MECHTRON 3TA4 Summary

Author: Kemal Ahmed
Instructor: Dr. Mark Lawford
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Math objects made using [MathType](); graphs made using [Winplot]().

Please join GitHub and contribute to this document. There is a guide on how to do this on my GitHub.

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Chapter 1

Market Window (W): the amount of time, in months, between the on-time entry of the company and peak revenue. It is also the amount of time from peak revenue to when revenue gets to 0. In other words, the entire lifecycle of a product is 2×W

Delay (D): the entry point of a company given a delay

Revenue loss depending on entry = $\frac{\text{On-time} - \text{Delayed}}{\text{On-time}} \times 100\%$

Percentage revenue loss = $\frac{D(3W-D)}{2W^2} \times 100\%$

Design Metrics

Non-Recurring Engineering (NRE) cost: one-time cost to design a system. No more design costs are needed

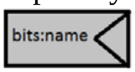
Unit cost: cost of manufacturing one instance of design

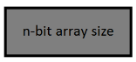
Chapter 2

Datapath

1. Identifying variables
2. Identifying operations

State machine data-path symbols:

- Register: 

- Multiplexor: 

- Operations: regular white rectangles

Non-volatile: doesn't erase at shutdown

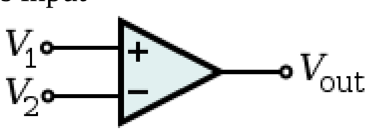
Memory Types

- **SRAM**: storing run-time data, which is processed (registers, stack, etc.)
- **EEPROM**: memory changeable during run-time, non-volatile
    - erase individual bytes
- **Flash**: memory changeable during run-time, non-volatile
    - quick writing, slower erase time, more compact

Op-Amps

[Recommended intro video]

Operational Amplifiers: this basic shape can be seen as a comparator; it only takes the larger one as input



$$V_{out} = \begin{cases} V_{S+}, & V_1 > V_2 \\ V_{S-}, & V_1 < V_2 \end{cases}$$

- outputs attempt to do whatever is necessary to make the voltage difference between the inputs zero (only for closed-loop output)
- inputs draw 0 current in/out

Ideal characteristics of op-amps:

1. Infinite voltage gain

2. Infinite input impedance
3. Zero output impedance
4. Infinite bandwidth
5. Zero input offset voltage (i.e., exactly zero out if zero in).

Inverting (−):
Non-inverting (+):

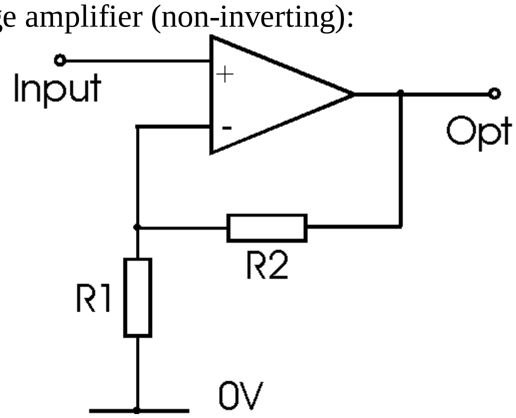
Closed-loop: if there's a feedback loop

Rail-to-rail: top and bottom input voltage are connected

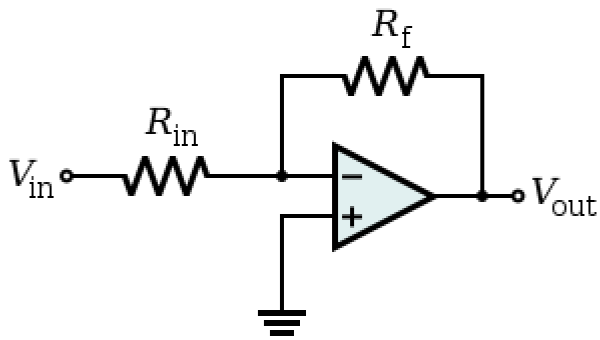
Slew rate [SR]: maximum rate of change of voltage / s
$SR = 2\pi fA$
$v_{out} = v_o$
$v_{in} = v_i$
Amplitude [A]:
Gain [*K*]: $v_o = K(v_+ - v_-) + K_{cm}\frac{v_+ + v_-}{2}$

