SDSU MASTERS of HOMELAND SECURITY

GEOL600 SENSOR NETWORKS

SENSOR COMPUTER INTERFACE

5 3 4 4 5 . 9 6 8 9 1

Binary Numbers
Representation of binary values
Digital logic
Analog to Digital Conversion
Digital Ramp ADC
Successive Approximation ADC
Tracking ADC
Practical considerations of ADCs

Serial Communications
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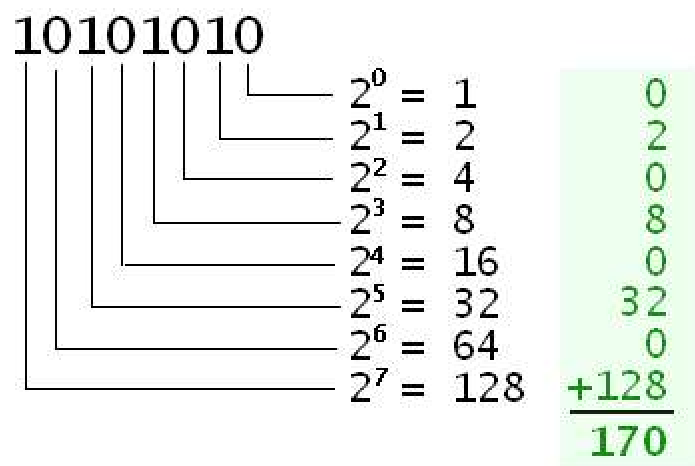
Inter-IC Serial Buses
Example: Hyperterminal to GPS
USB to RS-232
RS-232 to ethernet
DAQ Hardware
NeatTools

BINARY NUMBERS

Each digit in a binary (Base 2) numeral may have either of two different values, typically **0** and **1**.
It is used in virtually all modern computers due to its ease of implementation in electronic circuitry.

A binary number can be represented by any sequence of bits (binary digits), which in turn may be represented by any mechanism capable of being in two mutually exclusive states. The following sequences of symbols could all be interpreted as different binary numeric values:



11010011

on off off on off on

o x o o x o o x

N Y N N Y N Y Y Y

true false false true true false

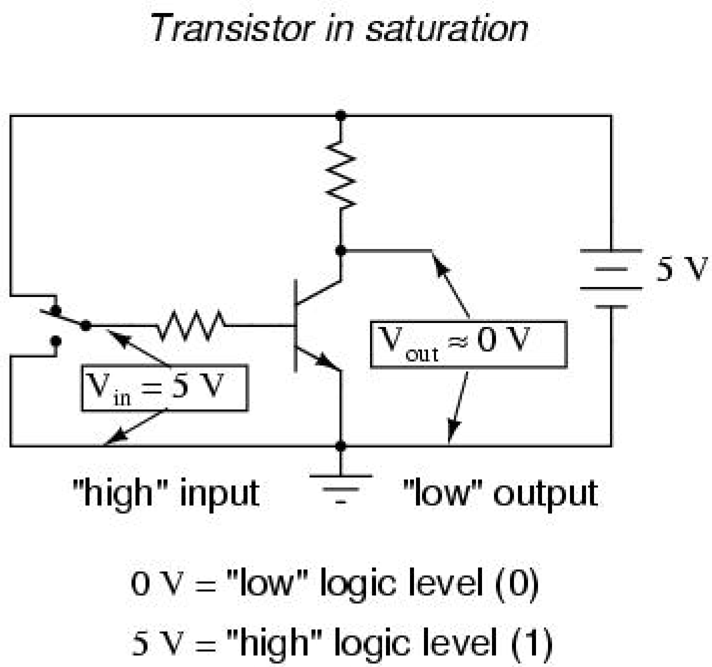
DECIMAL: BINARY CONVERSION

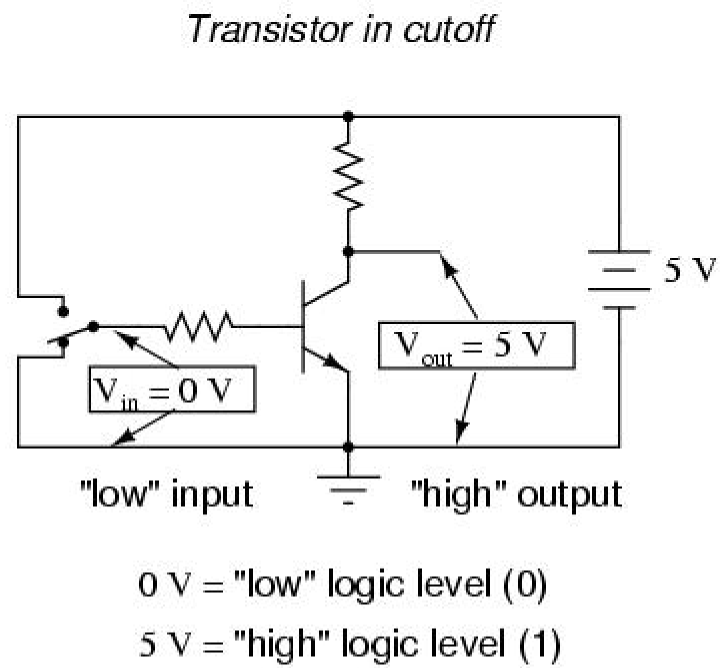
0: 00000	4: 00100	8: 01000	12: 01100
1: 00001	5: 00101	9: 01001	13: 01101
2: 00010	6: 00110	10: 01010	14: 01110
3: 00011	7: 00111	11: 01011	15: 01111

”There are only 10 types of people in the world: Those who understand binary, and those who don't”

REPRESENTATION OF BINARY VALUES

Real logic devices receive input and produce output in the form of voltages.
Necessary to define a voltage representation for binary logic values 0 and 1.
Positive logic represents True/1 by a high voltage and False/0 by a low voltage.
Negative logic represents True/1 by a low voltage and False/0 by a high voltage.





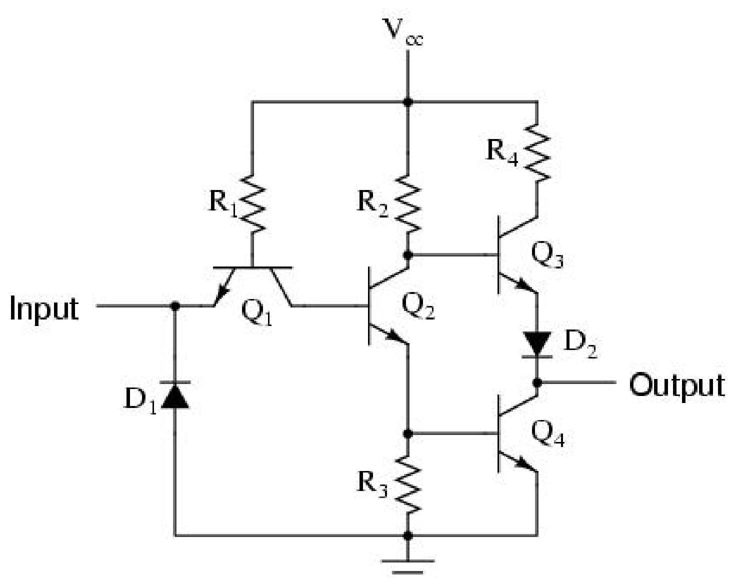
Electronic circuits are well suited to the representation of binary numbers. Transistors operated at their bias limits may be in one of two different states: either cutoff (no controlled current) or saturation (maximum controlled current). A transistor circuit designed to maximize the probability of falling into either one of these states (and not operating in the linear, or active, mode), can serve as a physical representation of a binary bit.

