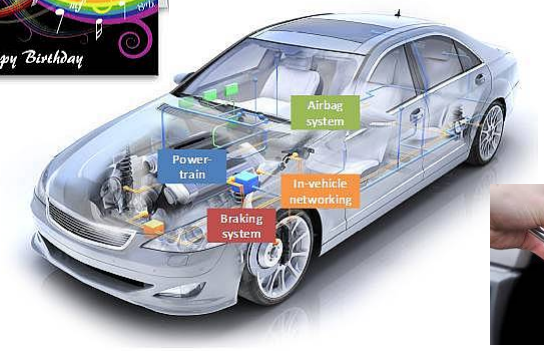
EGR 304
Embedded Microcontroller Systems
Spring, 2020







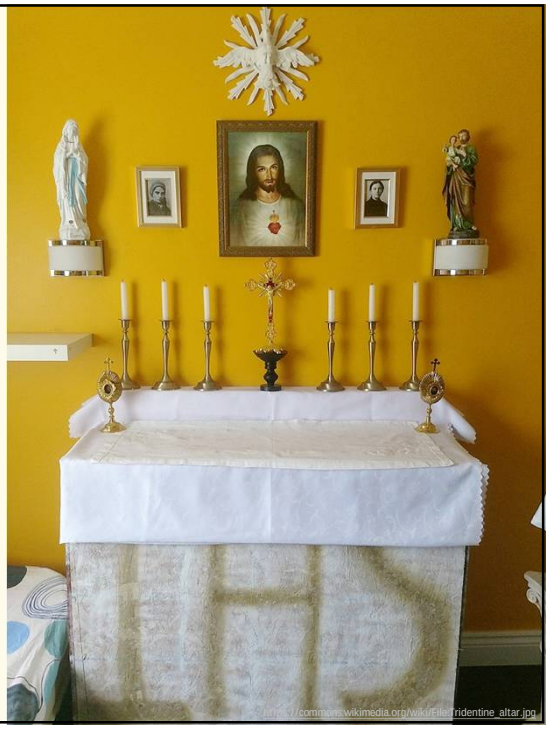
1

Piety: A quality of being religious or reverent.

From the Latin, pietas, the quality of being “devout” or “dutiful.”

At the right: A photo of a home alter, in this case a shrine to Jesus and the saints. This is a place where a pious person might pray or sing hymns to Jesus and the saints.

We all have our places of prayer and worship and duty.



2

I long to be strong,
full of vitality
with energy to spare,
wide awake
with my brain in gear,
spiritually ready,
heart motivated,
purposed possessed,
raring to go
with unstoppable zeal,
a competitor,
the envy of others with
no frailties,
no worries, and
no regrets.

3

I long to be strong,

4

I long to be strong.

But you have made me weak,
unable to be what I once was
ever again,
not in this life.

The old me—
Gone.

I cannot live as I once did.
I cannot do what I once did.
I cannot press through
what you have chosen for me.
I cannot escape.
I cannot break free.
I cannot will for something better.
Weakness is my lot;
suffering is my prison.
You have chained me to frailty:
I cannot break free.

5

I long to be strong.

But you have made me weak,
I cannot break free.

6

I long to be strong.

But you have made me weak,
I cannot break free.

But this prison is your workroom,
and I am your clay.
You are not a jailor:
You are a potter.
I have not been condemned;
I am being molded.
Your hands have been heavy;
your push on me is hard.
When the soil is resistant,
the molding is violent.

7

I long to be strong.

But you have made me weak,
I cannot break free.

But this prison is your workroom,
and I am your clay.

8

I long to be strong.

But you have made me weak,
I cannot break free.

But this prison is your workroom,
and I am your clay.

My weakness is not about what I am enduring.

My weakness is about what I am becoming.

May travail does not preach your anger.

My travail preaches your grace.

9

This prison is your classroom.
I am learning
your presence.
I am learning
your power.
I am learning
your mercy.
I am learning
your gospel
I am learning
learning,
learning.

10

This prison is your classroom.
I am learning
your presence.
I am learning
your power.
I am learning
your mercy.
I am learning
your gospel
I am learning
learning,
learning.

The danger for me was never weakness.
The danger has always been my delusions of strength.
You have shattered my delusion and, in shattering, have proven that my strength is and always has been you.

The quality of being "devout" or "dutiful."

11

This prison is your classroom.
I am learning
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learning.

The danger for me was never weakness
The danger has always been my delusions of strength.
You have shattered my delusion and, in shattering, have proven that my strength is and always has been you.

Do you not know?
Have you not heard?
The LORD is the everlasting God,
the Creator of the ends of the earth.
He will not grow tired or weary,
and his understanding no one can fathom.
He gives strength to the weary
and increases the power of the weak.
Even youths grow tired and weary,
and young men stumble and fall;
but those who hope in the LORD
will renew their strength.
They will soar on wings like eagles;
they will run and not grow weary,
they will walk and not be faint.
—Isaiah 40:28-31

This devotional derived from Paul David Tripp's book, *My Heart Cries Out: Gospel Meditations for Everyday Life*, Crossway Books, 2019.