Differential Mode Gain [K_d]: $K_d = \frac{v_o}{v_d}, v_d = v_1 - v_2$

Common Mode Gain [K_{cm}]: $K_{cm} = \frac{v_o}{v_{cm}}, v_{cm} = \frac{v_1 + v_2}{2}$

Common shapes: recommended reading
- Voltage amplifier (non-inverting):
  - 

  - Gain = $\frac{R_F}{R_1} + 1$, since the output tries to compensate for voltage divider rule going into V_- to match the V_+.
  - $v_o = \left(1 + \frac{R_f}{R}\right)v_i$
  -
- Inverting amplifier



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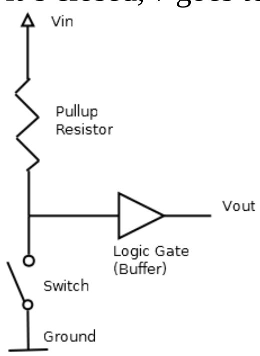
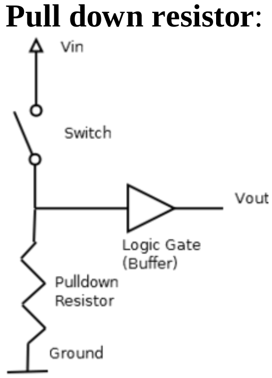
- **Virtual Ground**: since the bottom guy is ground, it has 0V, but the op-amp tries to make both have 0V
- If there's a +1V input, this results in an inverting amplifier because it uses the output to compensate for the difference in the inputs, sending back a negative through the feedback loop. Now there's −1V coming in and it tries to compensate again.
- $A_V = \frac{R_F}{R_1}$

Pull up resistor: When the switch is open, the pull-up resistor brings the voltage up, while when it's closed, *v* goes to ground

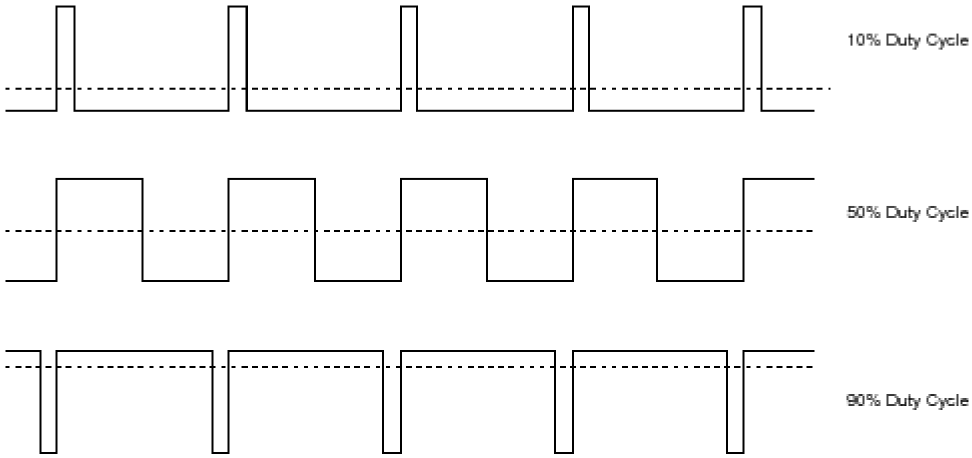


InitTypeDef: general object

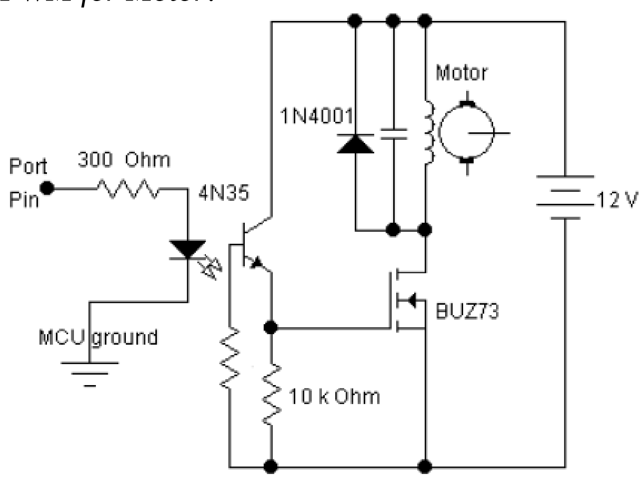
GPIO.initStructure.GPIO_PuPd_UP;
Pull down resistor:



Pulse-Width Modulation (PWM): a technique for getting analog results with digital means e.g. To create a 3V signal given a digital source that can be either high (on) at 5V or low (off) at 0V, you can use PWM with a duty cycle of 60% which outputs 5V 60% of the time. If the digital signal is cycled fast enough, then the voltage seen at the output appears to be the average voltage



PWM for Motor:



Transfer function: [$G(s)$] a function that represents what the system does to the voltage

$$G(s) = \frac{v_o}{v_i} = \frac{Z_2}{Z_1 + Z_2}$$

Units: V/mV (to reduce the number of 0's

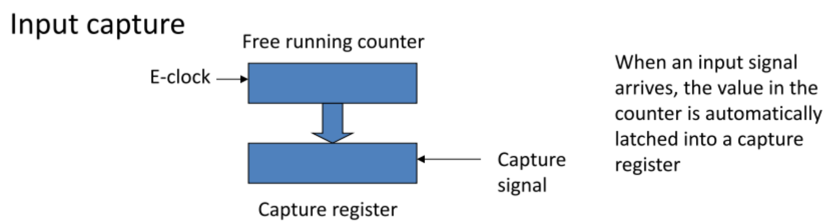
$s = j\omega$

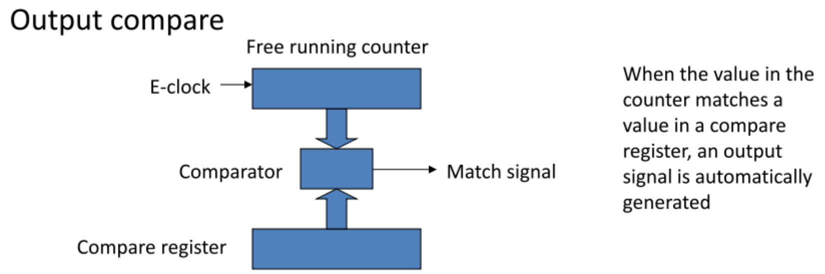
Common Mode Rejection Ratio (CMRR): measured in dB

$$\text{CMRR} = 20\log_{10}\left(\frac{K_d}{|K_{cm}|}\right)$$

Actuator:

Input impedance: allows for more sensitive inputs, prevents current in
Output impedance: drives current





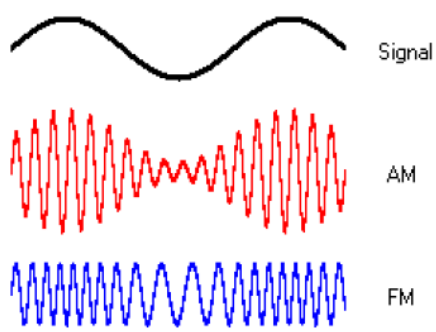
When the counter gets to the time held in the compare register, the comparator sends a match signal, sparking an event.

Modulation

Modulation: reducing noise when transmitting signals

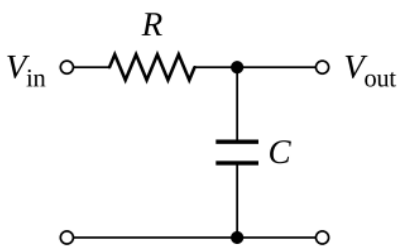
Amplitude Modulated (AM): signal causes varying amplitude
- low quality output
- cheap hardware to transmit & receive

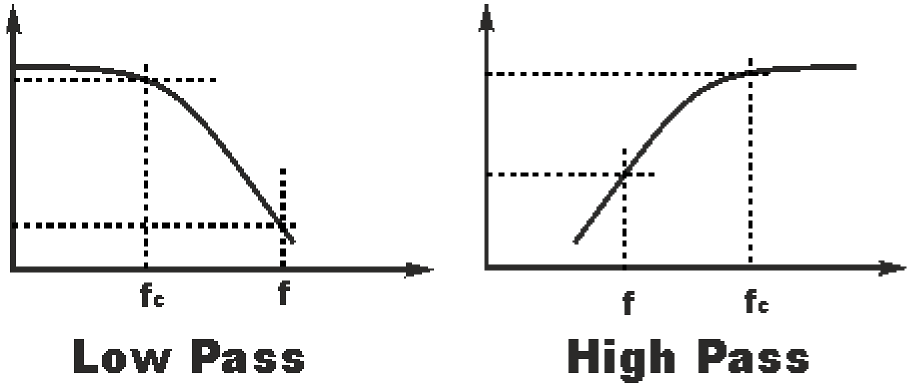
Frequency Modulated (FM): signal causes varying frequency
- high quality output
- expensive hardware to transmit & receive



