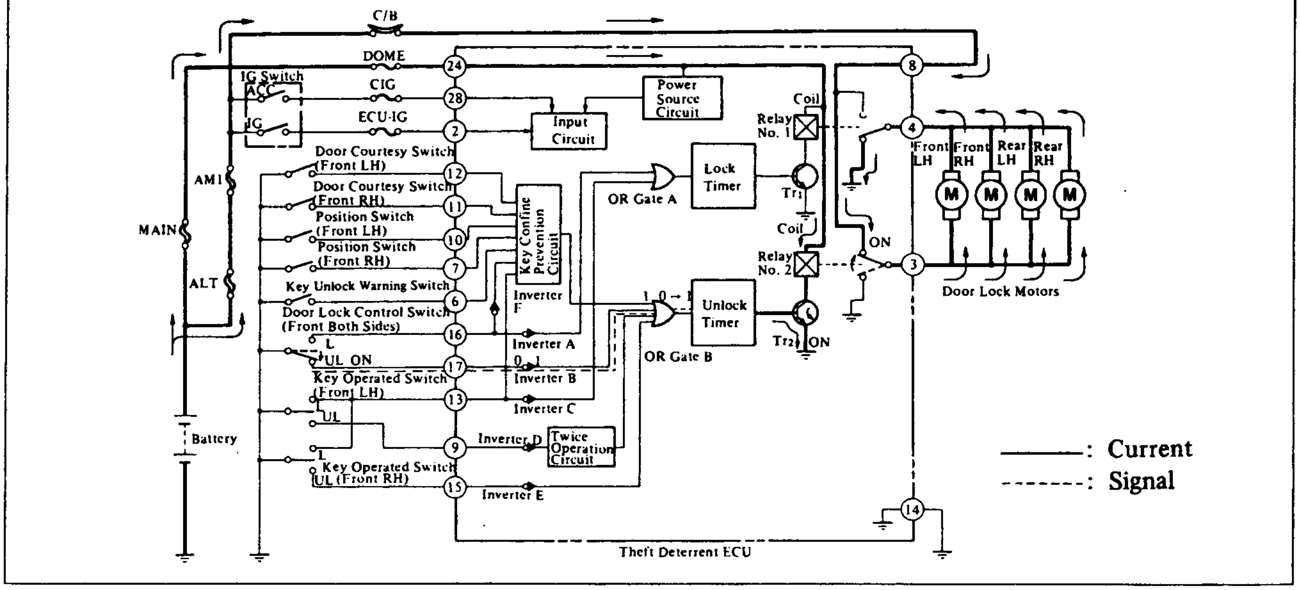


COMPUTER LOGIC SCHEMATIC

COMPUTERS AND LOGIC CIRCUITS

Dealing with computers can seem overwhelming for those who are accustomed to working with mechanical systems. Since we cannot actually see what is going on inside the computer or the system it controls, computers may not be as easy to understand as mechanical components such as transmissions and engines. However, computers are not as complicated as they might sound. This chapter will help demystify computers.

The computers found on a vehicle are really no different than any other computer encountered in everyday life. Vehicle computers rely on data from some type of input device and then follow the instructions in their programs to determine the required output. The input device may be a keyboard or a coolant temperature sensor, and the output may be video display or a fuel injector. The program the computer follows may be for word processing or for controlling fuel metering and engine timing.

Computers can process a great deal of data very quickly and accurately, making them very useful for several jobs including controlling many of the systems on an automobile. This chapter explains how a computer functions, starting with the inputs and outputs, the computer's central processing unit (CPU) and memory, and logic gates and their symbols.

Understanding how computers work is essential because most vehicles have some type of computer. Knowing how computers operate and fit together with various sensors and actuators will increase your ability to diagnose and repair problems.