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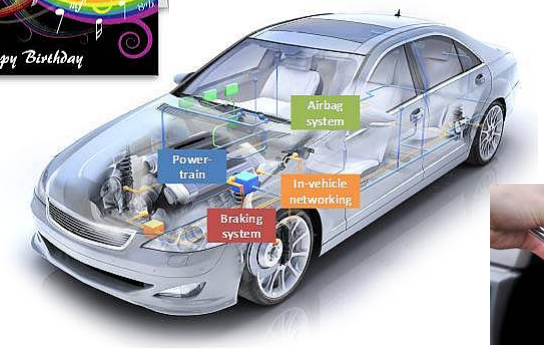

Where have we been? A fast review in order to get up to speed after spring break.

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History of computing
- -Early computers--abacus, mechanical adding machines, Babbage (difference) engine, relays, tubes, transistors --then miniaturization
- -microprocessor—CPU on a chip, enables Apple, PC etc.
- -microcontroller—special purpose CPU with I/O ports, memory all on one chip, enables appliance control, etc.
- -System-on-a-Chip (SoC)—more general-purpose, enables smartphone technology
- -now emerging: Cyber-Physical Systems—many sensors, world-spanning networking, distributed processing.

Software development
- -machine language, assembly language, platform independent procedural (C), object-oriented (C++, Java, Python
- -compiled vs. interpreted
- -software version control; server-client w/ central repo. (e.g. SVN) Vs. peer-to-peer with distributed repo (e.g. Git)

I/O Ports and General-Purpose I/O pins
- -Typical Arduino GPI**O** pin functionality, typical Raspberry Pi GPIO pin functionality
- -Parallel port—an array of GPIO pins acting in coordination. (e.g. IEEE-488 bus a.k.a GPI**B**)
- -I/O strategies: 1.) Blind Cycle, 2.) Busy-waiting, 3.) Polling, 4.) Interrupt driven, 5.) Direct memory access.
- -Typ. output connections: LED with series R, Motors with flyback diode, higher voltage loads via transistors, relays
- -Typ. Input connections: switch debouncing

Analog inputs
- -sensor modeling, decibels, dynamic range, accuracy, precision
- -A/D conversion means anti-aliasing, sampling, quantizing. (Implications of errors in these processes.)
- -Analog signal integrity: cable design (shielding, impedance), single-ended vs. differential
- -Specific common analog inputs: Time, Temperature

Accuracy needs to be put in context. E.g. False positives are common when positives are rare.

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Motor Control
- -Types of motors: DC, Stepper-Servo, AC (many sub-varieties)
- -Mechanical degrees of rotation vs. electrical degrees
- -Pulse-Width-Modulation
- -Current is related to torque, voltage is related to no-load speed (usually)
- -Holding torque vs. running torque
- -H-bridge driver (hardware)

Position feedback
- -Relative feedback: Quadrature encoder (sensing direction, resolution)
- -Absolute feedback: Grey-code, V-scan, U-scan
- -Accuracy needs to be put in context. E.g. False positives are common when positives are rare.

Interrupt-driven programs including interrupt-driven I/O
- -Memory capabilities needed, stack, stack-pointer
- -Instructions needed, enable/disable, push, pop, return from interrupt
- -Hardware needed, interrupt-enabled pins
- -Sources of interrupts: HW, SW, Exception
- -Advantages of interrupt-driven—foundational to object-oriented programming
- -Risks of interrupt-driven I/O: density limit, latency, timing res., interval restrictions, critical regions, deadlock
- -Puts emphasis on data and objects. Program flow and algorithmic efficiency tend to get ignored.
- -Interrupt interval and density calculations, example

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Scheduling Tasks
- -Two types of tasks: 1.) Preemptive (interrupts disabled) or 2.) Cooperative
- -Task table (Example: making a 5 second-long pulse)
- -Using counter-timers for faster or higher-resolution tasks
  - --Input Capture Events
  - --Output Compare Events
  - --Combined use of input capture and output compare for period and/or frequency measurements
  - --Direct vs. indirect measurements of periods and frequencies

Digital Memories
- Cloud/Networked Storage, Archival/Mass Storage, Main Mem, Virtual Mem, Cache Mem, Register Memory
- Harvard vs. Von Neumann Architecture
- Storage hierarchy
- Characteristics: Volatile vs. non-volatile, Mutability (ease of writing),
- Accessibility and Granularity (any address any time? Must read entire sectors? etc.)
- Semiconductor media: Static RAM, Dynamic RAM, ROM, EPROM, EEPROM, Flash, Ferroelectric
- Other media: Magnetic, Magneto-optical, Optical (Note the archival qualities of tape at 200 GB/square inch.)
- Now obsolete: Paper tape, punch cards, tubes, electro-acoustic , core
- Future possibilities: Digital storage via DNA.

AC Loads
- On-Off (bang-bang) control via relays, solid-state (with optical isolation) or mechanical.
- Waveform alteration via triac to alter RMS voltage (non-ideal for most AC motors, good for incandescent lighting)
- Variable-frequency drive—ideal for AC motor control.

