

MODULE 10- SHIFT REGISTERS,UARTS, USB & SERIAL DATA TRANSMISSION

OVERVIEW:

A shift register is a series of "D" Flip Flops with each successive device outputs running to the "D" input of the subsequent device. This arrangement allows a binary bit input to the first flip flop to be subsequently shifted or clocked to the next flip flop and the next and so on until the data bit is clocked through the entire chain of flip flops. There are several applications of shift registers, but probably the most used is for serial to parallel and parallel to serial data conversion. This is the basis for serial data transmission between two computers, or from a computer to some type of modem or network system. Shift registers can be parallel load and then the data shifted out in series, or serially loaded and the data then read in parallel. Figure 1 below shows a 74LS164 Serial in Parallel out shift register. A 74LS194 is a shift register that allows you to serial or parallel load and serial or parallel read the data. In addition, you can either shift the data left or right. This really represents the spectrum of what can be done with a shift register.

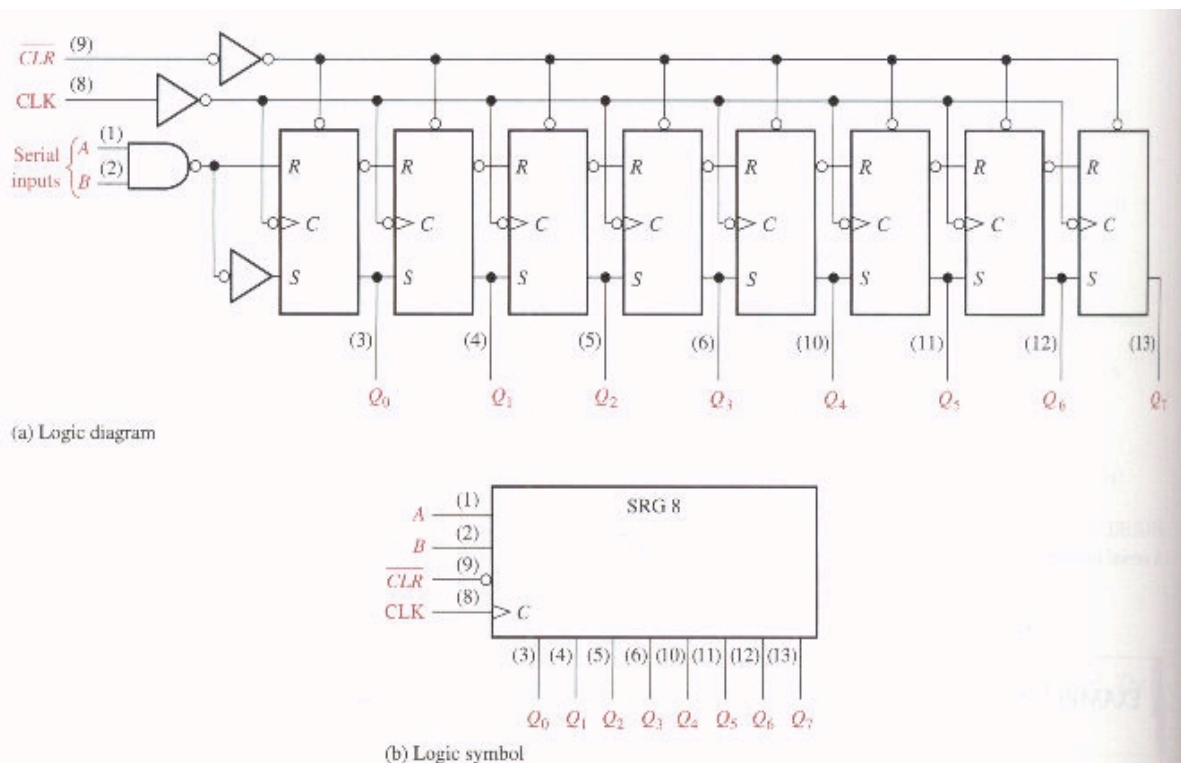
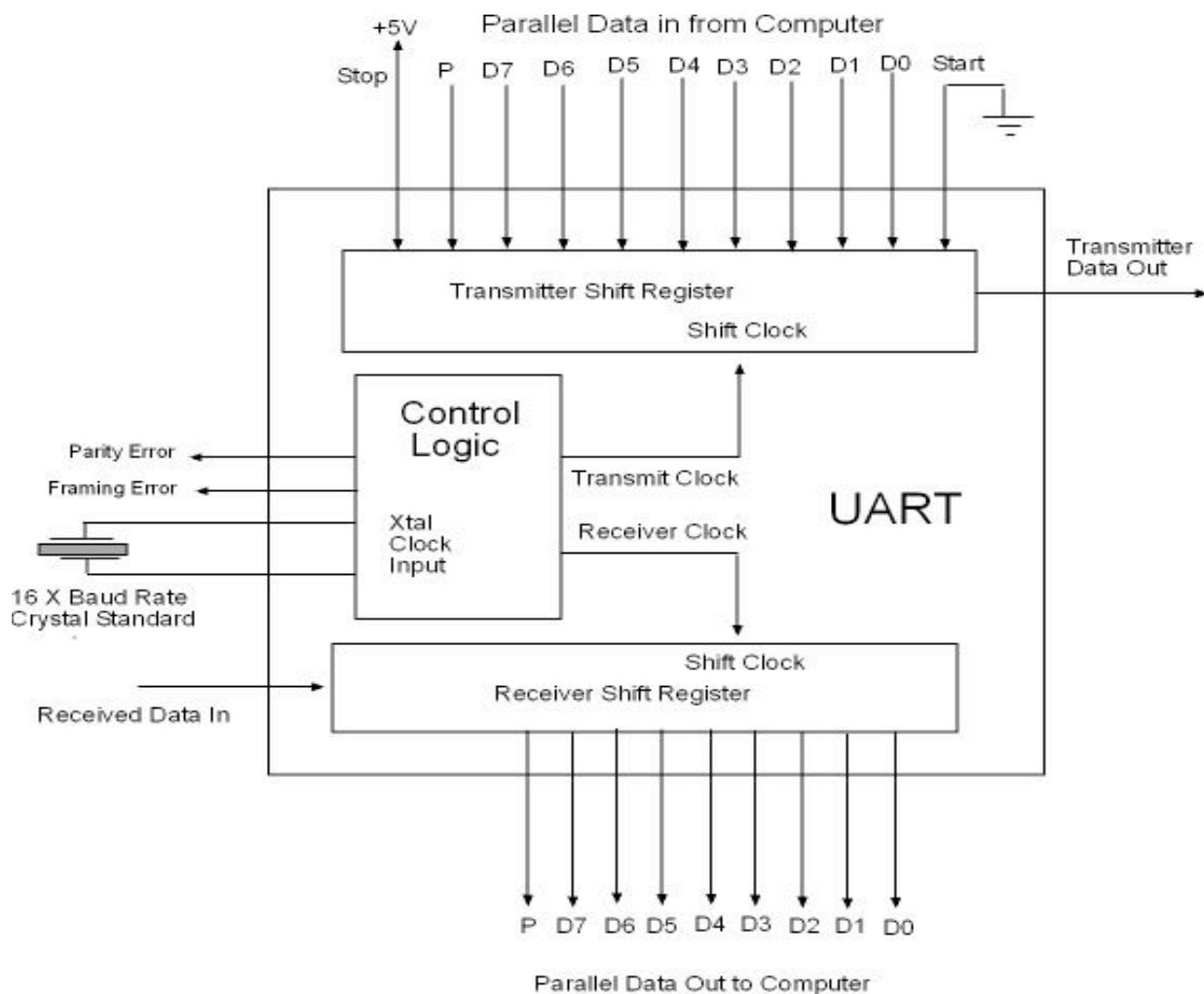