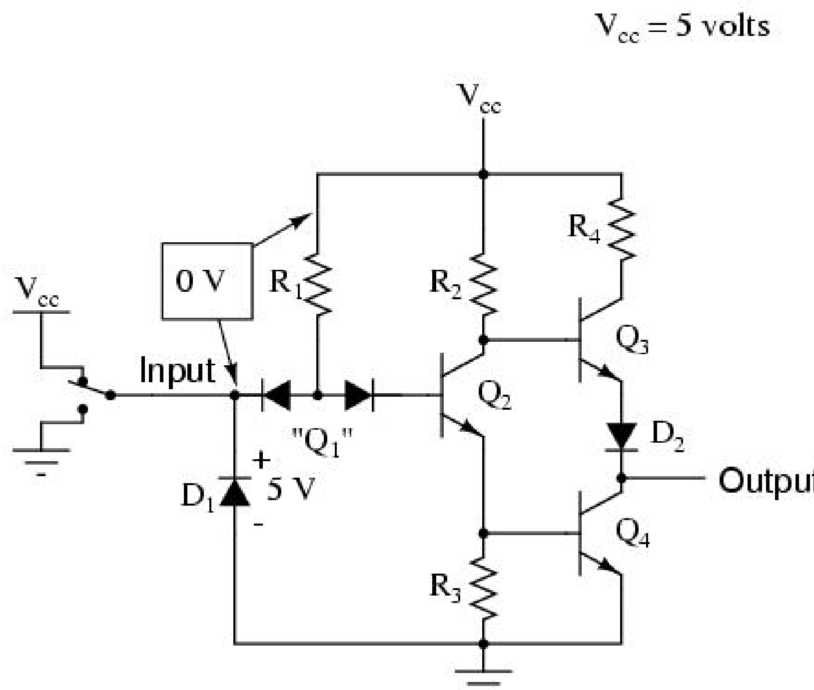
The single transistor circuit above is a logic gate, known as an inverter, or NOT gate, because it outputs the exact opposite digital signal as what is input.

Gates are special types of amplifier circuit designed to accept and generate voltage signals corresponding to binary 1's and 0's. As such, gates are not intended to be used for amplifying analog signals (between 0 and full voltage). Used together, multiple gates may be applied to the task of binary number storage (memory circuits) or manipulation (computing circuits), each gate's output representing one bit of a multi-bit binary number.

The single-transistor inverter circuit illustrated earlier is actually too crude to be of practical use as a gate. Real inverter circuits contain more than one transistor to maximize voltage gain (so as to almost guarantee that the final output transistor is either in full cutoff or full saturation), and other components designed to reduce the chance of accidental damage.