This chapter is divided into the following sections:

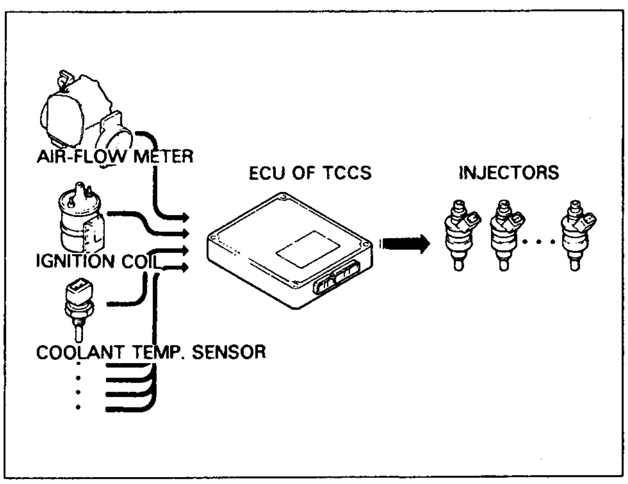
Analog and Digital Inputs
Analog and Digital Outputs
Signals, including.
- *Analog and digital wave forms*
- *AID converters*
- *D/A converters*

Microprocessor
Random Access Memory (RAM)
Read-Only Memory (ROM)
Programmable Read-Only Memory (PROM)
Logic Circuits

INPUTS

As demonstrated in the previous chapter, the ECU, as well as any other automobile computer, depends on sensors to monitor various system functions and report their status back to the computer. Once the computer receives the data from the sensors, it analyzes it against pre-programmed standards and acts accordingly.

One problem with many of these inputs is that they do not speak the same language as the computer. The computer only understands digital signals or on/off signals. A resistive type sensor provides the computer with a variable voltage, known as an analog signal. Some sensors, like the switch type sensors, do provide a digital signal for the computer. In this case, the computer can interpret the signal because it is either on or it is off-nothing in-between.



Because computers must have digital inputs to use the data received, all analog signals must be converted to digital. How computers interpret the analog signals with an A/D converter will be covered later.

OUTPUTS

Computer output to most actuators is digital. The signal tells the actuator to either turn on for a specified length of time or shut off. Stepper motors, relays and solenoids have only two modes of operation: on or off.

Again, when actuators require a variable voltage, such as the speed control for a blower motor for air conditioning, the computer needs another interpreter. In this case, the interpreter is a D/A converter, which will be covered later.

SIGNALS

As explained previously, the two types of signals are analog and digital. The voltage of these signals may change slowly or very quickly depending on the sensor and what it monitors. When signals are expressed as wave forms on an oscilloscope, the analog signal shows up as a flowing line with curved peaks and valleys, indicating variable rises and drops in voltage. The digital signal has vertical rises and drops, and a horizontal line with sharp corners. The top horizontal lines indicate when the voltage is high or on and the bottom horizontal lines indicate when the voltage is low or off.

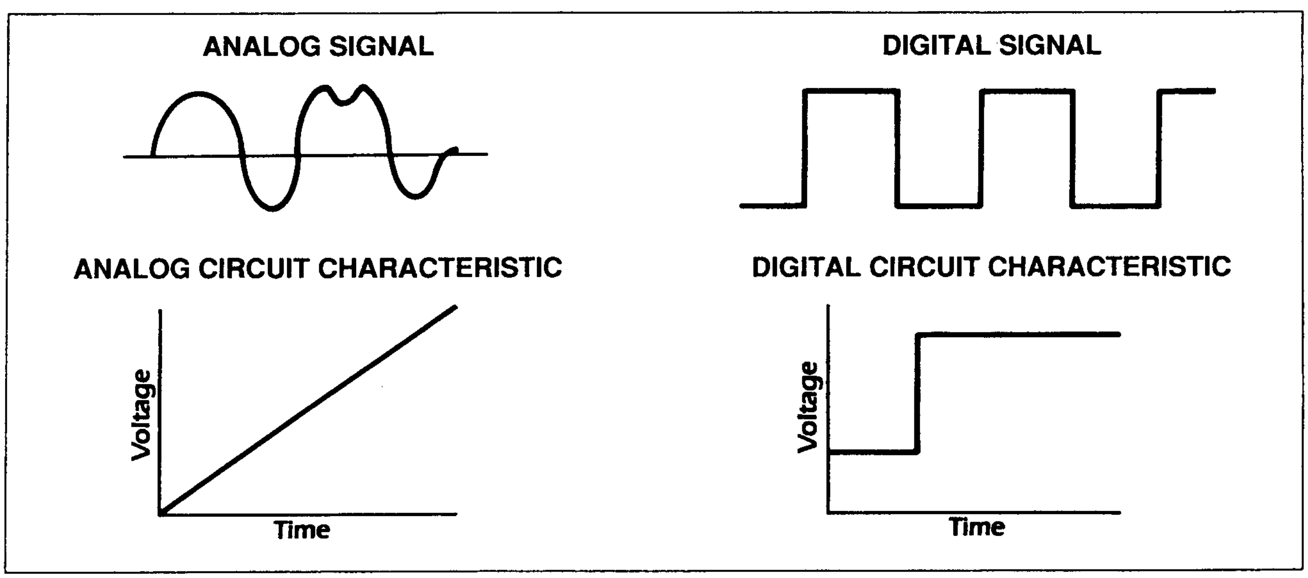
When using a voltmeter to measure digital or analog signals that change very quickly, such as speed sensor or RPM signals, it is important to remember that the meter reading is not a true representation of the signal. A voltmeter displays the average reading of the signal. For example, with a digital signal the voltmeter will display the average between zero volts (off) and the voltage when the circuit was on. The computer looks for "on" signals, not voltage. The voltmeter, however, is looking for voltage, not whether a signal comes through. A voltmeter may show that the voltage is within specifications even if a pulse is missing. That missing signal could represent the cause of an engine problem. You might not know it by the voltmeter, causing you to assume incorrectly the problem is elsewhere and waste time searching.