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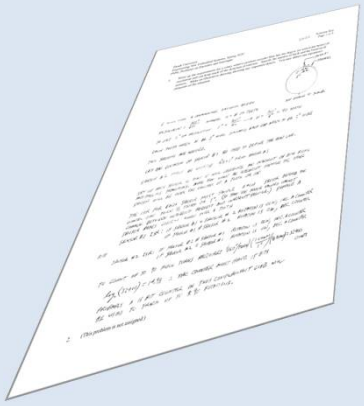
A note on homework:

Prof. dDB forgot to record the grades for PS#6.
Thus, the entire class is given 23/23 in the gradebook for this assignment.

Solutions to PS#6 are now available.
(Click on the "returned" date on the homework page.)

PS#7 is due this Friday.
We will cover all you need for this assignment today and Wednesday.

To turn in homework. . .
Best option is to do it all electronically in a word processor,
Then export to PDF and upload to Canvas at the link provided.
This *may not be very practical* considering time pressure.
An equivalently good option is to do the homework on paper as usual.
Then. . .
-Scan it to PDF and upload the PDF to Canvas.
-or use a "scanner" app on a smartphone and upload the file to Canvas.
-or use a camera on a smartphone and upload the file to Canvas.
-if none of these options are available to you, please contact me.



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How will labs work?

We will divide into three teams of four persons as follows:

Team One:
Patrick
Kyle
Stephan
Nolan

Team Alpha:
Zachary
Dan
Tyler
Ryan

The A Team:
Lucas
Shane
Matthew
Charley

On Wednesday I will introduce the second project requirements just as I would have in a normal lab period, except I will do it via a Zoom conference starting at 2 PM CDT.

At the conclusion of the introduction I will set up three "breakout rooms" in zoom, one for each team. I will also reserve three workbenches in our actual lab, SB2803, one bench for each team. I will be your hands and eyes in the lab, building things, connecting things, testing and reporting results as we go.

I will rotate my time between groups making sure that I spend as close as possible to 1/3 of my time in 10-minute intervals with each group. Think of my lab time as being divided into 10-minute packets and your group will get 1/3 of my time packets.

During the 20-minute intervals when I am not present in your breakout room, your groups should be diagnosing, designing, de-bugging, etc. so that you can direct my hands to do your bidding efficiently when I am present.

We will build and test the project with real hardware in SB2803.
Any hardware one of your team members has and any emulators or other software you can find may be used in the breakout rooms as well.

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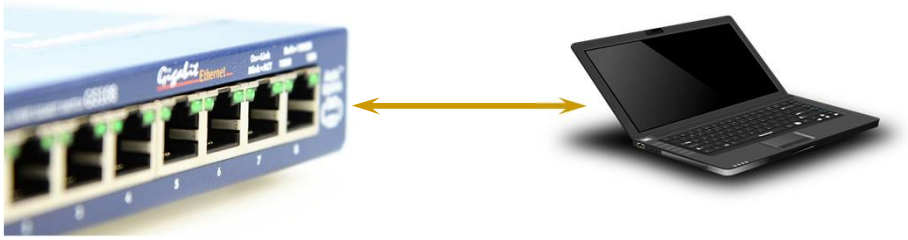
Serial interfacing techniques

The main advantage of serial interfacing techniques:
Low-cost and long-distance copper or optical connections!



Serial interfacing is one of two important styles of digital communication.
The other style is parallel interfacing.

https://www.amazon.com/Quaker-00030000065310-CapN-Crunch-Cereal/dp/B00GV46API
https://www.amazon.com/Monster-Cereal-Count-Chocula-10-4-Ounce/dp/B005DQGIA2

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SUMMARY SLIDE

Serial interfacing techniques

Asynchronous vs. Synchronous

Definition of an ***asynchronous*** serial interface:
Data is sent in short bursts called symbols (e.g. a symbol could be a byte of data). The data need not be streamed continuously. There may be idle intervals of arbitrary duration between symbols. The receiver decodes the received symbols by timing various features of the received waveform relative to the receiver's clock. (Typically timing from the start of the transmission of a byte.) ***The transmitter and receiver clocks are independent, and some margin of speed difference (a few percent) is tolerable***.

RS-232, RS-422, RS-423 are examples

Definition of a ***synchronous*** serial interface:
The data may be streamed continuously or sent in bursts called packets. Packets are composed of many bits of data, several bytes to a tens of kilobytes typically. The on-going nature of data transmission allows timing information for symbol (bit or byte) decoding to be embedded in the stream of data. ***The receiver recovers a phase coherent clock signal from this embedded timing information***. *Phase coherent* means exactly zero frequency error (has only timing delay—to match path length) when comparing received clock to the transmitter's clock.

USB and Ethernet are examples

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Asynchronous:
Will be illustrated via RS-232

RS-232 The "non-standard standard" that won't go away.

It is the oldest form of digital communication, predating computers, predating its own standard.

