Command and Data Handling: Microcontrollers and Associated Components

Mark Campbell

AA420 Space Design

Outline

- Data: Bits, bytes, words, etc.
- Microcontrollers
- Interfaces
  - Digital inputs/outputs
  - Analog to Digital (A/D)
  - Digital to Analog (D/A)
  - Serial and Parallel
  - Common protocols: RS-232, etc.
- Important System Design approaches:
  - Multiplexing (MUX) signals
  - Signal Conditioning
  - Timers
- Memory

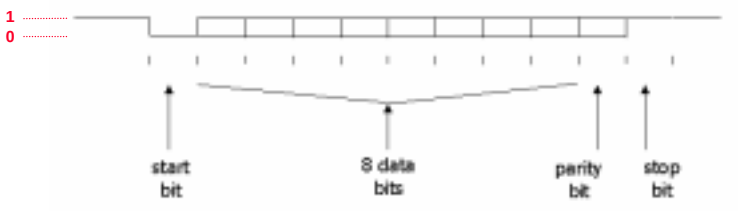
- References:
  - Larson and Wertz
  - CS477 on-line class notes, Questions to mentors

Data Structure

- Almost all microcontrollers need the information in terms of "numbers" to do fast computations
- Binary Numbers
  - 1 or 0
  - Number of digits is a "bit"
- 2 bit
  - 00 = 0
  - 01 = 1
  - 10 = 2
  - 11 = 3
- 3 bit
  - 000 = 0
  - 001 = 1
  - …
  - 111 = 8
- For *n* bits, there are 2^n options or numbers that can result
- 8-bit is common: 256 options, like your keyboard!

Data Structure

- A *byte* is 8 bits put together (not used as much as it was when computers first came out).
- A *word* is a group of bits that the computer can/will interpret.
- For example, a line is always high (i.e. 1), then dips to 0 to indicate a start to the word. The sender and receiver must know the word length (8 bits in this case).

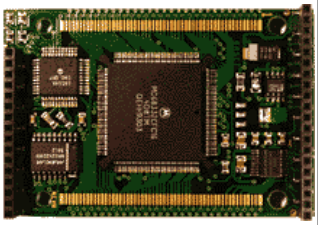


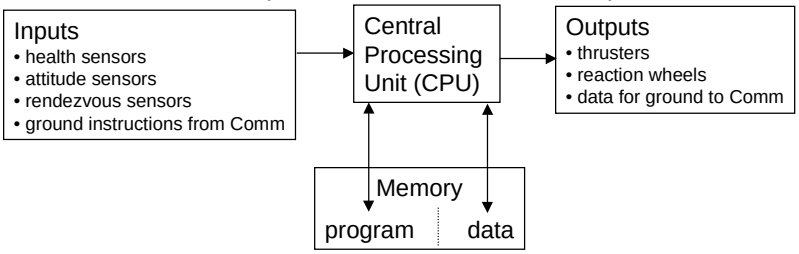
- Parity is bit (odd or even sum) for error checking
- The number of bits per second gives the data flow rate. For example, 9600 bits/sec is 9600 baud (think of your modem)

Microcontroller

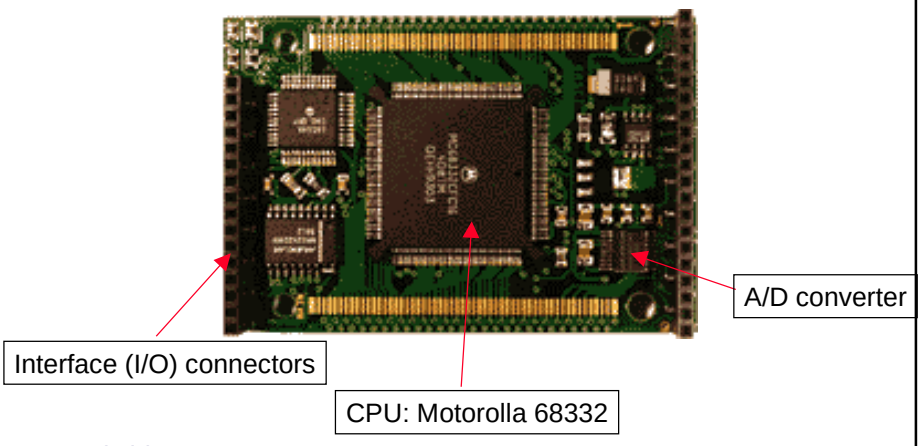
- A microcontroller / computer is used on a satellite for
  - Processing/storing payload/science data (docking measurements)
  - Gather and process routine housekeeping/ health data (temperatures, voltages, etc.)
  - Process/carry out instructions from the ground (a series of pre-determined burns to get one s/c closer to the second).
  - Process/carry out instructions in memory (attitude control)
  - Control data flow (within sat, communications, etc.)