FIGURE 1: THE BLOCK DIAGRAM OF A 74LS164 SHIFT REGISTER

CONCEPT 10.1: SERIAL DATA TRANSMISSION

A shift register can convert parallel data into serial data, send it to another computer over two wires, and then convert it back to parallel data. The device that contains two shift registers and the control circuitry to send and receive serial data is called a Universal Asynchronous Receiver/Transmitter (UART). The block diagram of a UART is shown below:

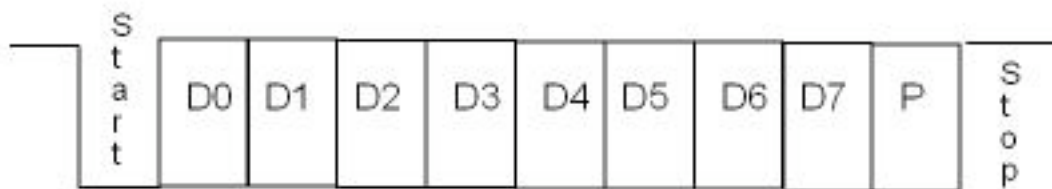
If you put a parallel in serial out shift register in the same package as a serial in parallel out shift register and add some control and clock logic, you have created a device known as a UART or Universal Asynchronous Receiver Transmitter. A UART is used with a computer to convert the computer parallel data into serial data, to send it out serially, and to then to receiver data serially and convert it to parallel data back into the computer.