Around 1910 electric typewriters were interconnected by wires using a 5-bit serial code called Baudot Code. Initially used for such things as interconnecting police precinct offices in a city. Later used for sending stock price information, news information (AP "wire service" for example) and many government roles, especially in wartime for diplomatic paperwork and codebreaking. (More at http://www.dbase.com/Knowledgebase/dbulletin/bu07sh.htm)

Finally this system was standardized in 1960 by the Electronic Industries Association.

http://www.knobstick.ca/cjpgs/b281a.jpg

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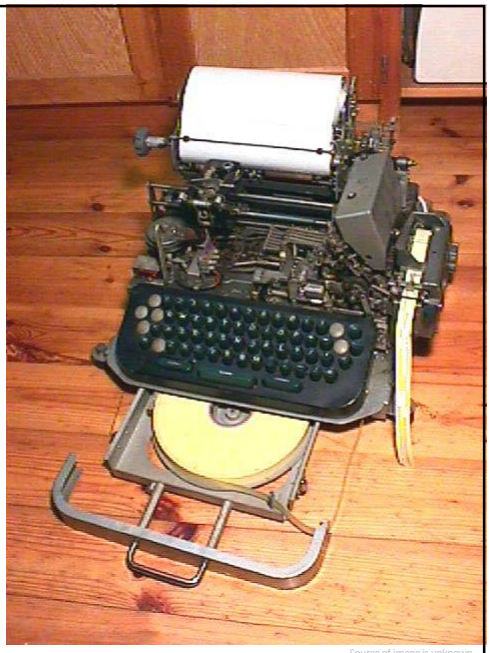


Source of image is unknown.

WACs assigned to the Eighth Air Force in England operate teletype machines. (DOD photograph)

https://commons.wikimedia.org/wiki/File:WACsOperateTeletype.jpg

23

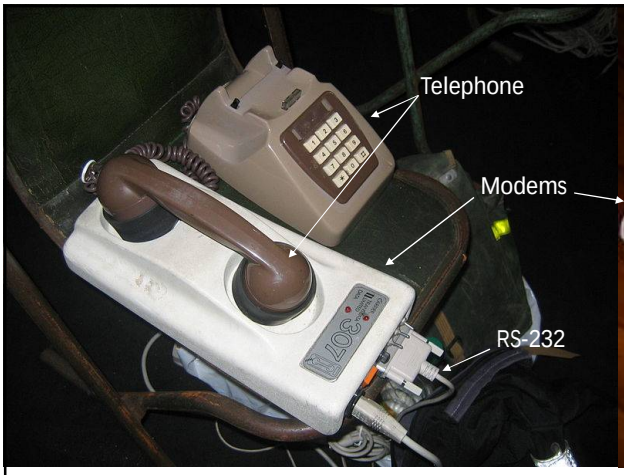
Teletype model 33

https://commons.wikimedia.org/wiki/File:Teletype_with_papertape_punch_and_reader.jpg

https://commons.wikimedia.org/wiki/File:DEC_VT100_terminal.jpg

Digital Equipment Company
DEC-VT100 (Keyboard is detached)

24



First practical laptop computer, 1983.
There was no Internet.
Connect to various services via modem over dial-up telephone lines.
America Online was a big favorite. Others: CompuServe, Prodigy
The connection between the modem and the computer was always RS-232.

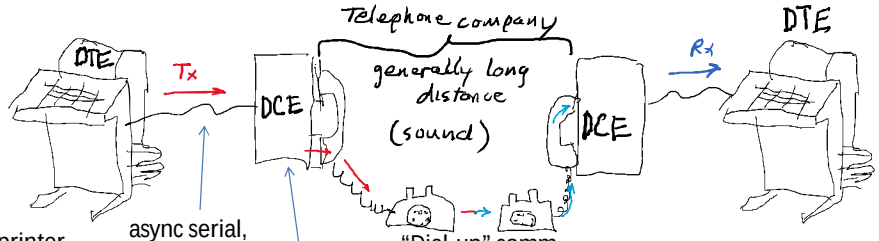
"I'm not used to giving Radio Shack kudos, but the Model 100 is a brave, imaginative, useful addition to the realm of microcomputerdom" and "a leading contender for InfoWorld's Hardware Product of the Year for 1983", an award which it indeed won. [https://en.wikipedia.org/wiki/TRS-80_Model_100]

https://commons.wikimedia.org/wiki/File:Analogue_modem_-_acoustic_coupler.jpg

25

The pre-computer era of asynchronous serial communications.

No computers in this block diagram!