TattleTale8 Microcontroller





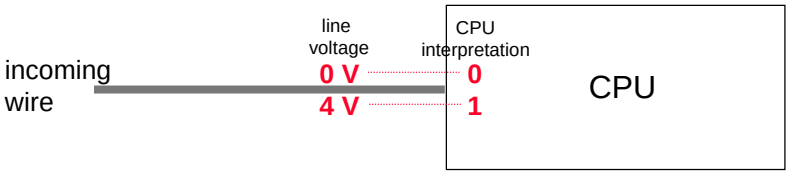
Components on a Microcontroller



- Backside
  - memory (RAM, ROM)
  - other components

Digital Inputs / Outputs

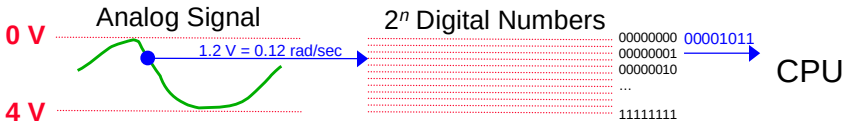
- The CPU will access digital inputs lines check to see if the line has a high or low voltage:
  - 0 V is given a value of “0”
  - 4 V is given a value of “1”

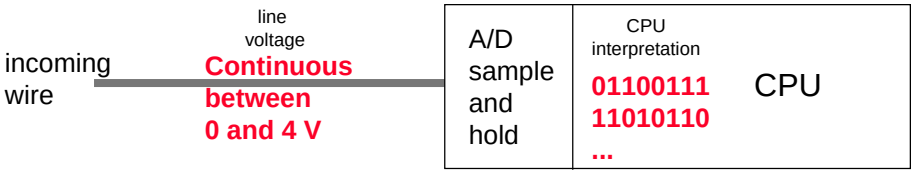


- Groups the digital numbers in words (i.e. an 8-bit word)
- Just the reverse for digital outputs
- A few sensors/actuators are digital:
  - digital encoders which count number of pulses as it rotates
  - thruster pulse

Analog Inputs and A/D

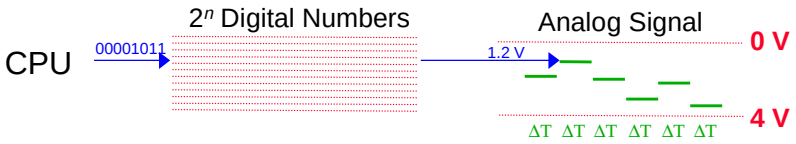
- The most common input is analog, which is a continuous and varying.
  - thermocouples, gyros, voltages, etc.
- Analog inputs are usually accompanied by an A/D converter (Analog to Digital)
- *n* bits in each word gives 2^n resolution for incoming data





Analog Outputs and D/A

- Same as the analog inputs but in reverse.

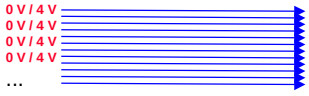


- With ΔT small, this looks like a continuous signal

Serial versus Parallel Interfaces

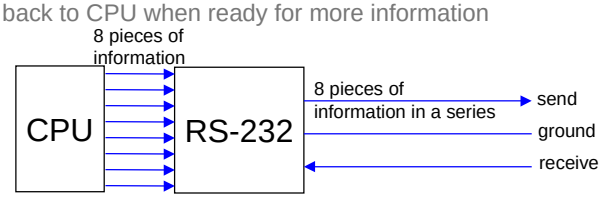
- Serial interfaces: only one signal / bit at a time
  - O V = “0”
  - 4 V = “1”
  - Example: a single wire

- Parallel interfaces: multiple signals / bits at a time
  - 0 V or 4 V for each wire
  - N wires
  - Example: ribbon cable for video, SCSI hard drive, etc.



Common Protocol Communicating between Serial Components: RS-232

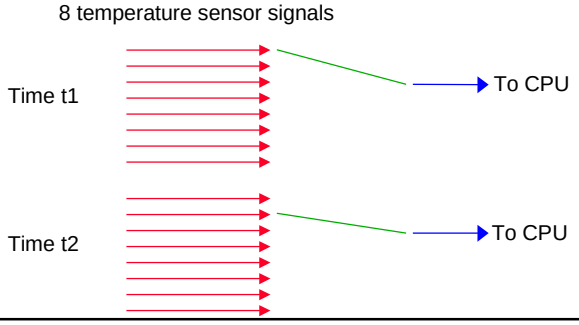
- UART: Universal Asynchronous Receiver / Transmitter - General name for being able to *send* and *receive* a signal
- RS-232: A very common set-up (protocol/architecture) for UARTS on small microcontrollers
- Another example: USB
- Process:
  - sample all 8 pieces of information at the same time
  - save in a buffer (UART memory)
  - send one at a time
  - call back to CPU when ready for more information