Universal Asynchronous Receiver / Transmitter

The UART is called an asynchronous device because it does not require the data to have a clock to identify the location of each serial bit. The clock is embedded in the signal using an ANSI Standard Format. ANSI stands for American National Standard for Information Interchange. When data is sent out, the first bit goes low signaling the UART that data is coming. The eight data bits follow in serial as D0, D1, D2, D3, D4, D5, D6, and D7. Next comes a parity bit that is either odd or even. An odd parity bit is added as a one or a zero to guarantee that there are always an odd number of 1's in the bit stream. Even parity would do the same but make the number of 1's in the serial bit stream an even number. After the parity bit comes a high stop bit. The process continues for the next eight bit serial byte, continuing until all of the data is sent.

ANSI - Typical Serial Byte Format



ANSI Means American National Standards Institute

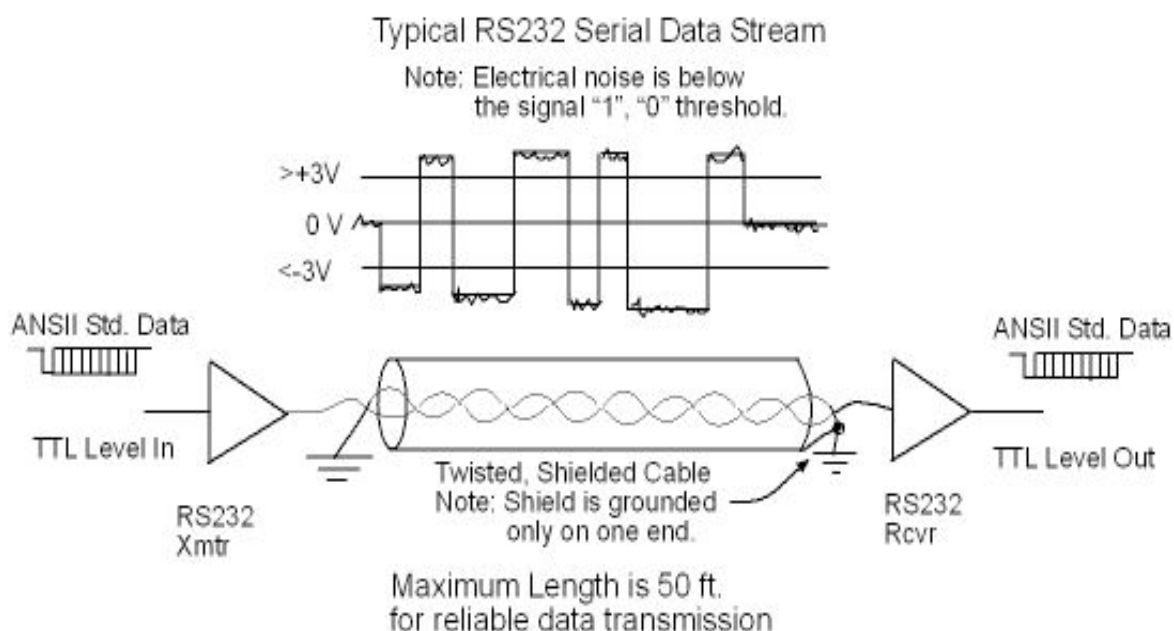
The rate the data is sent out is called the BAUD rate and it is the number of transitions per second. Since this rate is known, the UART has its own clock that is 16 times the BAUD rate. It uses this 16 X over clock system to count to where the middle of each data position should be and then to sample the data stream. If at the end of the eleven transitions required to send eight bits of data, the signal is not high, a framing error flag is sent out. If it is high, the UART assumes the data is good and continues. The UART next checks the parity. If the parity is odd and the received data has an even number of 1's, the UART sends out a parity error flag. If the parity is also good, the UART sends the next eight bit byte of data.