So if you suspect the problem is in a certain circuit, but the voltmeter does not show it, consider using an oscilloscope for a more accurate reading. At the very least, you should be aware of this voltmeter limitation with digital signals.

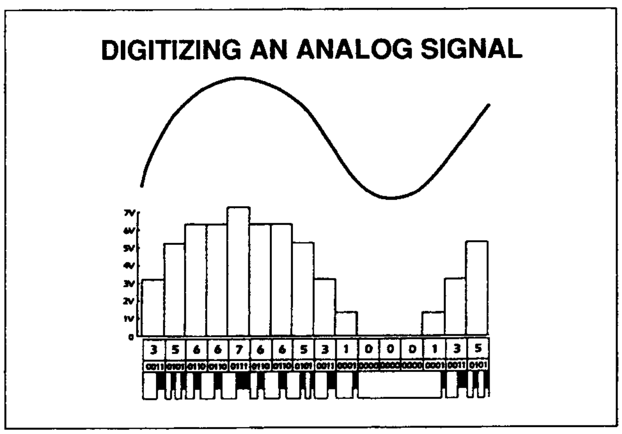
When dealing with computer signals it is also important to remember that there is a difference between the signal source and the source of the voltage on the signal wire. This is especially important when a sensor input goes to more than one computer, such as a speed sensor signal, or if the signal is from one computer to another. One computer may supply the voltage to the sensor which toggles the voltage to ground, and the other computer may just monitor the signal. If a wire is disconnected from the computer that supplies voltage to the sensor, the signal is lost to both computers. Do not mistake this for a defective computer.

Analog signals also have limitations in that their inputs are not usable by the computer until translated into digital signals. The A/D converter handles that translation.

This takes us briefly back to computer language. Digital on/off can be represented by the binary numbering system of 0 (off) and 1 (on). Any decimal number (1, 2, 3, etc.) can be represented using O's and 1's so the computer understands. The several thousand transistors inside the computer's microprocessor can switch on and off in combinations that equal any binary number in a microsecond.

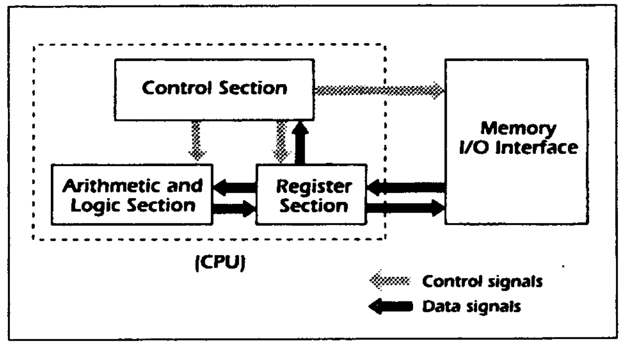


The A/D converter changes the analog signal to this binary language by taking samples of the analog signal at a frequency known as the sampling rate. The converter measures the wave and assigns a digital value to it. The higher the sampling rate, the closer the digital signal comes to representing the analog one. In most cases each sample is divided into eight bits. Each bit is assigned either a "0" or a "1". These eight bits are called a word. As illustrated (below), whenever the A/D converter samples the signal, it assigns a binary number to the voltage at that point (which the computer reads as a series of "ONs" and "OFFs"), and slices up the wave like a loaf of bread.



