ME 310: Microprocessors and Automatic Control Lab

Fundes: How to run motor?
PWM module

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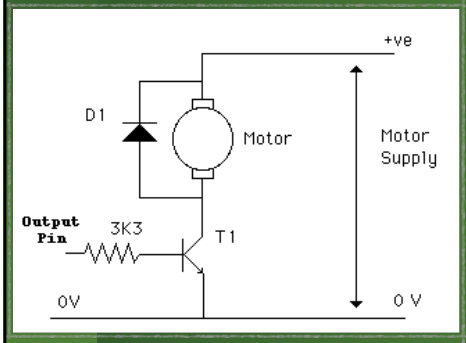
Taking stock of where we are

- What is that we have seen so far
  - How to program microprocessor interfaces: Digital input output interface
  - Basics of D-FlipFlop: sequential combinational logic
- Q: How to run motor using microcontroller? the feeedback problem we started off with:
  - PWM interface to run motor and change power and direction

What all we need to run motor using muc?

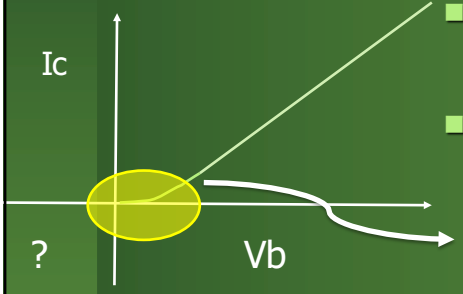
- Q: does microcontroller have large power needed to drive motors? NO ☹
- So some kind of power amplifier is needed
- What would be input to this power amplifier?
- How to regulate power/voltage given to motor and how to change the direction? Any ideas!!!

Power Amplifier



- Lets look at simple power amplifier circuit we know: power transistor
- Would this work
  - How do we vary power
  - How do we change direction?

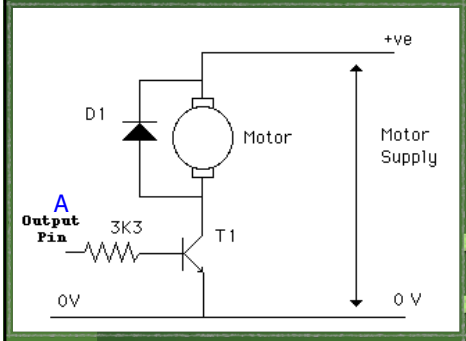
Power Amplifier



- Recall transistor characteristics
- Problems
  - Forward bias voltage is required before current can flow
  - Which input from microprocessor can vary power?
  - Analog / Digital??

- Reverse characteristics not favorable to change direction of motor

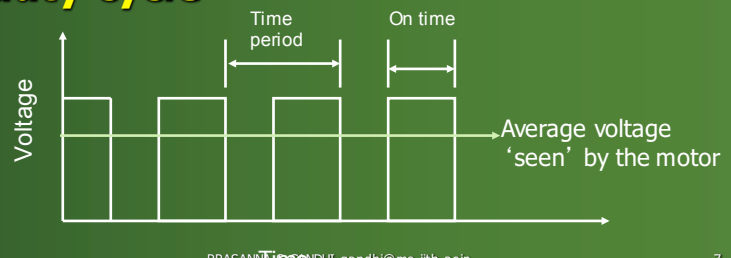
How do we get over these problems?



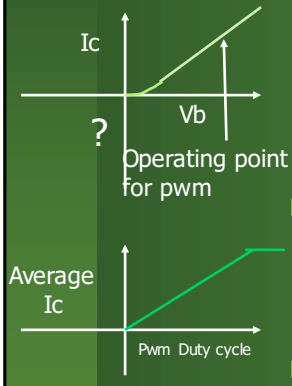
- Can we use digital input instead of analog input at A in smart way to deliver varying power?
- How to vary power?
- Switch on and off digital signal at A. Vary 'on time' as compared to 'off time'

What do we achieve?

- Pulse Width Modulation (PWM): Power supply regulated by varying the % of "on-time" of a digital signal also called **duty cycle**



What do we achieve?