- Faster than MUXing, duplex, but need RS-232 on other end

Multiplexing (MUXing)

- Gang multiple sensors into one line
- Saves the number of input/output lines required on microcontroller
- Requires more complex software to “decode”
- Concept: Take advantage of the low sampling required for sensors (i.e. 1 Hz for temp sensors) and the high throughput of the input channels of the microcontroller (i.e. 100 KHz)
- Like a train track with a switcher:



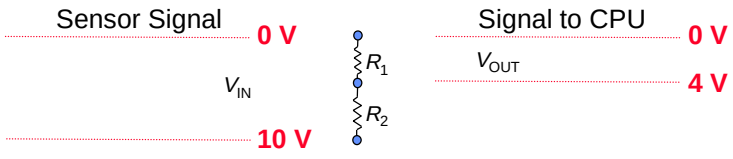
Processing or Clock Speed

- The speed at which one instruction executes is the processing or clock speed
- The constraint is usually not a factor if a smaller number of inputs and outputs are used.
- But if items are MUXed, or components are added (more A/D), then more processing is required

Signal Conditioning

- The microcontroller is expecting a signal between 0 and 4 V, with current less than 150 mA
- The microcontroller puts out a signal between 0 and 4 V, with current less than 150 mA
- What happens if the sensor or actuator do not fit these constraints?

  Signal Conditioning is required on both ends
- Sensor Example: Voltage Divider

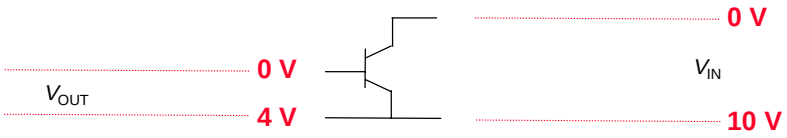


$$V_{OUT} / V_{IN} = R_1/(R_1 + R_2)$$

- The output voltage is proportional, but less than the input voltage!

Signal Conditioning

- Actuator Example: An amplifier circuit, such as using a transistor:



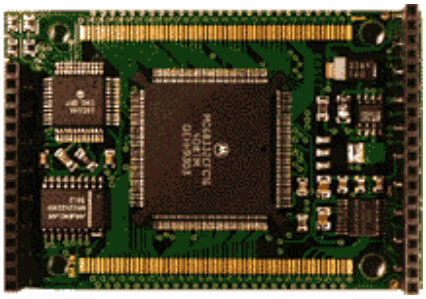
Timers

- Timers count down or up to help with clocking, checking, etc.
- One of the most important timers is the *Watchdog Timer,* used for fault detection in the computer system
  - a method of determining if the computer is functioning correctly (hardware or software)
  - important for more autonomous systems with decision making capability (including closed loop attitude control)
  - *independent* of the processor itself
- Approach
  - one or two timers count down
  - the processor must reset the timers before they hit zero (time-out) by writing a word to a specific address
  - If the timer times out, it is assumed that the processor is not functioning correctly
    - a reboot sequence is initiated
    - ground command must clear it.

Memory

- There are many types of memory for many types of applications.
- ROM: Read Only Memory
  - Non-volatile memory, i.e. it will still be there after a reboot
  - Used for programs
  - Fused Link ROM - nonerasable memory
  - EPROM - Can be erased using UV light
  - EEPROM - Can be electrically erased
- RAM: Random Access Memory
  - Volatile memory, i.e. it is gone after reboot
  - Used for (non-)critical data, such as temporary data before downlink
  - Scratch - place to store very temporary data
- Other Definitions:
  - FIFO (First In First Out) - queue of memory, not addressable, keep track of head and tail of queue

Components on a Microcontroller



SIZE (INCHES)	2 x 3 x 0.5
WEIGHT (0Z)	1
PROCESSOR	MC68332
DATA CAPACITY(RAM)	256K (1 MB)
ADDITIONAL CAPACITY	POSSIBLE
EEPROM	256K
A-D CONVERTER	12-BIT
ANALOG CHANNELS	8
ANALOG REF VOLTAGE	0-4.096V
MAX SAMPLING RATE	100 KHZ
DIGITAL I/O LINES	UP TO 25
MINIMUM CURRENT	<200 uA
PEAK CURRENT	150 mA
UARTS: RS-232 PORTS	2
MAIN UART'S BAUD	9600
TPU UART BAUD	TPU LINES CAN BE SET UP TO 500K
VOLTAGE INPUT	7 - 15V
CLOCK	HARDWARE 160KHZ-16MHZ
OPERATING TEMPERATURE	-40 - 85 C
PROGRAMMING	IN C