teleprinter
Data Terminal Equipment

async serial,
this is RS-232

Modem,
Data
Communications
Equipment

"Dial-up" comm
Through the phone
system

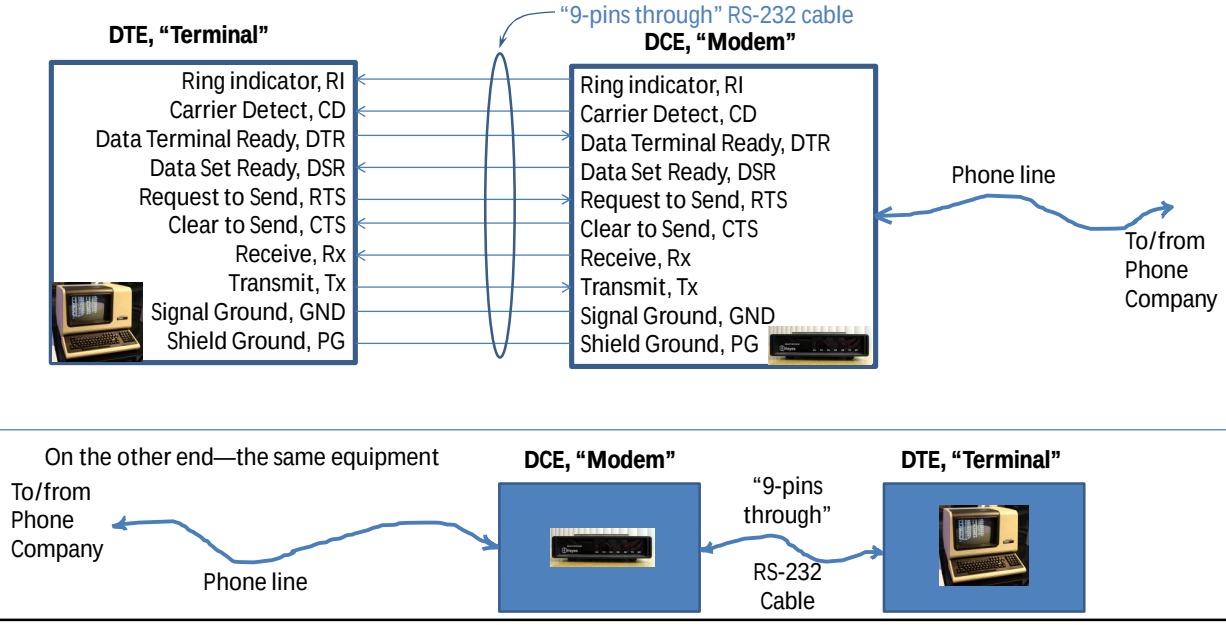
Crossover from Tx to Rx happens in the land-line phone system

RS-232 standardized the connection between the teleprinter and the modem. But only addressed the connector and the electrical signal levels, not the symbol encoding (now often the ASCII standard is used for that).

26

Some of the many wires specified in the RS-232 standard.

The 1960's era standard calls for a 25 pin connector! The 9-pin version is shown here



27

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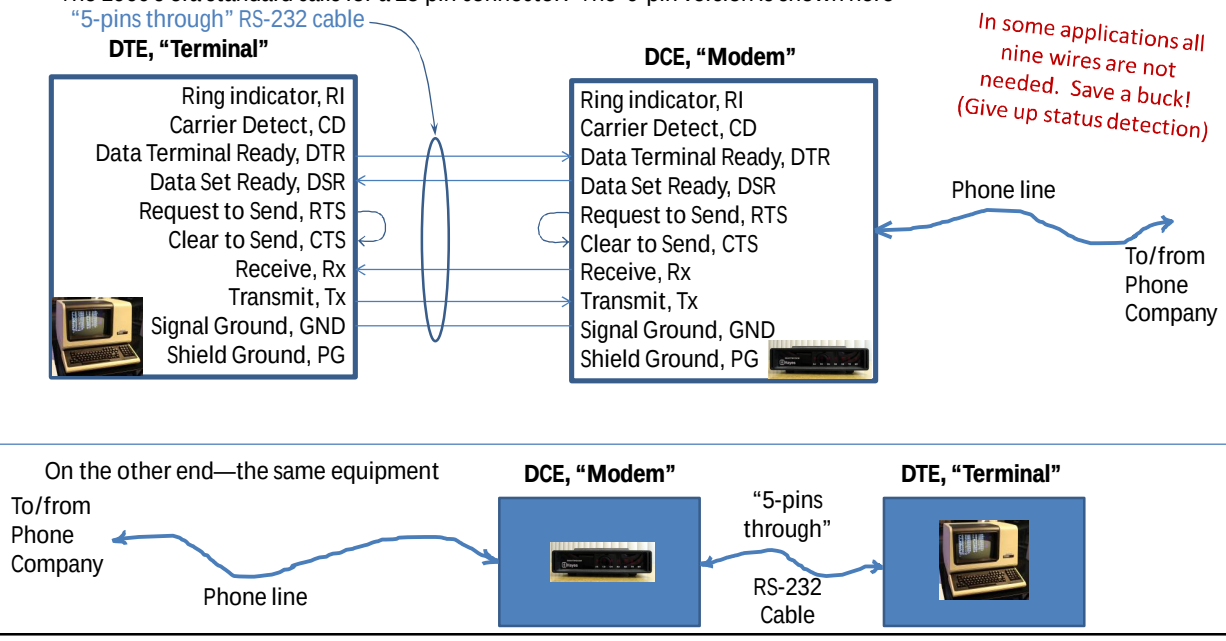