Every system that sends and or receives serial data has a UART at the serial to parallel interface to process the data. Serial data has the advantage of needing only one wire and a signal return ground to transmit and receive data from one computer or data system to the next. The UART does the parallel to serial and serial to parallel conversion needed by most computers and also controls how fast the data is sent and received.

CONCEPT 10.2: ELECTRICAL DATA TRANSMISSION STANDARDS, RS232

RS232 is the original COM port standard used by the personal computer. It is a single line standard that ignores electrical noise on the line by setting the signal threshold beyond the noise. A logical 1 must be at a voltage level between +3 volts to +12 volts. A logical 0 is at a negative voltage level of -3 volts to -12 volts. There is a +/- 3 volt noise band in between a logical 1 voltage level and a logical 0 voltage level.

The electrical standard has nothing to do with the data format or with ANSI standard for asynchronous data. It only provided a way the data can be sent as electrically noise immune as possible. The electrical data transmission standard RS232, works well to ignore electrical disturbances caused by 60 Hz power as an example. As the distance between two computers increases, the level of the electrical noise picked up increases until at around 50 feet, RS232 cables start to have too many errors detected to work reliably.



The top data bit rate or BAUD rate for RS232 is somewhere around 100 kilobaud. Up until 20 years ago, this was considered a fast serial data transfer rate. Presently, top serial data transmission rates can exceed a

billion bits per second. This has come about through advances in MODEM technology and the adoption of differential signal transmission standards. Both of these subjects are discussed in the pages that follow.

CONCEPT 10.3: ELECTRICAL DATA TRANSMISSION STANDARDS, MODEMS

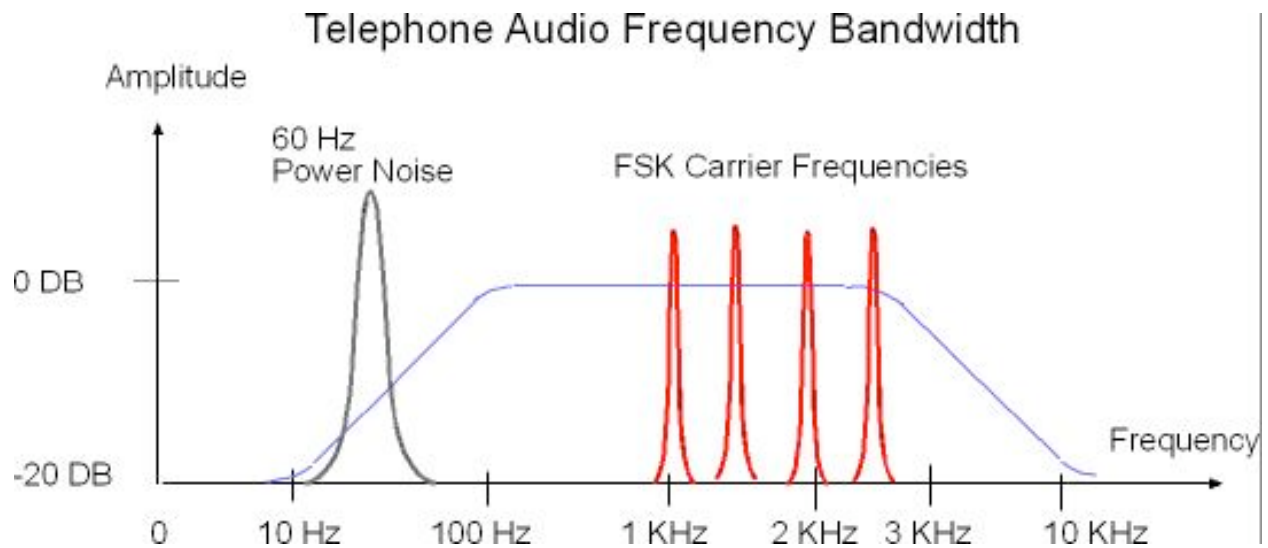
MODEM stands for modulator, demodulator and is used to combine digital data with a carrier signal in order to send the data long distances, at greater speeds, over electrically noisy media such as telephone lines.

There are several types of MODEMs. We will first look at the **FSK** or “Frequency Shift Keyed” MODEM, then we will discuss the **PSK** or Phase Shift Keyed” type of MODEM.