With the signal converted to eight-bit words, the computer can use the data from the sensor. The computer then sends out instructions in the form of a digital signal to an actuator. In most cases this works because most actuators are solenoids or stepper motors which operate on digital commands.

There are, however, some components such as blower motors or the power steering pump motor on the 1991 MR2, that require variable voltage to operate motors at variable speeds. In such cases, the computer uses a D/A converter to change the digital signal to analog. The principles of D/A converter operation are the same as the A/D converter. The pulses of voltage coming from the computer are converted to variable voltage.



THE MICROPROCESSOR

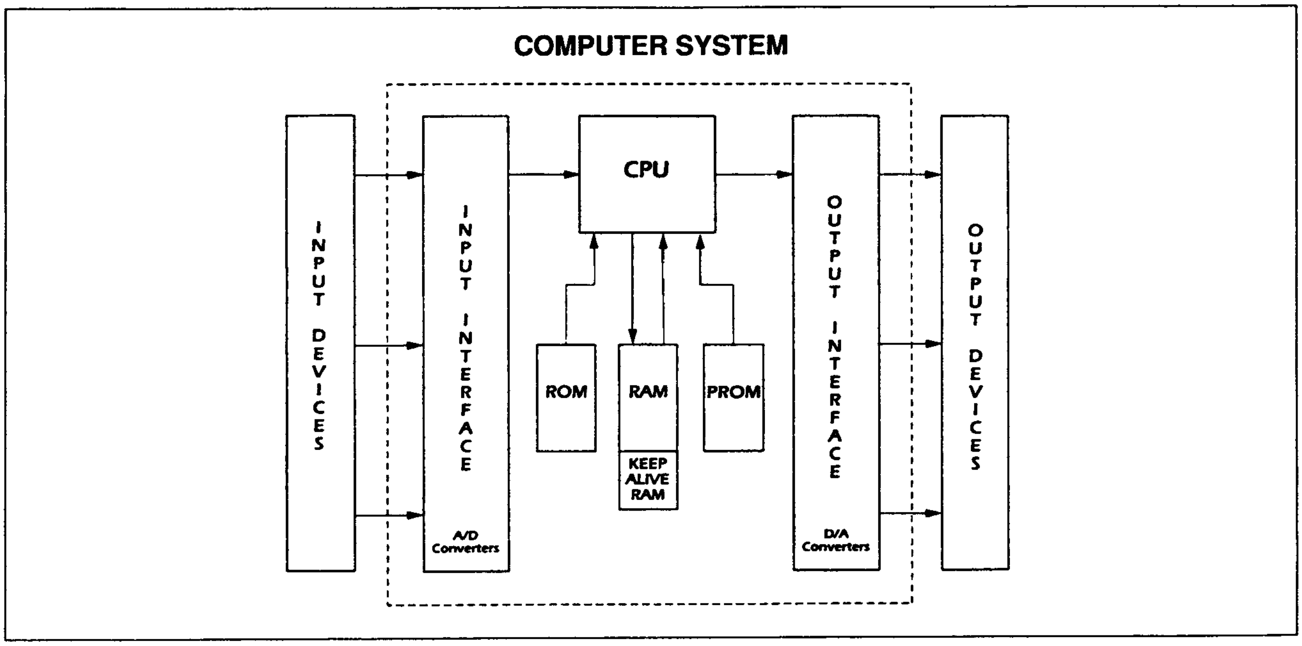
The microprocessor is the heart of the computer. It is also called the central processing unit (CPU). Again, keep in mind that the CPU does not perform complicated operations. Instead, it performs thousands of simple operations incredibly fast. To keep all of the operations the CPU performs from becoming entangled, it executes them in order, paced by a clock.