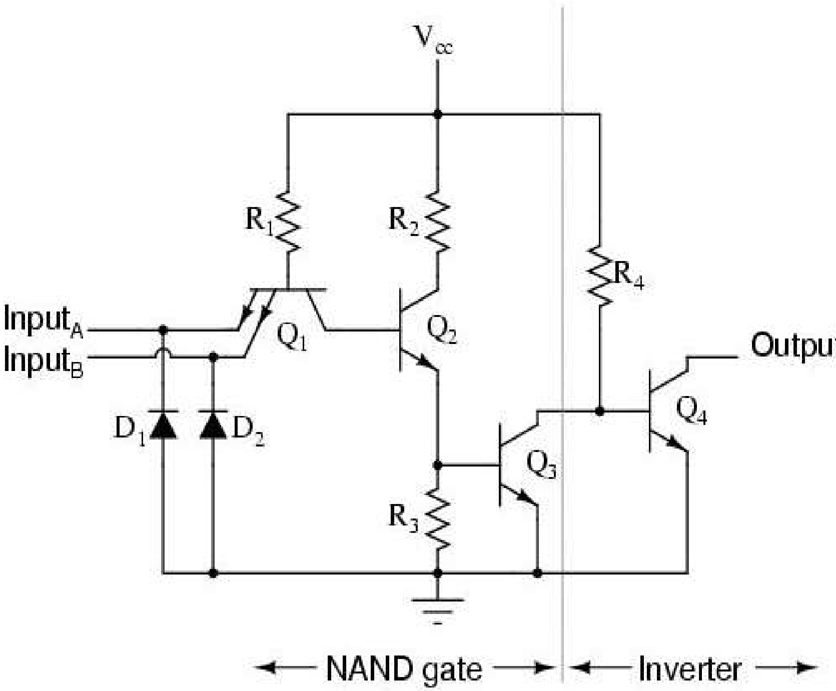
Practical inverter (NOT) circuit



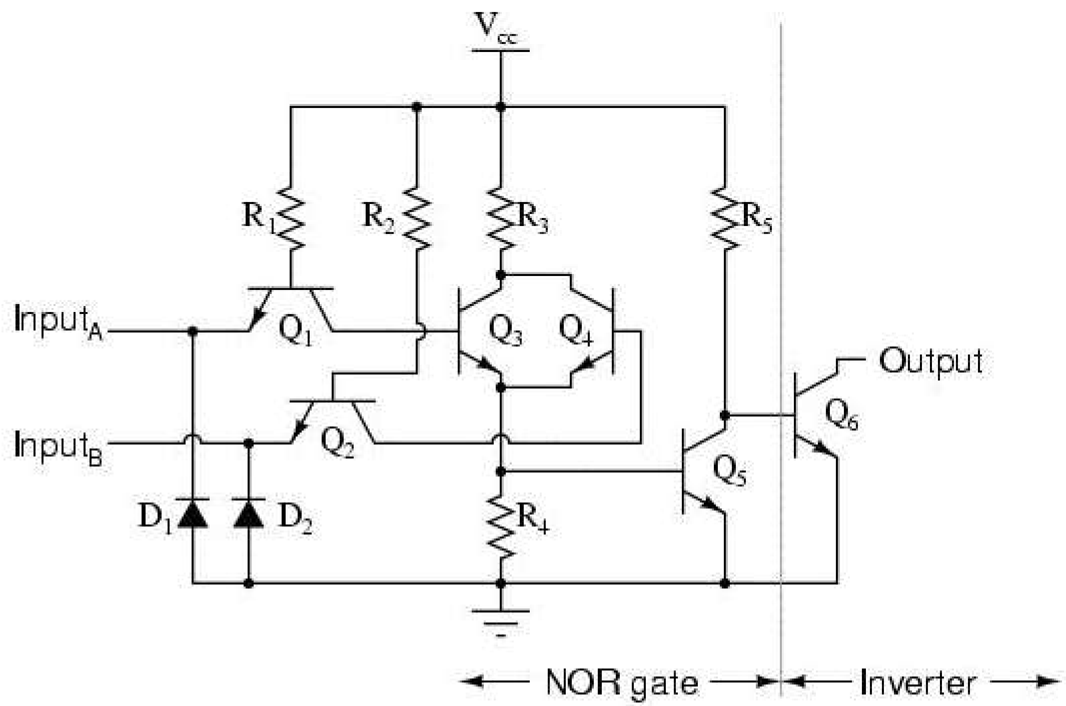


www.cybermike.net/reference/liec_book/Digital/DIGI_3.html

AND gate with open-collector output



OR gate with open-collector output

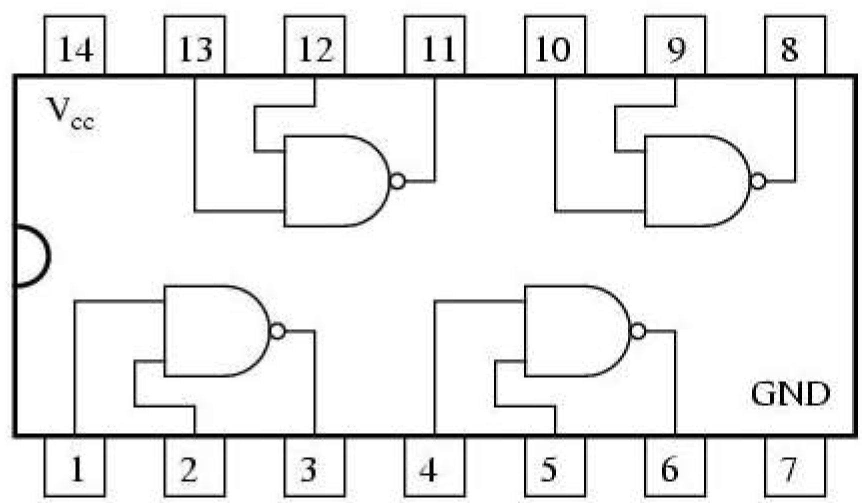


Circuits above are examples of TTL design paradigm..
FETs can also be used to design gates.

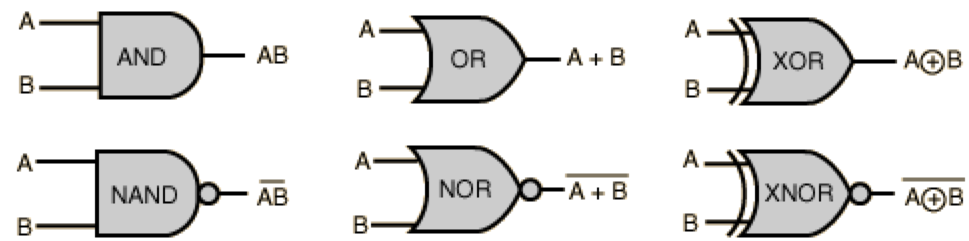
For convenience, gate circuits are generally represented by their own symbols rather than by their constituent components.

Digital logic gate circuits are available as DIP integrated circuits: all the components are manufactured on a single piece of semiconductor material.

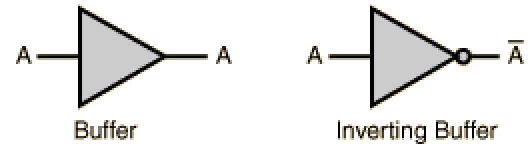
Quad NAND gate



DIGITAL LOGIC



Logic gates are the building blocks of digital circuits.



A	$\bar{A}$
0	1
1	0

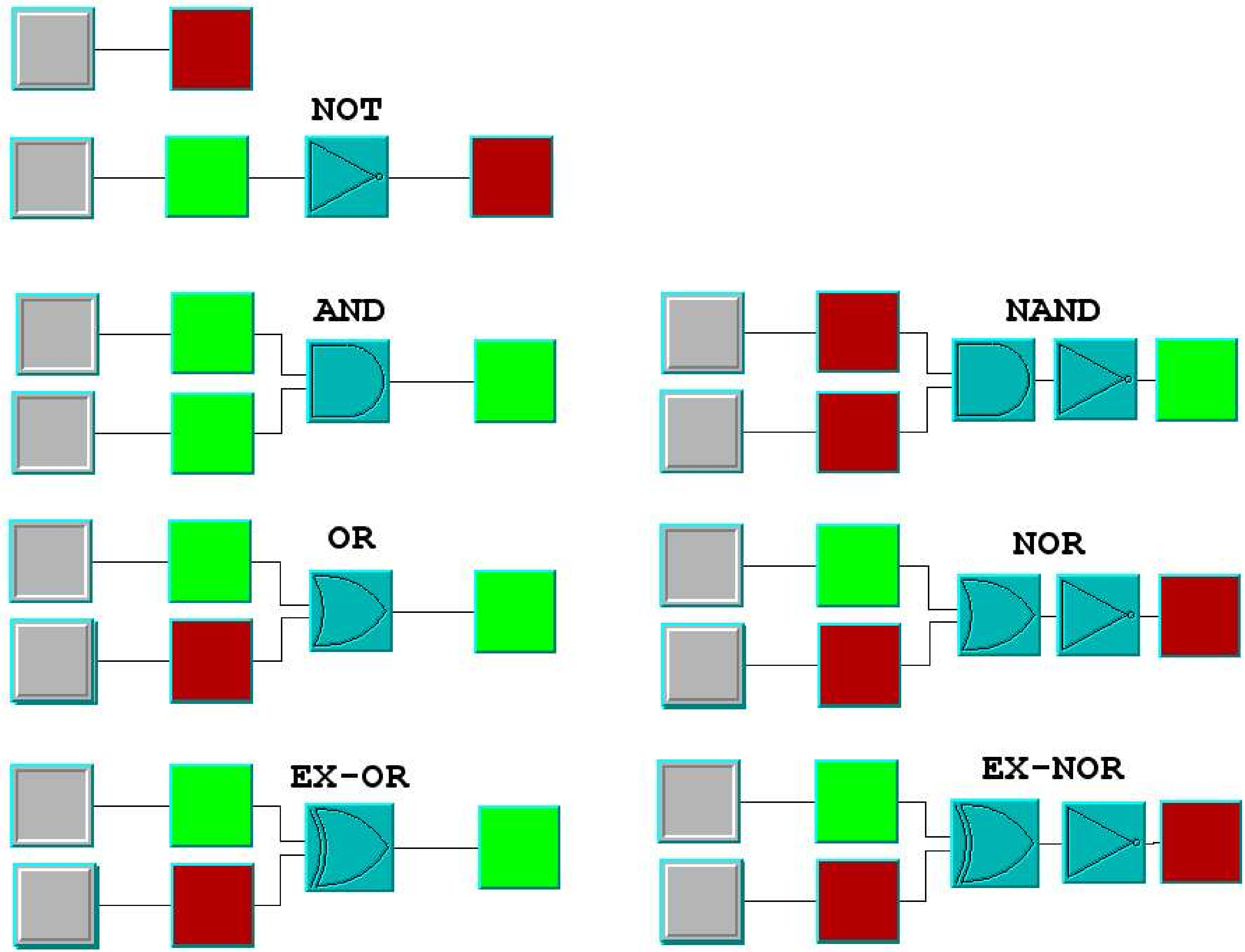
Truth tables have all possible logic levels for the inputs and the corresponding output logic level that define the gate.