Frequency Shift Keyed or FSK means that the presence or absence of a signal is detected as a logical 1 or 0. Since data was primarily sent over the telephone lines, the frequency of the carriers had to fall within the telephone line band width. Typically telephones send audio frequencies between 100 Hz and 3 KHz. Frequencies below 100 Hz are rejected to prevent 60 Hz noise from the power lines from overwhelming the audio telephone signals. Since the telephone was mainly designed for audio speech, there was no need for frequencies much above 3 KHz. Since it cost more money to send the higher frequencies, the system was designed to cut them off.

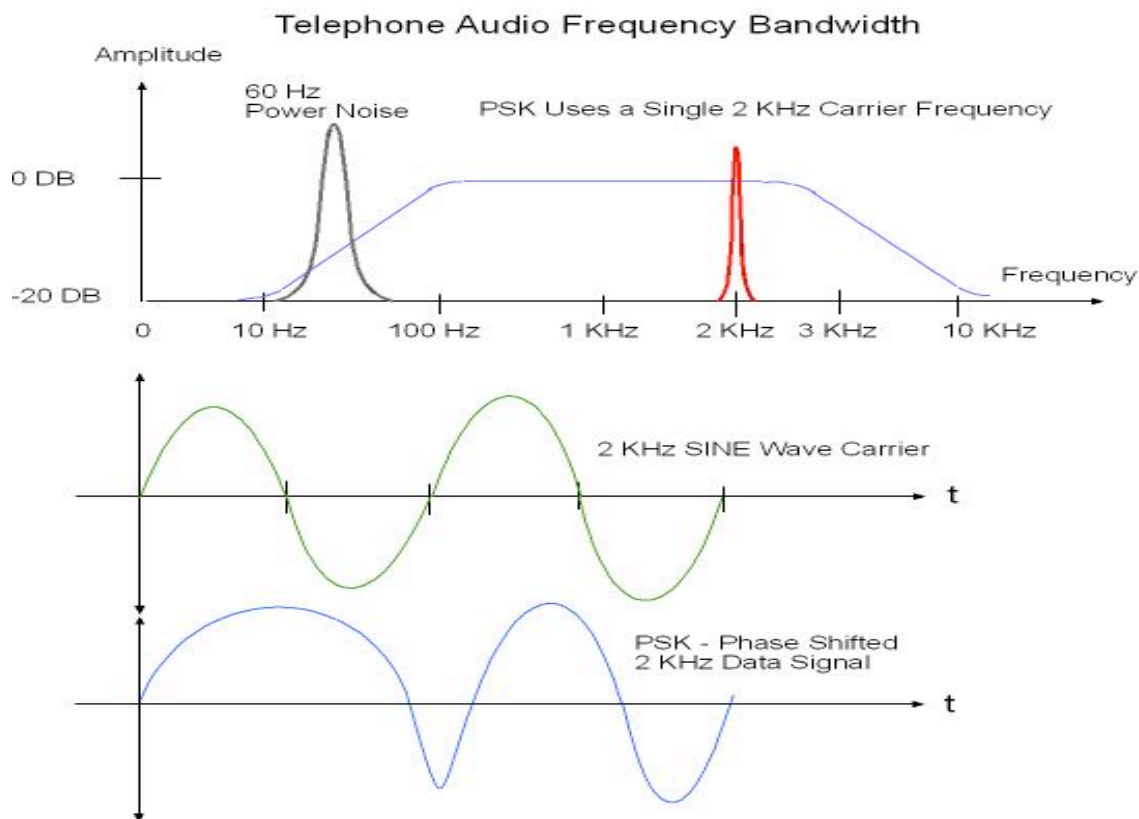
Data was sent on the telephone lines as four different frequencies ranging from 1 KHz to 2.5 KHz. The host computer used two frequencies, one for 1's and the other for 0's. The guest computer used still two other frequencies to send its 1's and 0's. The MODEM would turn on each frequency as needed when the transmitting computer was sending a message. It would then interpret the response by detecting the presents of the two frequencies from the other computer.

The MODEM frequency detection filters were quite good and could detect the presence of a 1 or a 0 frequency in less than one cycle of that frequency. Even with this achievement, the fastest data could be sent was 1200 BAUD, or 1200 data bit transitions per second. A later improvement got it down to $\frac{1}{2}$ of a cycle and got the BAUD rate up to 2400 BAUD but this was the best a MODEM could do over the telephone lines.



FSK type MODEMs were widely used up until the mid 90's when it was discovered that more information could be sent on a carrier by shifting the phase of the carrier then by measuring its frequency or individual cycles.

