearing across the drfferential's rotor terminals (R1, R2, and R3) are determined by the magnetic field produced by the stator currents, the physical positioning of the rotor, and the step-up turns ratio between the stator and the rotor. The magnetic field, created by the stator currents, assumes an angle corresponding to that of the magnetic field in the transmitter supplying the signal.

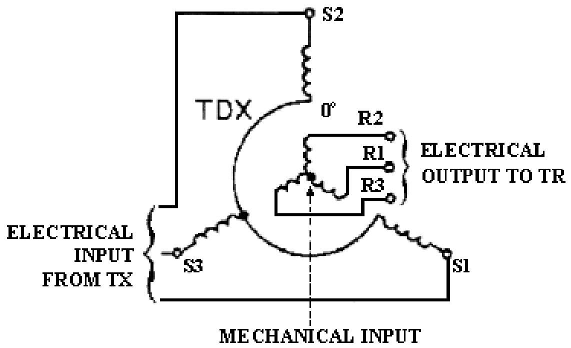

Figure 3-16. Torque differential transmitter

The position of the rotor controls the amount of magnetic coupling that takes place between the stator magnetic field and the rotor, and therefore, the amount of voltage induced into the rotor windings. If the rotor position changes in response to a mechanical input, then the voltages induced into its windings also change. Therefore, the output voltage of the TOX varies as a result of either a change in the input stator voltage or a change in the mechanical input to the rotor. This electrical output of the TDX may be either the sum or the difference of the two inputs depending upon how the three units (the TX, the TDX, and the TR) are connected.

Torque Differential Receiver

The torque differential transmitter (TDX) and the torque differential receiver (TDR) are electrically identical. The only difference in their construction is that the receiver (TDR) has a damper, which serves the same purposes as the damper in the TR - it prevents the rotor from oscillating. The real difference in the receiver lies in its application. It provides the mechanical output for a differential synchro system usually as the sum or difference of two electrical inputs from synchro transmitters. As in the case with the TDX, the TDR addition or subtraction function depends upon how the units in the system are connected.

Basically, the torque differential receiver operates like the electromagnets we discussed earlier in this chapter. In **Fig. 3-17**, the rotor and stator of the torque differential receiver receive energizing currents from two torque transmitters. These currents produce two resultant magnetic fields, one in the rotor