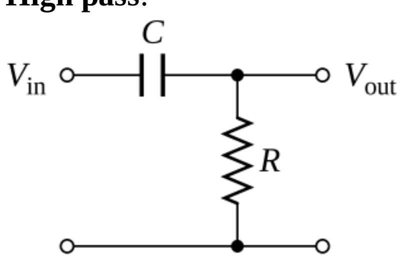
Filters

Orders: the order of the gain formula
Low Pass:

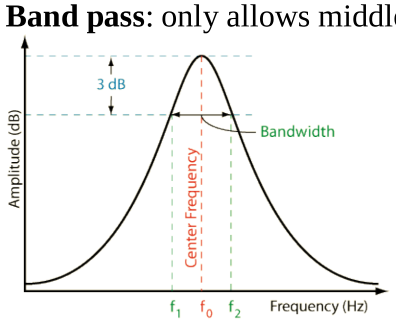




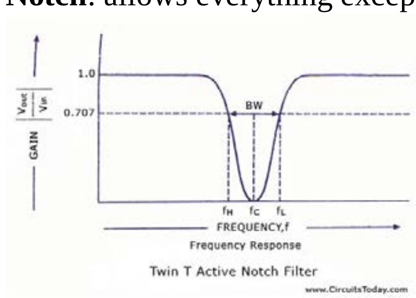
High pass:



Band pass: only allows middle of hill



Notch: allows everything except perfect frequency



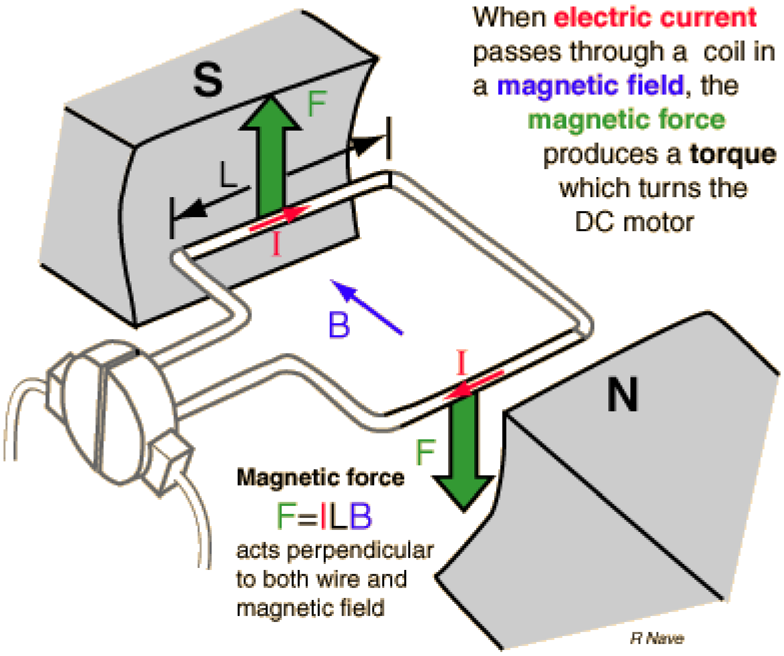
Bandwidth:

$$\omega_{\text{bw}} = \left\| \frac{1}{as^2 + bs + 1} \right\| = \frac{1}{\sqrt{b^2 - 2a}}$$

$$\omega_{\text{bw}} = 2\pi f_{\text{bw}}$$

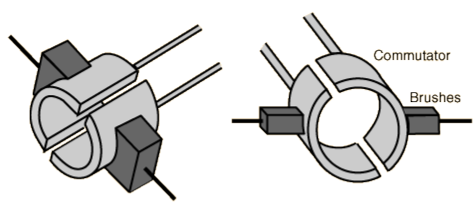
Stepper Motors

DC Motors: not stepper motors… finish this!!!!!!!!!!!!!!