The CPU can be divided into three sections: the control section, the arithmetic and logic section, and the register section.

The control section controls the computer's basic operations. It is programmed with instructions from a memory to handle these chief operations:

Sending data from one part of the computer to another
Data input and output to and from the computer
Arithmetic calculations
Halting computer operations
Jumping to another instruction during the running of a program

The arithmetic and logic section carries out the actual processing of data, which consists of arithmetic operations and logical operations.



The register section temporarily stores data or programs until they are sent to the arithmetic and logic section or the control section

COMPUTER MEMORY

Computers have their own filing system, known as "memory," which is the internal circuitry where programs and data are stored. Computer memory is divided into separate addresses to which data is sent y the CPU. The CPU then knows where to find that data when it is needed. Computers use their main memories for large amounts of data or program information. There are two kinds of memory: random access memory (RAM) and read-only memory (ROM).

RANDOM ACCESS MEMORY (RAM)

RAM is memory which the computer can both read from and write to. This is where the computer stores data received front sensors, such as engine RPM or coolant temperature. RAM works like thousands of toggle switches which can be either on or off to represent 0's and 1's. This is how the data is stored in RAM. The switches work like spring loaded switches, therefore they must be held in the on" position electrically. If power is lost, everything stored in RAM is lost.

In most of the computers used on Toyotas, the RAM is divided into two sections. One section receives its power from the ignition switch. This is where data about operating conditions, such as vehicle speed and coolant temperature, is stored. The other section, called Keep Alive Memory, is powered directly by the battery. Information such as diagnostic codes is stored in Keep Alive Memory so that it is retained after the ignition is off. This is why a fuse or battery cable has to be removed to clear diagnostic codes.

READ-ONLY MEMORY (ROM)

This is where the basic operating instructions for the computer are located. The instructions are built into the chip when it is manufactured and cannot be changed. The computer can only read the information located in ROM and cannot write to it or use it to store data. Since the information in ROM is built in during manufacture, it is not lost when power is removed.

PROGRAMMABLE READ-ONLY MEMORY (PROM)

A PROM is like a ROM except it can be programmed or have information written to it once. This is done before it is installed in the computer. The computer can only read from the PROM and cannot write to it. The PROM contains the specific program instructions for the computer, such as the timing advance curve for a particular engine or the shift points for an automatic transmission. There are other types of programmable ROM being used, such as erasable programmable read only memory (EPROM) which can be erased by ultraviolet light and reprogrammed. Another type is electronically erasable programmable read only memory (EEPROM) which can be erased electronically and reprogrammed. This is all done outside of the computer by the manufacturer.

NON-VOLATILE MEMORY

Some computers use a type of RAM that is non-volatile, meaning that it retains its memory when the power is removed. This type of memory can only be erased by going through a specific procedure. This is the type of memory used to store code 41 in the SRS air bag system on Celica and Supra.

LOGIC CIRCUITS

As computers and solid state control modules become more prevalent on automobiles, some of the logic gate symbols that represent their internal circuits will show up more often. It is necessary to know not only what the logic symbols stand for, but to understand the basic operation of the circuits they represent when you analyze wiring diagrams during troubleshooting. Therefore, you should know a little about logic circuits and the symbols used to represent them. A logic gate symbol is simply a shorthand way of representing an electronic circuit that operates in a certain way. Understanding the logic symbols can make understanding the operation of a circuit much quicker and easier than if the circuit were represented by showing all the transistors, diodes and resistors. The logic symbols shown in diagrams in the EWD and New Car Feature book show what pin voltages must be present for an electronic controller to function properly.

Again, anything connected with a computer is based on the digital on/off language. The same holds true for logic circuits, which are made up of transistors combined in units called "gates." These gates process two or more signals logically. In essence, they are switches. Depending on the input voltage, the gate or switch will be either on or off.

The first thing to learn about the different gates is their symbols. Once you know the symbols and how each gate works, diagnosing a computer related problem will be easier.

Five common logic gates are the AND, OR, NOT, NAND, and NOR. Each gate is represented by a different symbol and has a chart called a "truth table" which shows all different combinations of inputs and corresponding outputs. The inputs and outputs are represented by 0's and 1's with 0 meaning off or no voltage and 1 meaning on or voltage.