A	B	AND	OR	XOR	NAND	NOR	XNOR
0	0	0	0	0	1	1	1
0	1	0	1	1	1	0	0
1	0	0	1	1	1	0	0
1	1	1	1	0	0	0	1

Digital logic involves combinations of the 3 types of operations for 2 variables, giving 16 possible functions.

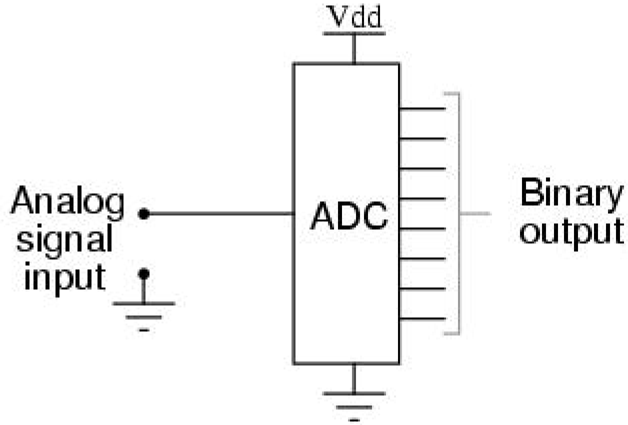
1. Null	0	9. NOT OR	$\overline{A + B}$
2. AND	AB	10. EXCLUSIVE NOR	$AB + \bar{A}\bar{B}$
3. A AND NOT B	$A\bar{B}$	11. NOT B	$\bar{B}$
4.	A	12. A OR NOT B	$A + \bar{B}$
5. NOT A AND B	$\bar{A}B$	13. NOT A	$\bar{A}$
6.	B	14. NOT A OR B	$\bar{A} + B$
7. EXCLUSIVE OR	$A\bar{B} + \bar{A}B$	15. NOT A AND B	$\overline{AB}$
8. OR	A + B	16. IDENTITY	1

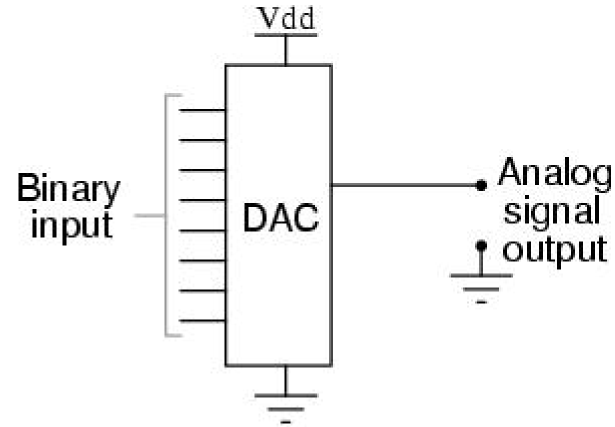
Example:
Computerized search engines use Boolean Logic, understanding how it works will enhance use.