Think: right hand rule

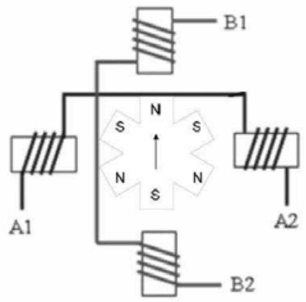
Brushes:



Stepper motor: brushless, AC motors

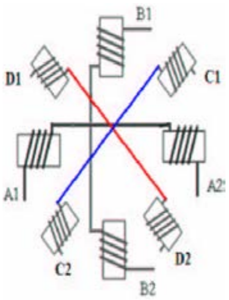
Poles: Most magnets have 2 poles, but a magnet in the shape of an asterisk (*) has 6 poles

- maintains number of wires
- increased resolution
- higher magnet cost



Phases: number of windings (the cork-looking thingys)

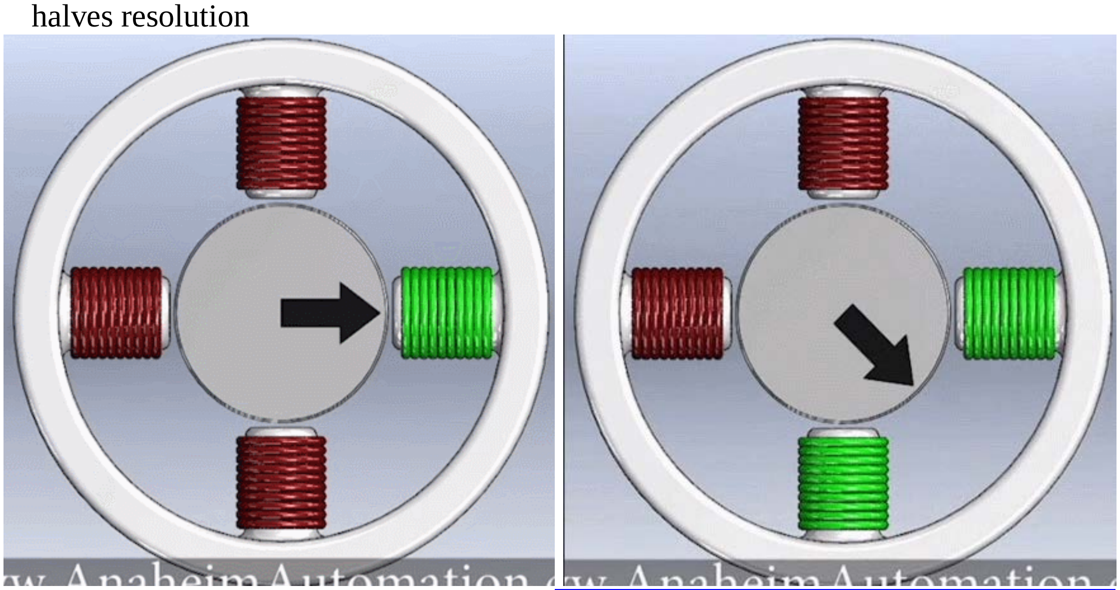
- more windings, more wires



Angular resolution: $\theta = \dfrac{360°}{\text{steps}} = \dfrac{360°}{n \times (\#\text{ of poles})}$, n = number of phases

Half-stepping: alternating between 2 phase and single phase

- reduces torque
- increases speed
- halves resolution



Micro-stepping: take the half-step model, but vary the current levels in the magnets to make tinier steps
http://en.nanotec.com/support/tutorials/stepper-motor-and-bldc-motors-animation/

Magnetic Reluctance: resistance, but of magnetic fields, not electric fields

Switched Reluctance Motor (SRM): non-permanent magnets

- low cost
- coils in the middle stay the same, magnets on outside rotate
- No permanent magnets
- $\theta = \dfrac{360°}{\text{magnets} \times \text{teeth}}$
- Number of coil pairs needs to be even
- Optimize the number of teeth to have odd number of teeth, with minimal windings, so that the top and bottom don't align simultaneously. The alternative is making your top bumps different than your bottom magnets