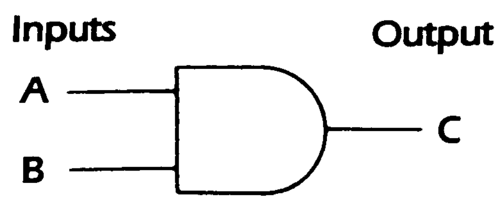
AND GATE

The AND gate can be thought of as a circuit with two switches connected in series. If either switch is open, the circuit does not operate. The same is true if both switches are open. Both switches must be closed for the circuit to operate. Refer to the truth table and note how an AND gate works—unless both inputs are "on," the output is "off." If you trace through the corresponding circuit schematic for an AND gate, you see that it also will function in the same manner.

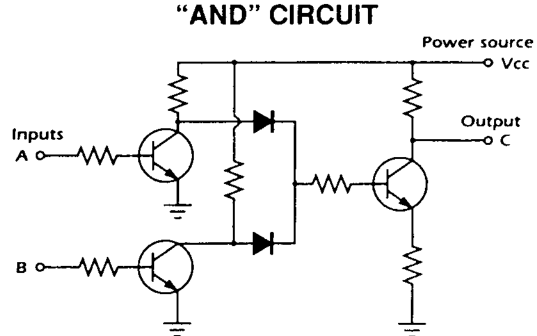
TRUTH TABLE FOR "AND" GATE

Input A	Input B	Output C
0	0	0
0	1	0
1	0	0
1	1	1

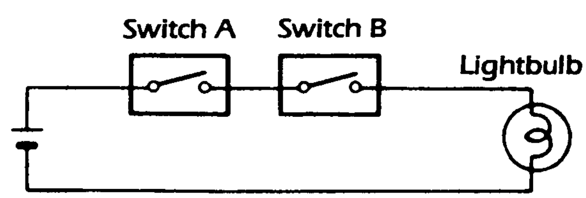
LOGIC SYMBOL FOR "AND" GATE



ACTUAL SEMICONDUCTOR "AND" CIRCUIT



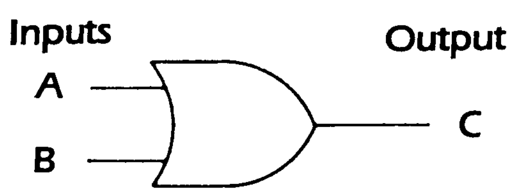
EQUIVALENT MECHANICAL CIRCUIT



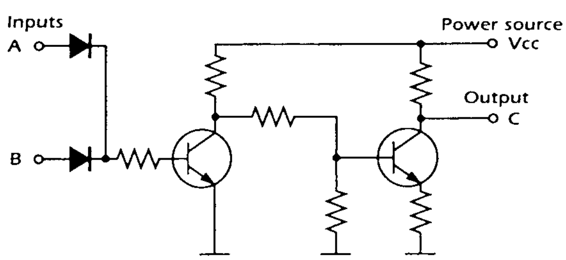
OR GATE

An OR gate can be thought of as a mechanical circuit with two switches connected in parallel. If both switches are open, the circuit does not function, but if either switch is closed the circuit can function. The same is true if both switches are closed—the circuit still operates. This is illustrated in the truth table for the OR gate.

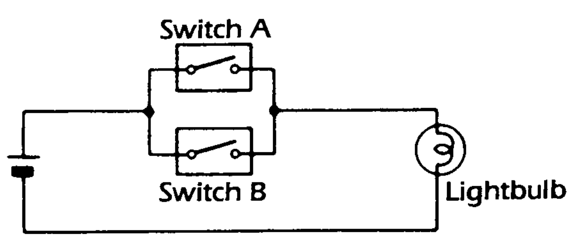
LOGIC SYMBOL FOR "OR" GATE



ACTUAL SEMICONDUCTOR "OR" CIRCUIT



EQUIVALENT MECHANICAL CIRCUIT



TRUTH TABLE FOR "OR" GATE

INPUTS A	INPUTS B	OUTPUT C
0	0	0
0	1	1
1	0	1
1	1	1

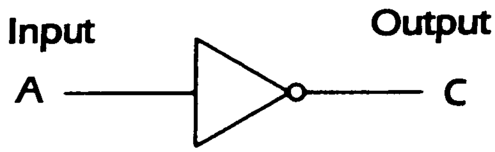
NOT GATE

The NOT gate is sometimes called an inverter because the voltage at the output is always the opposite of the input. In other words, if there is voltage at the single input, the output is off and if the input is off, the output is on. The NOT gate can be represented by a switch and a normally closed relay. When the switch is open the relay is not energized and the contacts are closed, but when the switch is closed the relay is energized and the relay contacts open.