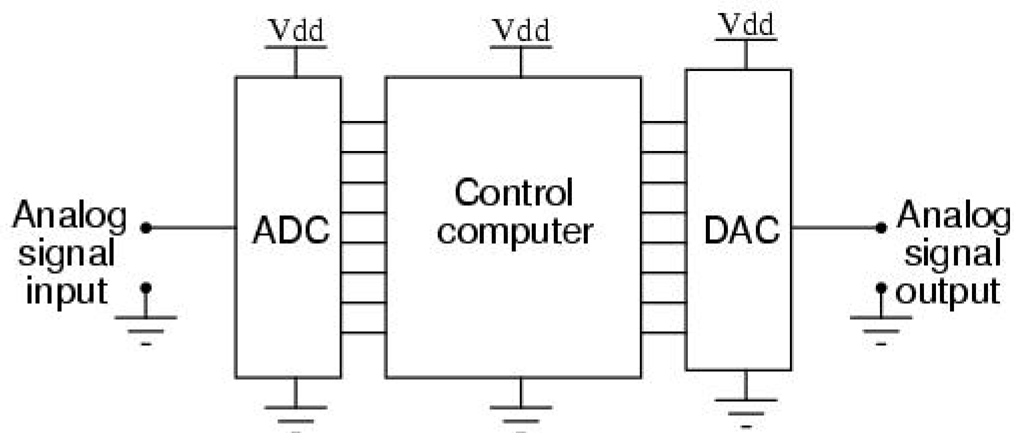
DIGITAL LOGIC NTL FILE

ANALOG TO DIGITAL CONVERSION





Digital control system with analog I/O

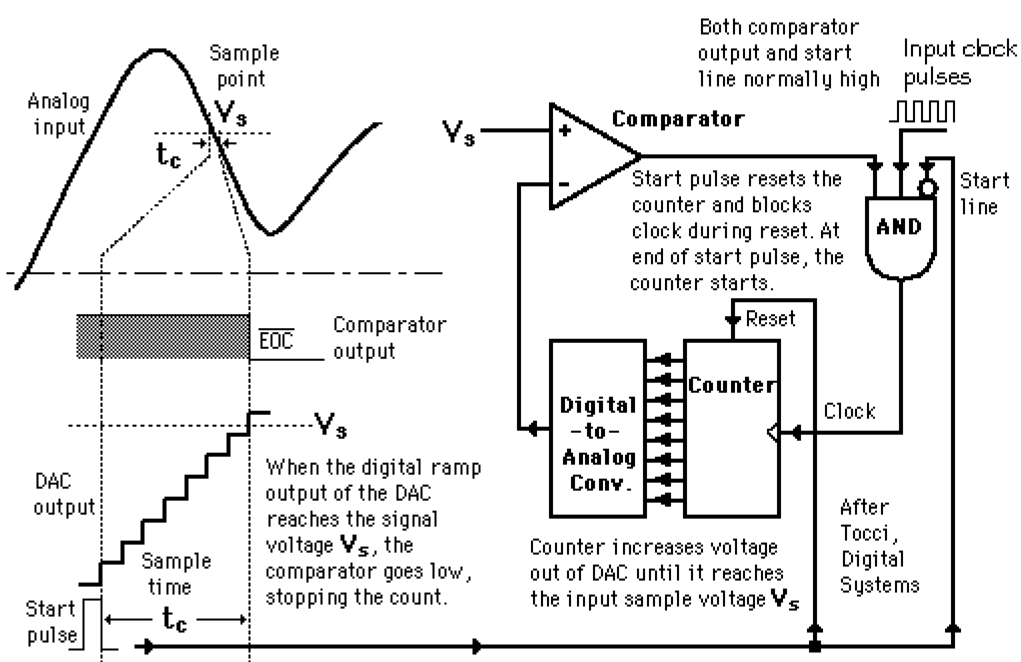


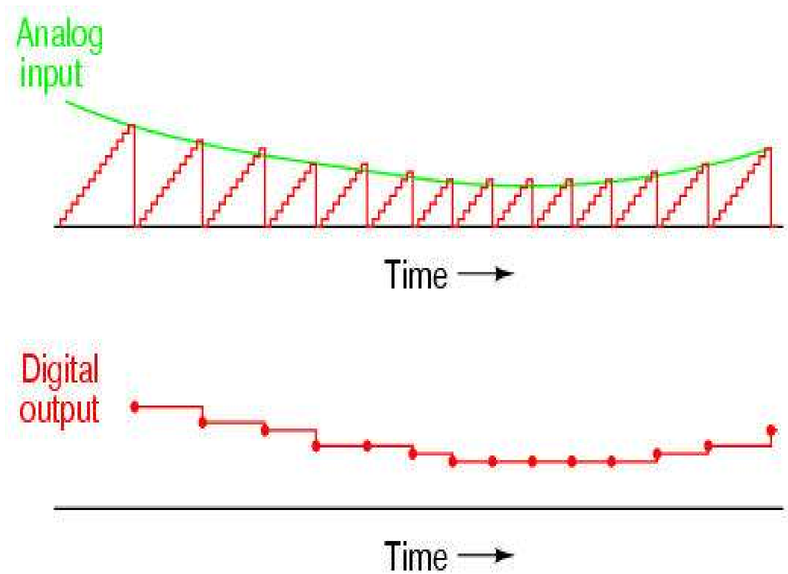
electronic process in which a continuously variable (analog) signal is changed, without altering its essential content, into a multi-level (digital) signal.

The basic principle of operation is to use the comparator principle to determine whether or not to turn on a particular bit of the binary number output. It is typical for an ADC to use a digital-to-analog converter (DAC) to determine one of the inputs to the comparator.

Digital Ramp ADC

Conversion from analog to digital form inherently involves comparator action where the value of the analog voltage at some point in time is compared with some standard. A common way to do that is to apply the analog voltage to one terminal of a comparator and trigger a binary counter which drives a DAC. The output of the DAC is applied to the other terminal of the comparator. Since the output of the DAC is increasing with the counter, it will trigger the comparator at some point when its voltage exceeds the analog input. The transition of the comparator stops the binary counter, which at that point holds the digital value corresponding to the analog voltage.

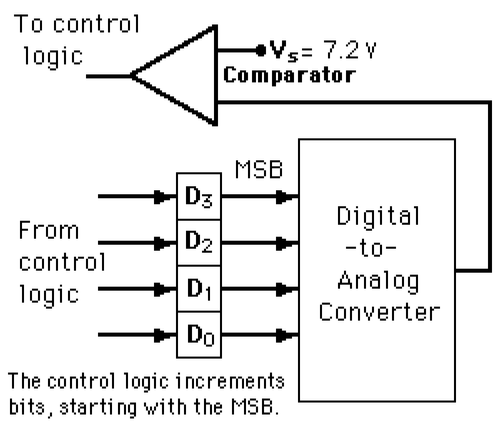


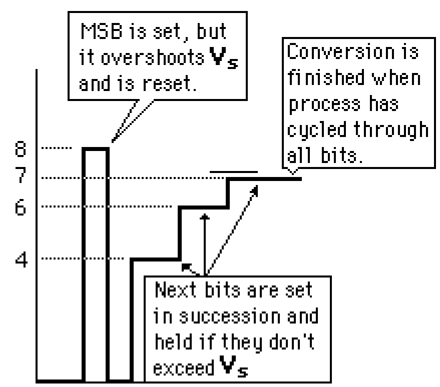


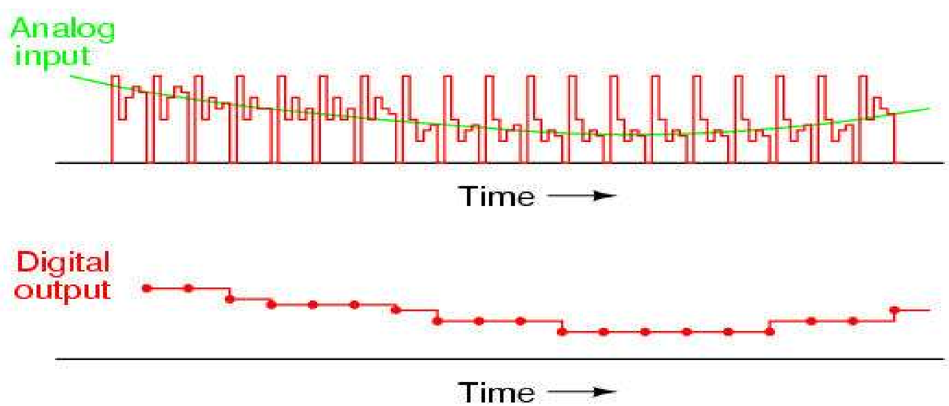
Note how the time between updates (new digital output values) changes depending on how high the input voltage is. For low signal levels, the updates are rather close-spaced. For higher signal levels, they are spaced further apart. For many ADC applications, this variation in sample time is not acceptable

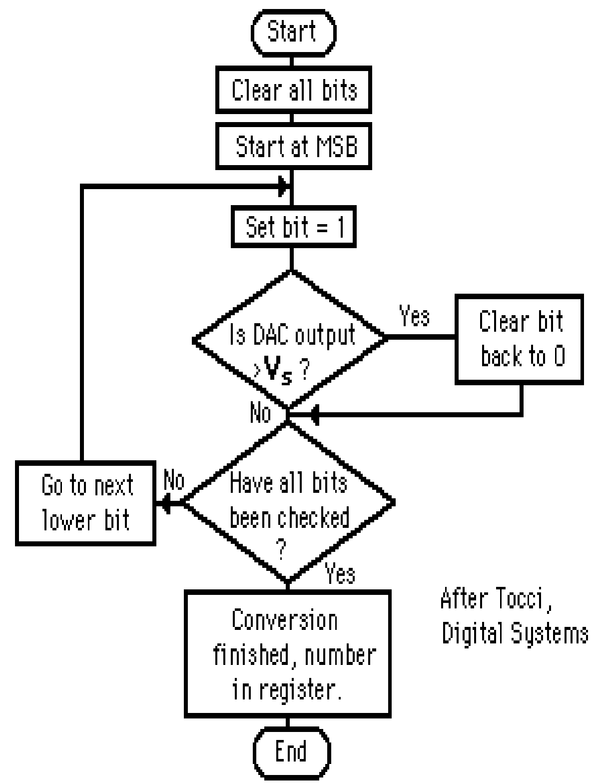
Successive Approximation ADC

Much faster than the digital ramp ADC because it uses digital logic to converge on the value closest to the input voltage. A comparator and a DAC are used in the process. Instead of counting up in binary sequence, the register counts by trying all values of bits starting with the most-significant bit and finishing at the least-significant bit. Throughout the count process, the register monitors the comparator's output to see if the binary count is less than or greater than the analog signal input, adjusting the bit values accordingly. The way the register counts is identical to the "trial-and-fit" method of decimal-to-binary conversion, whereby different values of bits are tried from MSB to LSB to get a binary number that equals the original decimal number.