28

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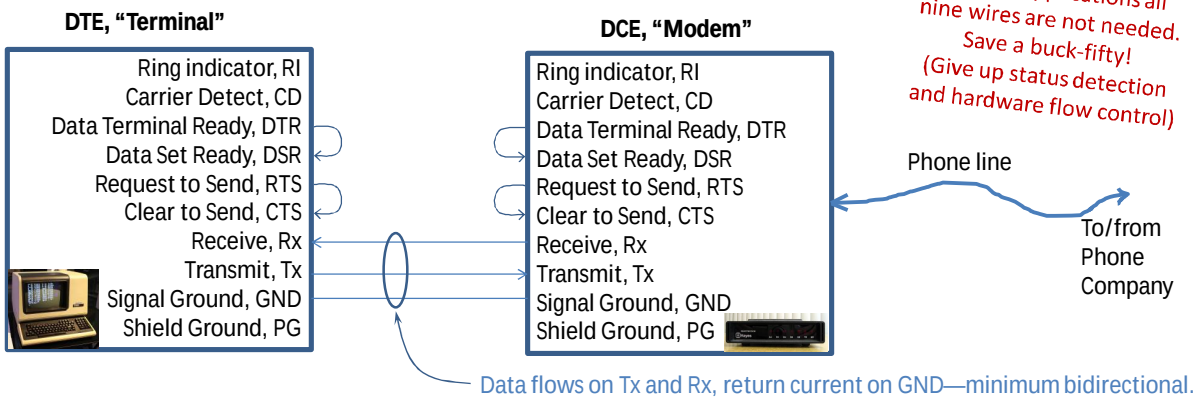
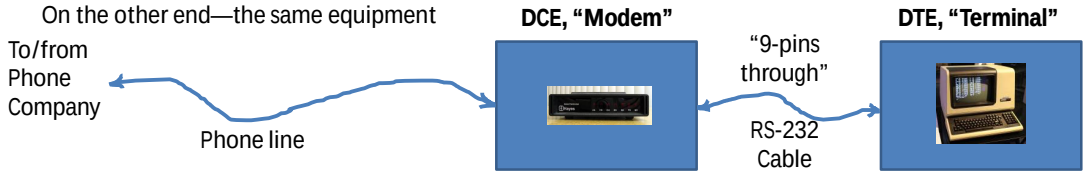


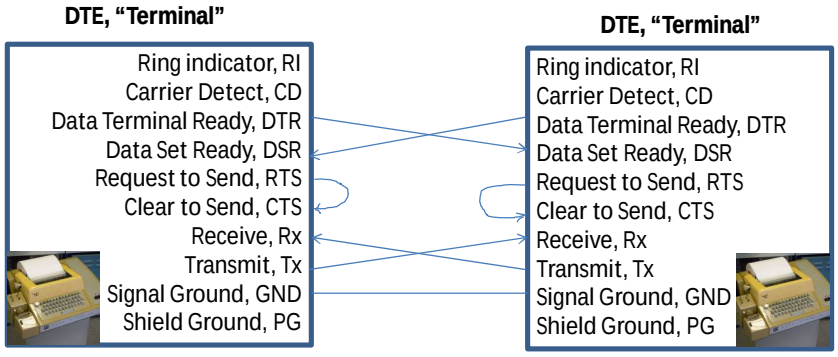
On the other end—the same equipment



29

Sometimes terminals were used within the same building. Example: editorial office of a newspaper to the typesetting room. A "five-wire" connection was common, but because there were no modems and no phone company involved, the crossover from Tx to Rx needed to be done in the cable between the two terminals.

This is called a "**null modem" cable**.



No phone company, no modems.
The computer is acting as another teleprinter.

30

Stage left—front:
Enter. . . THE COMPUTER. . . (1950's, 1960's)

IBM System 360
-Standardized the concept of a *byte* (8-bits)
-First commercially successful microcoded CPU
-Floating-point number crunching in the OS
-EBCDIC character encoding (competitor to ASCII)

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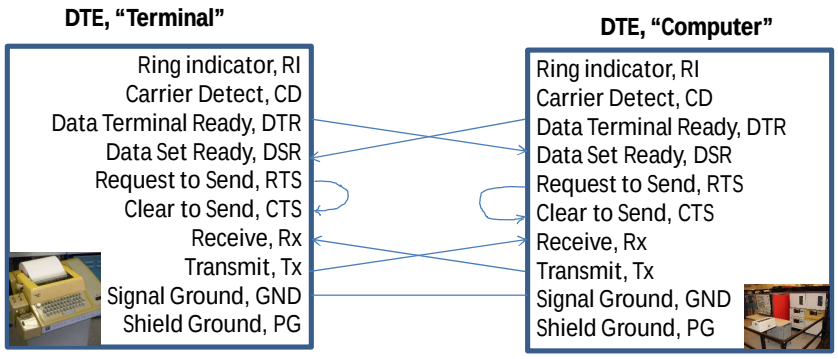
In the computer era, teleprinters were the perfect devices to use as console i/o. No modem is used since the computer and the terminal are in the same room. Computers of this era had no keyboard or display. Instead, a teleprinters was connected to serve as the computer's keyboard and display. A "five-wire" connection was used. Because there was no telephone involved, the crossover from Tx to Rx needs to be done in the cable. This is called a "**null modem" cable**.



Connected via RS-232

Computer

Teleprinter

No phone company, no modems.
The computer is acting as another teleprinter.

32

Electrical standards for RS-232

Negative true

T-line effects are anticipated

RS-232 Nomenclature	Computer nomenclature	Output (volts)	Input (volts)
SPACE	Logic-0	+ 5 to +15 +12 typical	+3 to +25 x to +25 typical*
MARK	Logic-1	-5 to -15 -12 typical	-3 to -25 x to -25 typical*

Rx threshold could be anywhere between +3V and -3V

*x was 0 volts on older equipment. On most newer equipment it is made about equal to 1.6 volts.
This is not standardized

Standard logic levels (for comparison to RS-232 signaling)

	TTL	CMOS, 5 V	CMOS, 3.3 V
Logic-0	<0.8 V, 0.1 V typ.	<1.5 V, 0 V typ.	<1.3 V, 0 V typ.
Logic-1	>2.0 V, 3.8 V typ.	>3.6 V, 5 V typ.	>1.9 V, 3.3 v typ.