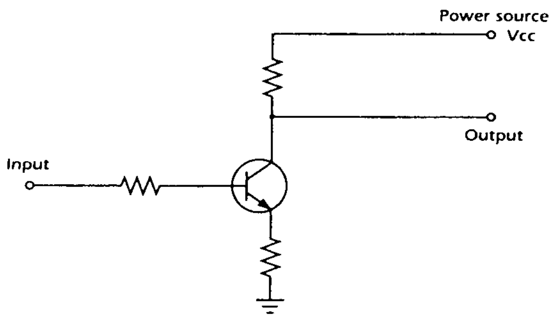
TRUTH TABLE FOR "NOT" GATE

INPUT A	OUTPUT C
1	0
0	1

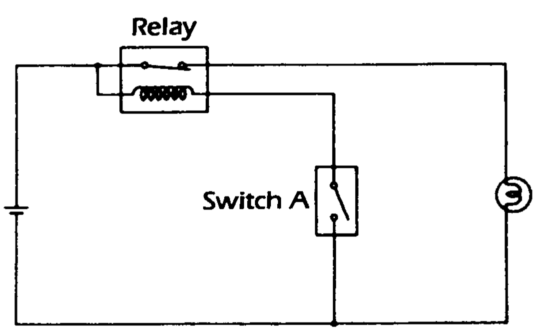
LOGIC SYMBOL FOR "NOT" GATE



ACTUAL SEMICONDUCTOR
"NOT" CIRCUIT



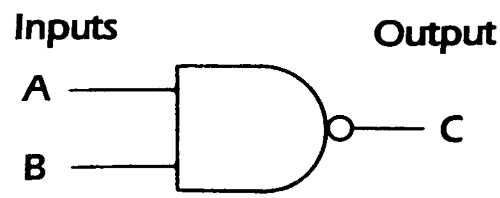
EQUIVALENT MECHANICAL CIRCUIT

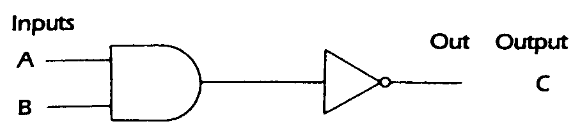


NAND GATE

A NAND gate is a combination of an AND gate and a NOT gate. It will function like an AND but the output will be the opposite. This means that the output is on for all input conditions except when there is voltage at both inputs.

TRUTH TABLE FOR "NAND" GATE





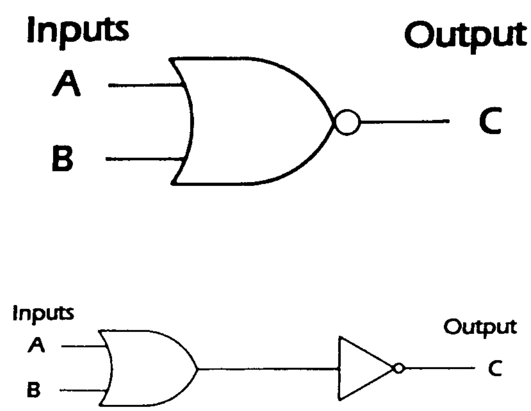
LOGIC SYMBOL FOR "NAND" GATE

Inputs A	Inputs B	Output C
0	0	1
0	1	1
1	0	1
1	1	0

NOR GATE

A NOR gate combines the OR gate and the NOT gate, so it functions like the OR gate except the output will be the opposite. This means that the output is only on if there is no voltage at both inputs.