PSK or Phase Shift Keyed type MODEMs came into being after better signal processing on the telephone lines dramatically reduced electrical noise both in the 100 Hz to 3 KHz bandwidth and outside. The sensitive changes on the carrier necessary to encode the data could now be detected. **PSK** uses a device called a Phase Locked Loop or PLL to detect small almost subtle changes to the waveform pulse widths. These changes are called "Phase Shifts". The carrier is a sine wave that has 360 degrees per cycle. The carrier phase angle can move anywhere from a few degrees to several hundred degrees each cycle. The PLL detects these phase changes and returns a voltage proportional to the amount of phase shift. Now instead of one carrier being assigned to a single bit, each amount of phase shift is assigned several bits and data rates are now hundreds of times faster than the carrier frequency. Data transmission rates went from 2400 BAUD to well over 128 K BAUD almost over night. This one change made the internet possible for serious information handling and not just ASCII documents and email. PSK and the various variations of phase shift modulation that have come since mark the present state of the art in serial data transmission on a carrier system such as the telephone and wireless data links. It is where we are until the next big innovation makes it obsolete.

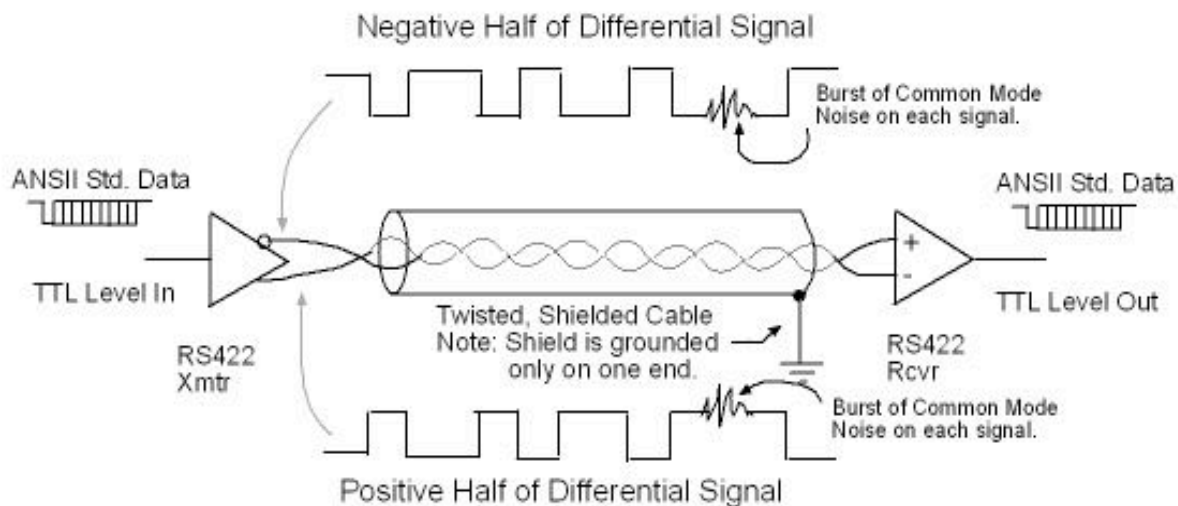


CONCEPT 10.4: ELECTRICAL DATA TRANSMISSION STANDARDS, RS422

RS422 is a “Differential Data Transmission System”. In RS422 the signal is sent out along with a mirror image of the signal. When the data is sent out as a high signal, the differential signal is sent out as a low signal and visa versa. The receiver on the other end processes the signal by amplifying the difference between the two signals and rejecting signals of the same voltage level. Same voltage level signals on the two data lines are called common mode signals. The reason this system is so popular and powerful is that electrical noise will appear at almost the same level with the same polarity on both data lines. If the data receiver only amplifies the difference between voltage on the two data lines, the electrical noise will be electrically rejected or cancelled out by the receiver circuitry. The modern data receivers are so good at rejecting common mode electrical noise while amplifying differential data signals, electrical noise is rejected by almost 100,000 to 1 over proper differential signals.

Typical RS244 Differential Serial Data Stream

Note: Electrical noise is common mode or at the same polarity and voltage level on each line while the signal is differential or has a positive and negative inverse.



Maximum Length can be over a mile and you still can have reliable data transmission.