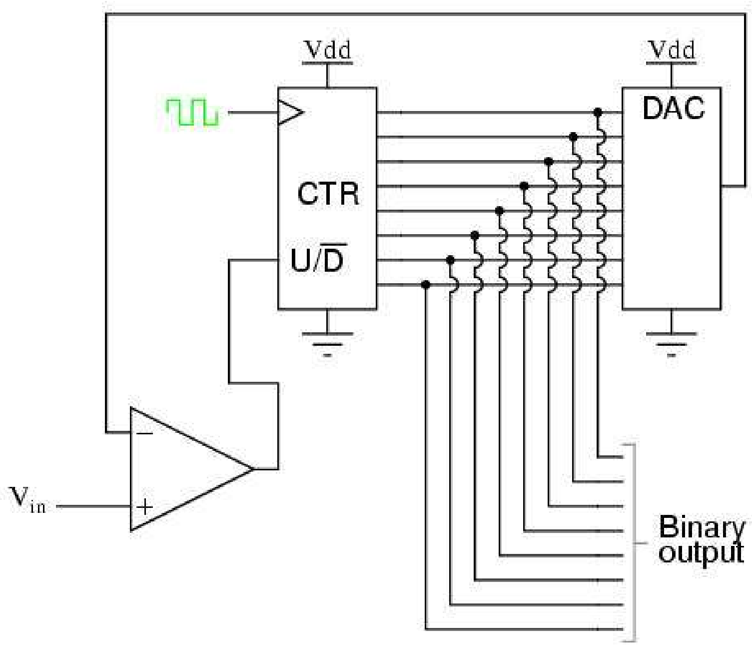


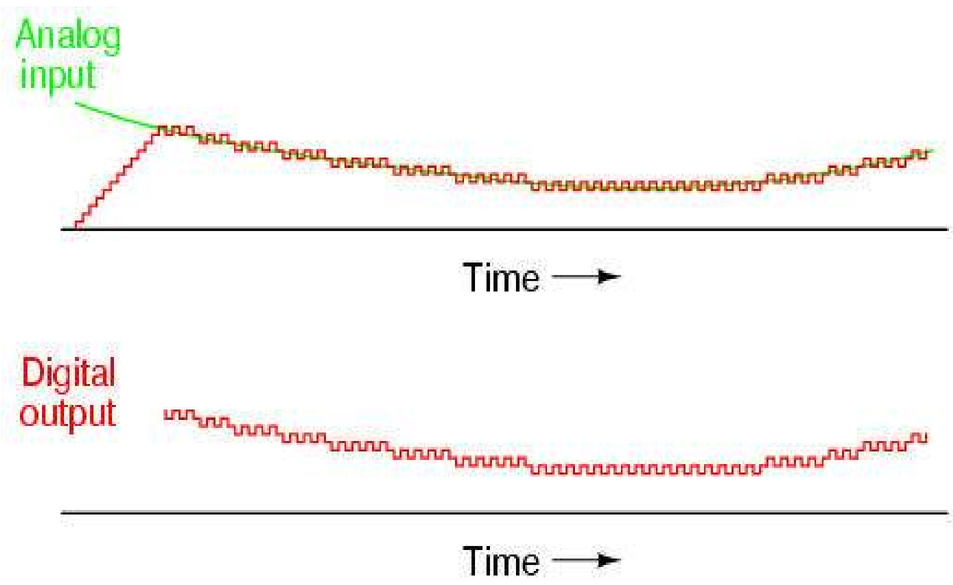
After Tocci, Digital Systems

Tracking ADC

Elegantly simple. Instead of a regular "up" counter driving the DAC, this circuit uses an up/down counter. The counter is continuously clocked, and the up/down control line is driven by the output of the comparator. So, when the analog input signal exceeds the DAC output, the counter goes into the "count up" mode. When the DAC output exceeds the analog input, the counter switches into the "count down" mode. Either way, the DAC output always counts in the proper direction to track the input signal.

No shift register is needed to buffer the binary count at the end of a cycle. Since the counter's output continuously tracks the input (rather than counting to meet the input and then resetting back to zero), the binary output is legitimately updated with every clock pulse.
An advantage of this converter circuit is speed, since the counter never has to reset.





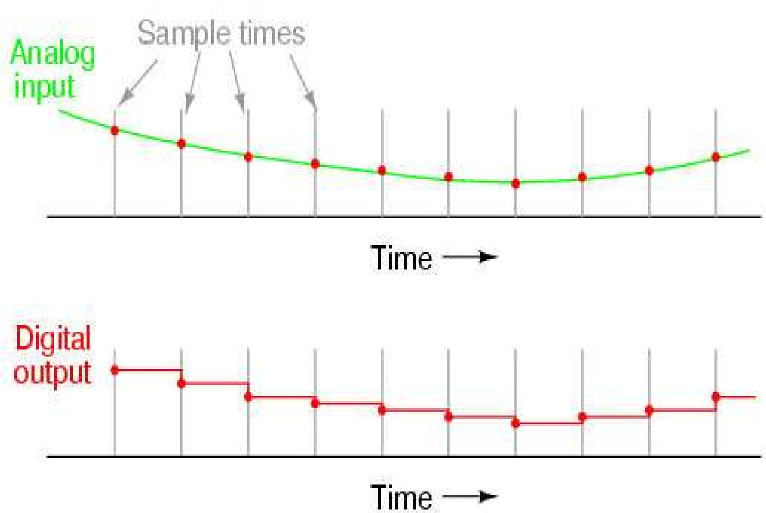
PRACTICAL CONSIDERATIONS OF ADC CIRCUITS

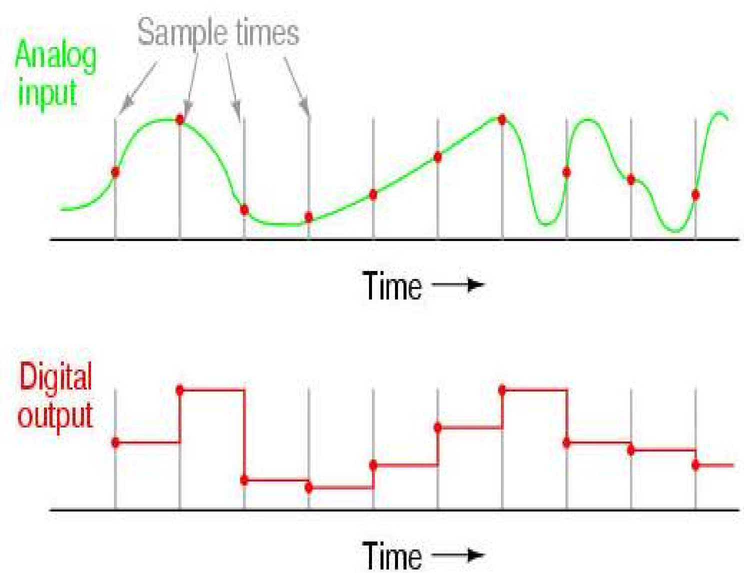
RESOLUTION

Perhaps the most important consideration of an ADC is its resolution. Resolution is the number of binary bits output by the converter. Because ADC circuits take in an analog signal, which is continuously variable, and resolve it into one of many discrete steps, it is important to know how many of these steps there are in total.