TRUTH TABLE FOR "NOR" GATE



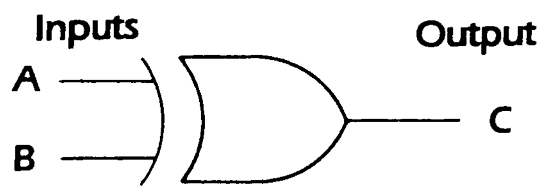
LOGIC SYMBOL FOR "NOR" GATE

Inputs A	Inputs B	Output C
0	0	1
0	1	0
1	0	0
1	1	0

XOR GATE

The exclusive OR gate limits the output to certain combinations of inputs. An even number of 1s will produce a 0 or low output. An odd number of 1s will produce a 1 or high output. The XOR gate symbol is different than the OR gate in that it has an added curved line to denote an exclusive feature.

LOGIC SYMBOL FOR "XOR" GATE



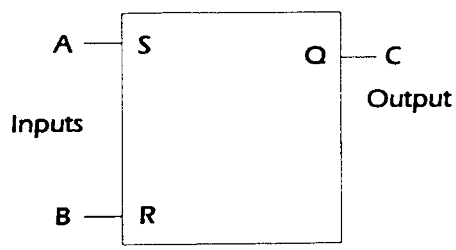
TRUTH TABLE FOR "XOR" GATE

Input A	Input B	Output C
0	0	0
0	1	1
1	0	1
1	1	0

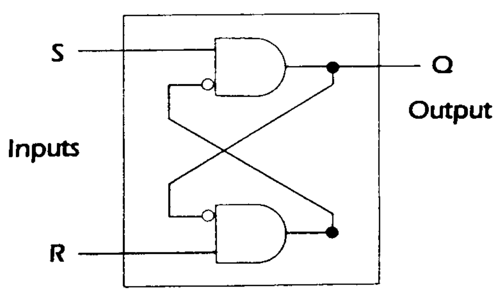
FLIP-FLOP CIRCUIT

By combining two NAND gates together, a circuit can be created called a Reset-Set flip-flop. The R-S flip-flop will toggle as the inputs switch between 1s and 0s. The unique feature of the circuit is the ability to remember or hold the last output (1 or 0), if both inputs are 0. The R-S flip-flop can be found in the moon roof and light auto-off systems of Toyota vehicles.

R-S FLIP-FLOP WIRING DIAGRAM SYMBOL



R-S FLIP-FLOP CONSTRUCTIION



TRUTH TABLE FOR R-S FLIP-FLOP CIRCUIT

Inputs A= Set	Inputs B=Reset	Output C=Q
0	1	0
1	0	1
0	0	Hold
1	1	1

The following worksheet demonstrates how logic symbols can be used to determine how a system should operate and how malfunctions in seemingly unrelated areas can affect the system's operation.

Taken with permission from the Toyota Advanced Electrical Course#672

COMPUTERS AND LOGIC CIRCUITS

ASSIGNMENT ***NAME:*** ________________________________

1. **Explain both the purpose and different types of inputs used by the computer.**
2. **Name the type of output signal most often used by the computer.**
3. **Name the components that are typically used as output devices.**
4. **Explain the difference between Analog and Digital Signals.**
5. **Explain both the purpose and complete name of an A/D converter.**
6. **Draw both an Analog and Digital signal.**
7. **Explain the binary numbering system and why it is used.**
8. **Explain the function of the Microprocessor.**
9. **Describe the purpose of the RAM (Random Access Memory)**
10. **Describe the purpose of the ROM (Read Only Memory)**
11. **Describe the purpose of the PROM (Programmable Read Only Memory)**
12. **Explain the basic function and list the truth table of an "AND" logic gate circuit.**
13. **Draw the equivalent mechanical circuit of an "AND" logic gate circuit.**
14. **Explain the basic function and list the truth table of an "OR" logic gate circuit.**
15. **Draw the equivalent mechanical circuit of an "OR" logic gate circuit.**
16. **Describe the basic function and list the truth table of a "NOT" logic gate circuit.**
17. **Describe the basic function and list the truth table of a "NAND" logic gate circuit.**
18. **Describe the basic function and list the truth table of a "NOR" logic gate circuit.**
19. **Describe are the two basic components of a "FLIP-FLOP" logic gate circuit.**