~+1.6 V threshold works for most logic families.

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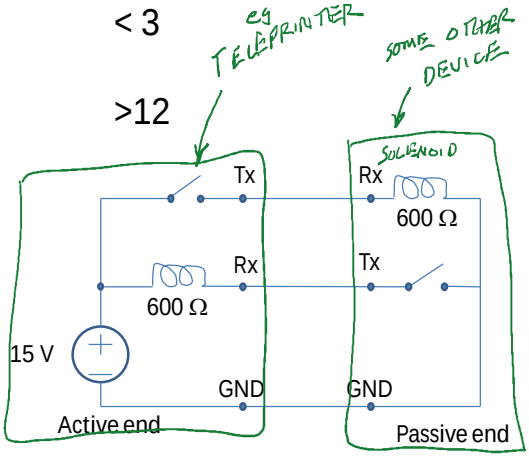
EGR 304 Tuesday 2/07/2017

The "C" does not mean "revision C"– it means "current loop."

Electrical standards for RS-232C, with the current loop option

RS-232C Nomenclature	Computer nomenclature	Output (mA)	Input (mA)
SPACE	Logic-0	0	< 3
MARK	Logic-1	20 or 60 nominal	>12

The above information is not actually in the standard. It is merely an industry convention used with the RS-232 connectors and wiring styles.



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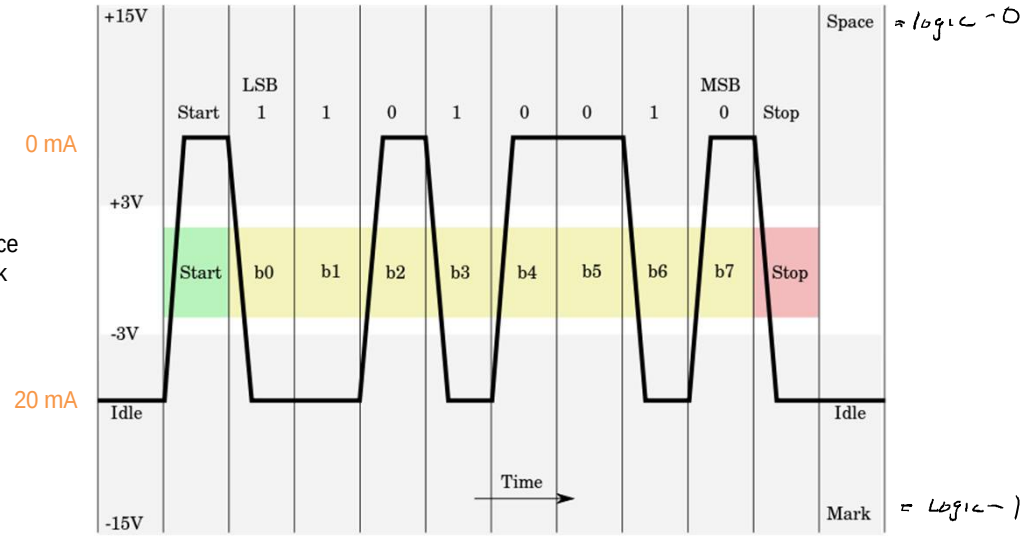
RS-232 Timing

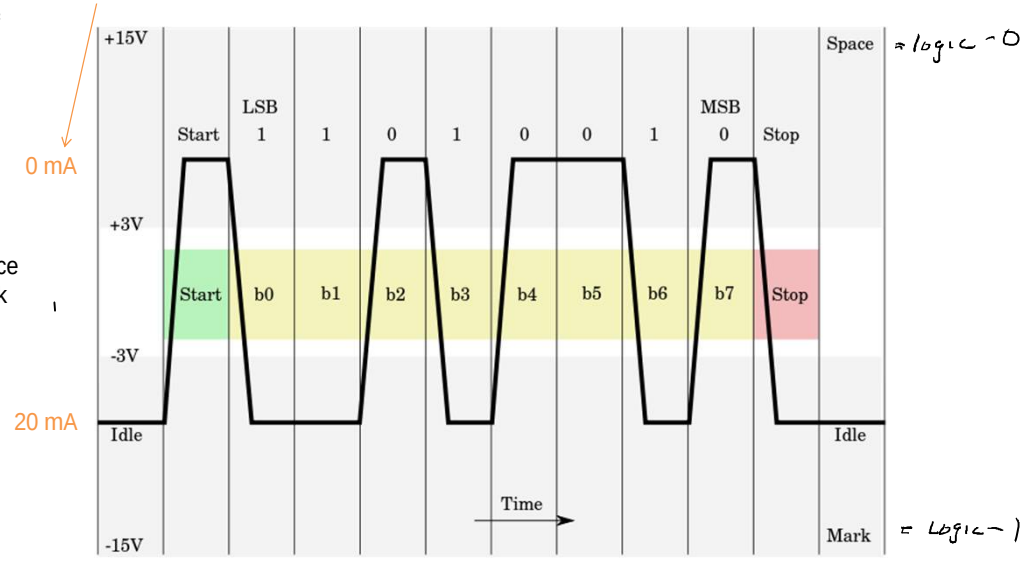
Illustration of sending one "symbol"



35

RS-232 Timing (Re-label the vertical axis for the current-loop type interface.)