SAMPLING RATE

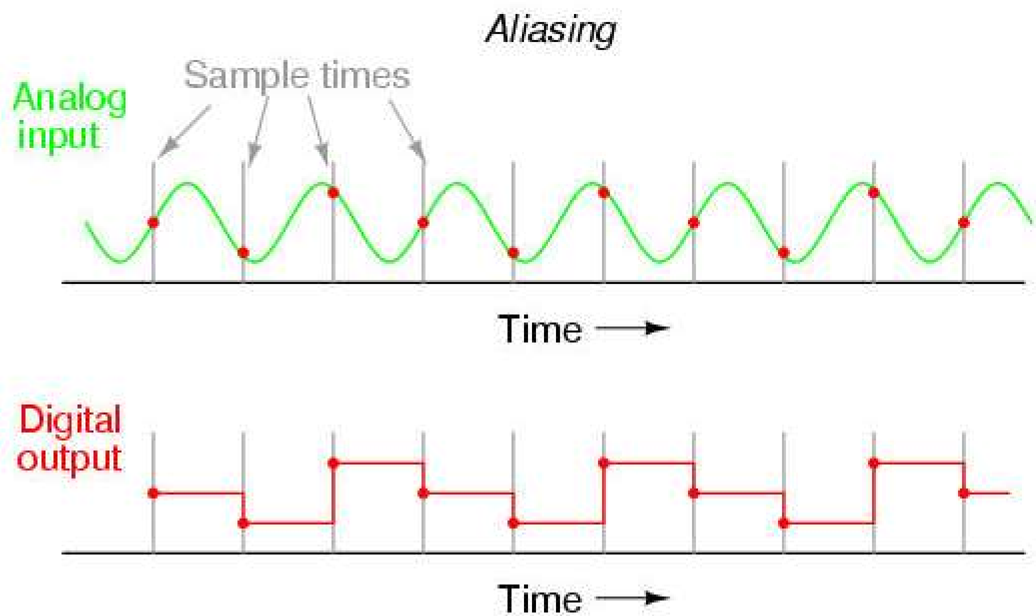
sample frequency, or conversion rate. This is simply the speed at which the converter outputs a new binary number. Like resolution, this consideration is linked to the specific application of the ADC. If the converter is being used to measure slow-changing signals, it could probably have a very slow sample frequency and still perform adequately. Conversely, if it is being used to digitize a rapidly changing signal, the converter needs to be considerably faster





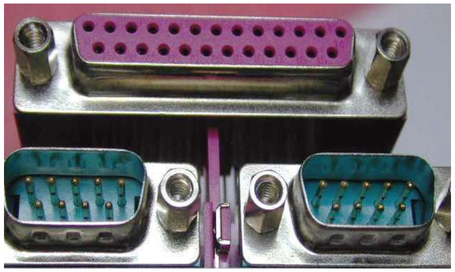
ALIASING
It is imperative that an ADC's sample time is fast enough to capture essential changes in the analog waveform. In data acquisition terminology, the highest-frequency waveform that an ADC can theoretically capture is the so-called Nyquist frequency, equal to one-half of the ADC's sample frequency. Therefore, if an ADC circuit has a sample frequency of 5000 Hz, the highest-frequency waveform it can successfully resolve will be the Nyquist frequency of 2500 Hz.

If an ADC is subjected to an analog input signal whose frequency exceeds the Nyquist frequency for that ADC, the converter will output a digitized signal of falsely low frequency. This phenomenon is known as aliasing



SERIAL COMMUNICATIONS

PC compatible desktop computers are typically equipped with one parallel port and two serial ports.
Although these two types of ports are used for communicating with external devices, they work in different ways.



A parallel port sends and receives data eight bits at a time over 8 separate wires. This allows data to be transferred very quickly; however, the cable required is more bulky because of the number of individual wires it must contain. Parallel ports are typically used to connect a PC to a printer.

A serial port sends and receives data one bit at a time over one wire. While it takes eight times as long to transfer each byte of data this way, only a few wires are required.

The serial port on your PC is **full-duplex**, meaning that it can send and receive data at the same time. In order to be able to do this, it uses separate lines for transmitting and receiving data

Once the **start bit** has been sent, the transmitter sends the actual **data bits**. There may either be 5, 6, 7, or 8 data bits, depending on the number you have selected. Both receiver and the transmitter must agree on the number of data bits, as well as the baud (modulation) rate.
Almost all devices transmit data using either 7 or 8 databits.
After the data has been transmitted, a **stop bit** is sent. A stop bit has a value of 1 and it can be detected correctly even if the previous data bit also had a value of 1. This is accomplished by the stop bit's duration. Stop bits can be 1, 1.5, or 2 bit periods in length.

Baud rate, or the number of times per second that a line changes state, is only the same as bits per second (BPS) if you connect two serial devices together using direct cables.

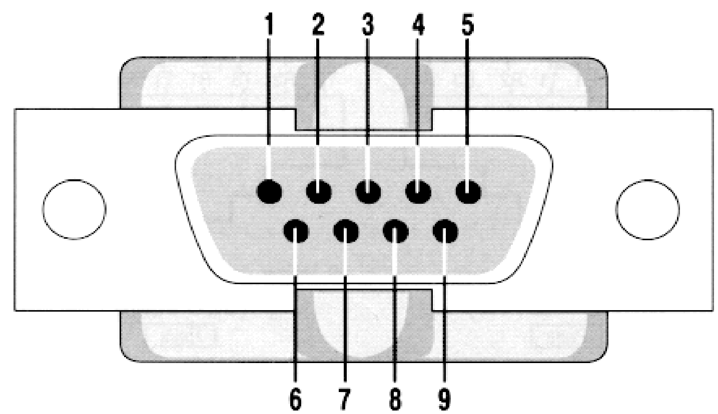
A **parity bit** may optionally be transmitted along with the data to help detect data corruption that might occur during transmission. You can choose either even parity, odd parity, mark parity, space parity or none at all.

EIA/TIA-232-E

A standard interface approved by the Electronic Industries Alliance (EIA) for connecting serial devices. Many people, however, still refer to the standard as **RS-232C**, or just RS-232.

A device that connects to the interface is Data Communications Equipment (DCE) and device to which it connects is called Data Terminal Equipment (DTE).

EIA-232 supports two types of connectors
a 25-pin D-type connector (DB-25) and
a 9-pin D-type connector (DB-9).
Recently defined successors to EIA-232 called RS-422 and RS-423 are backward compatible so that RS-232 devices can connect to an RS-422 port.



Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data Terminal Ready	9	Ring Indicator
5	Signal Ground		

www.taltech.com/TALtech_web/resources/intro-sc.html

INTER-IC SERIAL BUSES

I2C : Inter Integrated Circuit Bus, Philips Semiconductor.
Only two lines (clock and data) are required for full duplexed communication between multiple devices. The interface typically runs at a fairly low speed (100kHz to 400kHz). With I2C, each IC on the bus has a unique address. Chips can act as a receiver and/or transmitter depending on functionality

SPI : Serial Peripheral Interface, Motorola.
4-wire synchronous serial data link that is standard across many Motorola microprocessors and other peripheral chips. It supporta a low/medium bandwidth (1 megabaud) network connection amongst CPUs and other devices supporting the SPI. SPI is used frequently in handheld and other mobile platform systems.

MICROWIRE National Semiconductor.
essentially a subset of the SPI interface, also used by Microchip and Fairchild in their serial EEPROMs. In many applications Microwire devices can be interfaced to a microcontroller SPI interface with software.