CONCEPT 10.5: ELECTRICAL DATA TRANSMISSION STANDARDS, ELECTRICAL NOISE SHIELDING

Electrical noise is a reality that is minimized by shielding or blocking the noise with a conductive wall of foil or braided wire. The shield is effective if it is properly used and connected. The shield should never be used as the signal return line. Any noise on the shield will find its way into the system through the signal return currents. This is why good data cable will use two wires twisted together and then covered by some type of electrical shield.

The signal and signal return lines are twisted together to cause any noise that does get through the shield to be the same phase and amplitude on each line. This is called "common mode noise" and it can be easily filtered out using differential data receivers.

The shield must be grounded to a system ground that in turn runs to an earth ground, but it must be grounded only on one end. If it is grounded on both ends, electrical noise such as current from large electrical machines might use the ground shield as return path and induce even more electrical noise onto the data lines. This condition is called a ground loop. Ground loops have literally resulted in cables melting down due to high currents running in the shield because it found a path from the shield ground on one end to the shield ground on the other. **Only ground a shield on one end.**

CONCEPT 10.6: ELECTRICAL DATA TRANSMISSION STANDARDS, UNIVERSAL SERIAL BUS (USB) AND "FIRE WIRE"

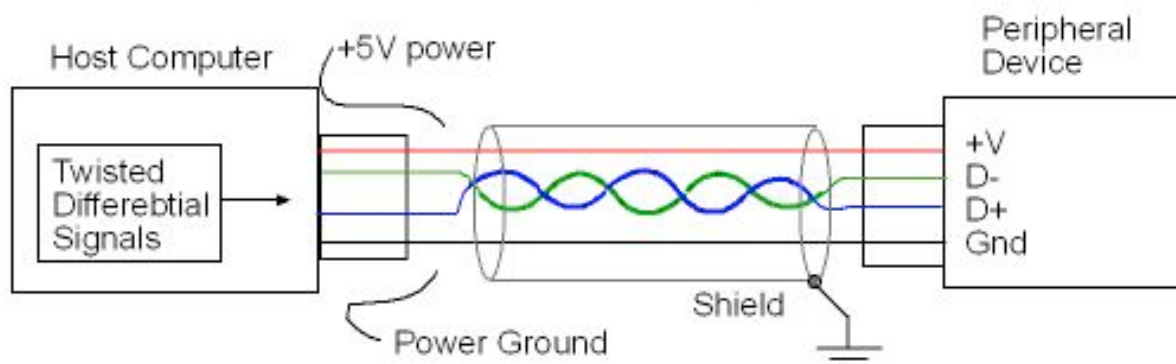
The Universal Serial Bus or **USB** utilizes both differential data transmission techniques to reduce common mode noise effects on data, and Phase Modulation (**PQM**). The two innovations working together on a twisted shielded cable allow for data transfer rates up to 1 Giga Bit per Second or one billion bits per second FOR "Fire Wire" and 500 Mega Bits per Second or 500 million bits per second for USB 2. This extremely high rate of data transfer can work up to 50 feet on a properly shielded cable. Much higher data rates have been tested successfully in the laboratory but presently USB 2 and Fire Wire are the main choices for high speed serial data transmission.

Both of these standards use the same technology and have the added feature of + and – 5 VDC power included in each cable. These new ultra high speed serial data transmission systems have become so popular in the computer world that experts are predicting that new computers may only

have Fire Wire and USB ports for all peripheral devices such as printers, displays, key boards and mouse pointers.

The data processing is very complicated, but commercial chips handle the details making it easy for computer equipment designers to use one of the many commercial interface chips to connect their equipment to the computer. The old RS232 COM port is already being left off of most new computers and soon the parallel printer port and other slower interface ports will follow suite.

USB Cable Description



CONCEPT 10.7: OTHER APPLICATIONS OF SHIFT REGISTERS

Other applications of shift registers include binary multiplication and division. Remember to multiply any number system by its base, simply shift the decimal point to the right on place. In binary shifting the bits one position to the left effectively multiplies the value by two. Shifting the bits one position to the left, divides by two.

A complex pattern of "1"s and "0"s can be generated by feeding the parallel bits back to the serial input after running the parallel bits through some combinational logic circuit that only outputs a 1 for certain conditions. The result can be almost random in nature and useful for certain games or random event controls.

By parallel loading a shift register with a complex pattern of 1's and 0's and then tying the serial out pin to the serial in pin on the shift register, you create a circuit known as a "Johnson Counter". It can be used to generate light patterns on displays and warning signs as well as in games and Christmas light systems.