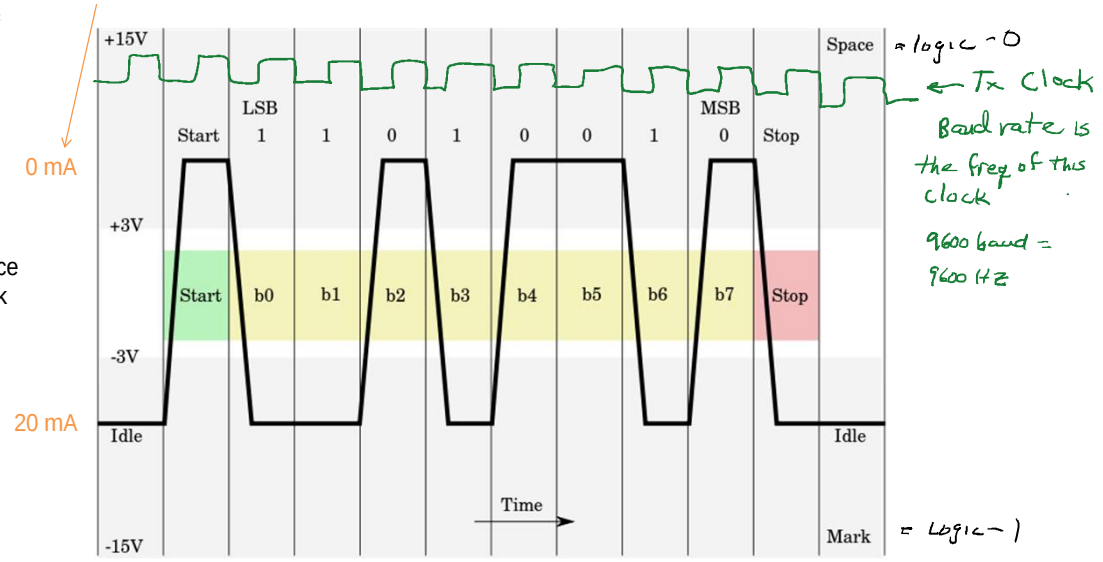
Illustration of sending one "symbol"



36

RS-232 Timing (Re-label the vertical axis for the current-loop type interface.)

Illustration of sending one "symbol"



Logic-0 = space
Logic-1= mark

= logic 0

← Tx Clock

Baud rate is the freq of this clock.

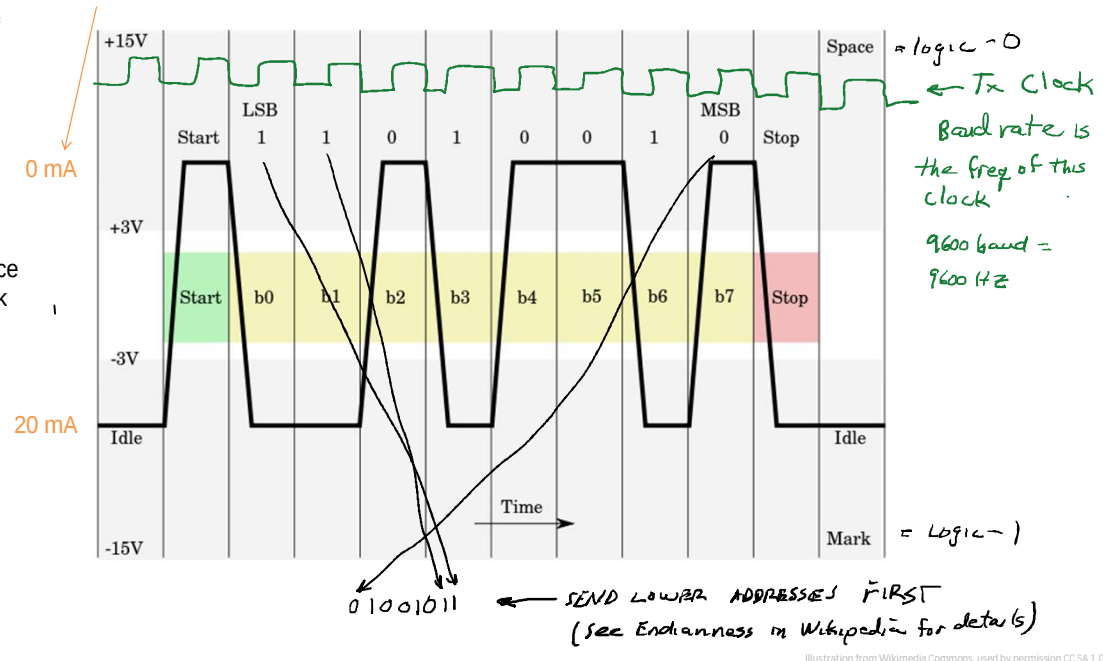
9600 baud = 9600 Hz

= Logic 1

37

RS-232 Timing (Re-label the vertical axis for the current-loop type interface.)

Illustration of sending one "symbol"



Logic-0 = space
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← Tx Clock

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38