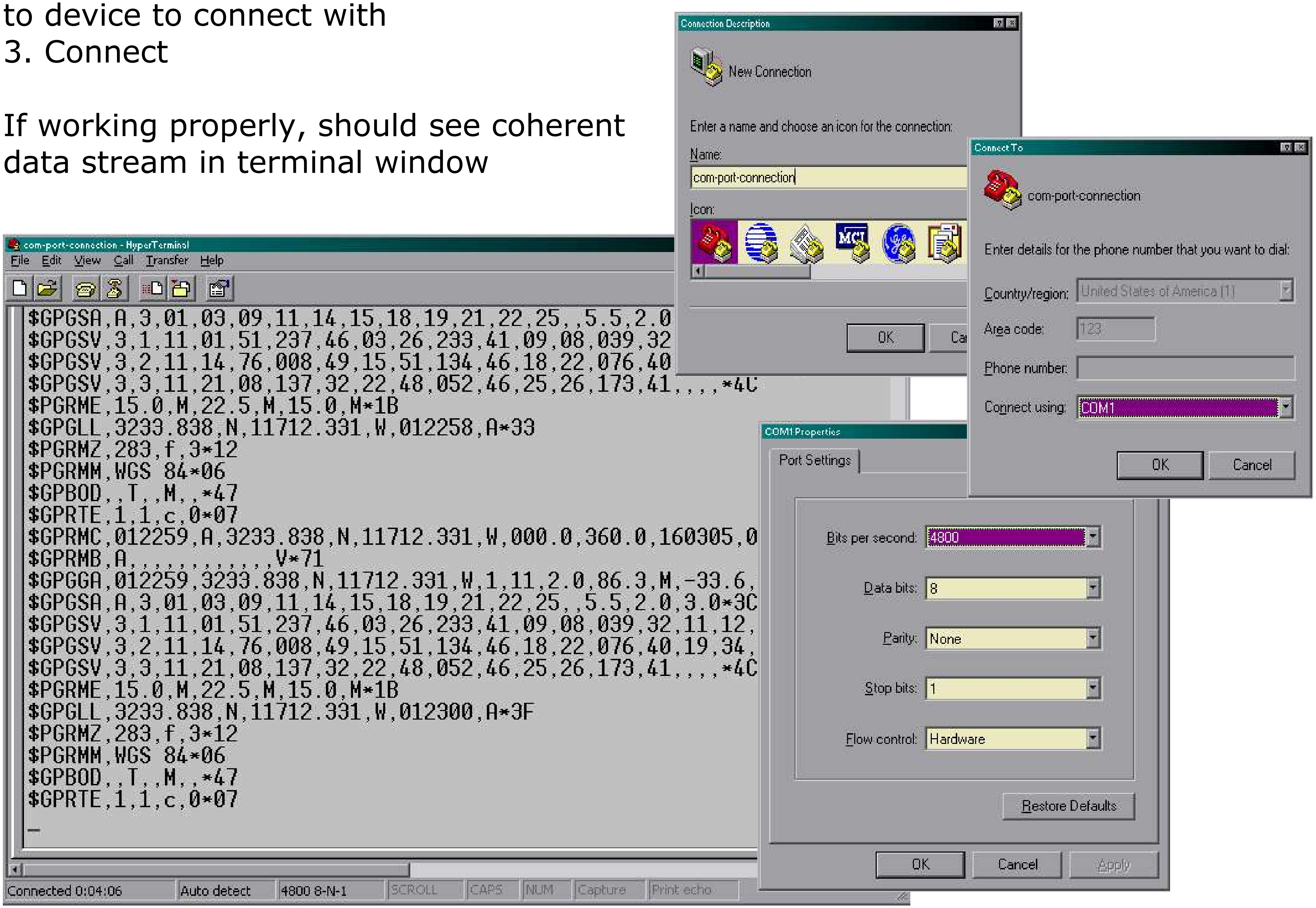
1-WIRE Dallas/Maxim
simple control network system, allows one signal wire to carry both operating power and signal. 1-Wire® devices aim to lower system cost and simplify design with an interface protocol that supplies control, signaling, and power over a single-wire connection. A variety of identification, sensor, control, and memory functions are available with this interface.

www.epanorama.net/links/serialbus.html

EXAMPLE: HYPERTERMINAL CONNECTION TO GPS

1. Start>Programs>Accessories>Communications>Hyperterminal
2. Select COM port and settings applicable to device to connect with
3. Connect

If working properly, should see coherent data stream in terminal window



USB to RS-232

Universal Serial Bus
(Compaq,DEC, IBM, Intel, MS, NEC, Nortel)

Four wire cable, carries enough power for low-power devices. Maximum bandwidth shared amongst all devices on the USB network.
Devices can be cascaded through usb hubs

When you plug in a device,computer senses voltage differences in the USB network and proceeds to query (enumerate) the device for type, vendor, functionality and bandwidth required. That device is assigned a unique address ID and co-exists with all other USB devices.
If two identical devices are plugged in, they will each have a unique address and can be distinguished separately by the computer.
Once enumeration is complete, the appropriate device driver is loaded by the operating system (O/S) and user will be prompted for the driver disk if necessary.
All contention of devices is handled by the host and by the software residing on the host. There is no need to configure interrupt IRQs, addresses, or DMA channels.

USB to RS-232 provide RS-232 functionality for laptops which don't have inbuilt ports. Be careful to get RS-232 converter and not specific PDA-usb adapters.

RS232 to ETHERNET

Examples:

www.tibbo.com

www.siteplayer.com

www.lantronix.com/device-networking/embedded-device-servers/

Compact solutions to ethernet enable any device with a serial interface

Can be programmed through the serial port, via a web interface or by telnet.

Contain embedded web server

Provide 10BaseT/100BaseT autosensing ethernet connections or 802.11B wireless connectivity

RS232 to TCP/IP converter
Software based conversion, allowing any serial port on computer to be connected to through ethernet, turning PC into a serial device server. Can also create virtual com ports that are actual connections to TCP/IP ports. Data collection device outputs connected to computer can thus be accessed anywhere on the network.

www.taltech.com/products/tcpcom.html

DAQ HARDWARE

Data Acquisition Hardware

Different vendors provide specialized DAQ hardware for use with data capture software.
Provide both USB and PCI/PXI interfaces.

Refer to National Instruments website for web evaluation of:
 DAQ software “LabVIEW”
 DAQ hardware
www.ni.com

Many other vendors competing for market

USB multifunction DAQ and Control device “LabJack”
www.labjack.com/products.html

With increasing tech development, it is useful to do frequent web searches for DAQ related keywords to find emerging hardware options

TNG 3 DAQ:
8 analog inputs, 8 digital inputs (0-5V)
RS-232 interface

www.mindtel.com/mindtel/anywear.html

NeatTools

object-oriented visual programming environment. It is a software application which allows the user to take any kind of input and program a computer system to respond according to your settings. The software can receive input from the mouse, keyboard, or any kind of input device that can provide a resistance, or a voltage of 0-5 volts. These devices are connected to the serial port of a PC by means of a TNG DAQ