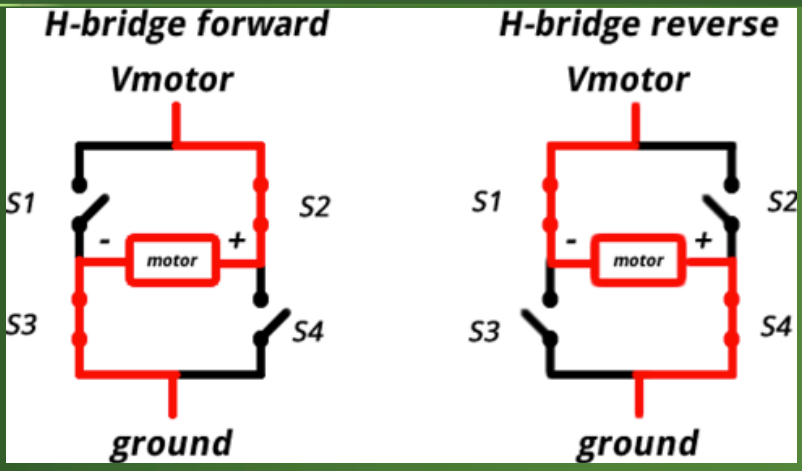


- Operating point on transistor characteristics is now fixed. Issue related to "dead zone" disappear.
- Smooth variation of average Ic in motor by varying "on time" of PWM waveform.
- IMP: PWM frequency should be high 'enough' : typically 2-10 kHz

Direction reversal?

- So far so good!
- We can now vary power delivered to our motor
- Q: How do we reverse direction?
- A: Concept of transistor based switching can be used

H Bridge for direction reversal



Power Amplifier

- Typically all these are packaged in one PCB called "power amplifier" along with other features such as opto-isolation, over temperature protection, current limitation etc.
- Look at details of power amplifier we have: two inputs In1 and In2

PWM: A dedicated interface

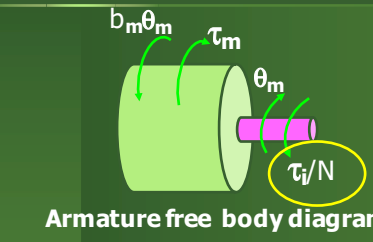
- Oh wait a minute! Why do we need this interface?
- We can program pins of PORTA to get such waveform with different delay isnt it? Already done in previous lab
- YES! It is possible but then microprocessor is continuously engaged in doing that and will have no time to take feedback or compute control etc. Too cumbersome to do.

PWM interface of XEP 100

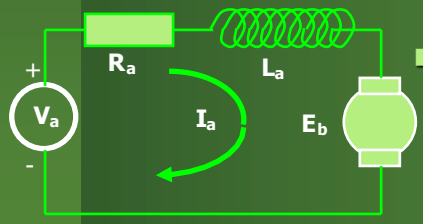
- Identify registers and their values to be used from datasheet of XEP 100
- Specifically look at PWME, PWMCLK, PWMPOL, PWMPRCLK, PWMDTYx, PWMPERx registers
- Use PWMPERx = 0xFF value. Do not change this value. Think why??

Calculation of duty cycle and frequency

Modeling Motor Dynamics



Armature free body diagram



Electrical circuit diagram

- Mechanical

If there is no Other load

$$J_m\ddot{\theta}_m + B_m\dot{\theta}_m + \frac{\tau}{N} = \tau_m$$

$$\tau_m = K_t\varphi I_a$$

- Electrical

Can be neglected

$$V_a = I_a R_a + E_b + L\frac{dI_a}{dt}$$

$$E_b \propto \varphi\omega$$

$$E_b = K\varphi\omega$$

Coupling terms

Modeling Motor Dynamics

$$V_a = I_a R_a + E_b$$

$$E_b \propto \omega$$

$$E_b = K\omega$$

$$\Rightarrow I_a = \frac{V_a - K\omega}{R_a}$$

$$\omega = \dot{\theta}_m$$

$$\tau_m = K_t I_a$$

$$J_m\ddot{\theta}_m + B_m\dot{\theta}_m = \tau_m$$

$$\Rightarrow J_m\ddot{\theta}_m + B_m\dot{\theta}_m = K_t\left(\frac{V_a - K\dot{\theta}_m}{R_a}\right)$$

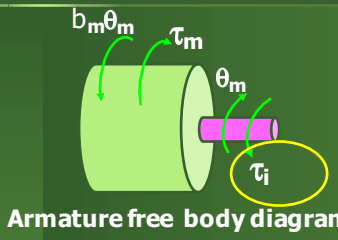
- Differential equation form:

- Transfer function: input $V_a(t)$, output $\theta_m(t)$

$$G(s) = \frac{Output(s)}{Input(s)}$$

$$G(s) = \frac{K_t\phi}{J_m s^2 + B_m s + (KK_t/R_a)s}$$

Motor Dynamics + friction



Armature free body diagram

Mechanical

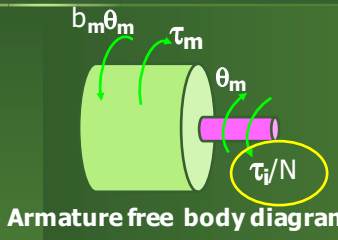
$$J_m\ddot{\theta}_m + B_m\dot{\theta}_m + \tau_f + \tau_l = \tau_m$$

$$\tau_m = K_t\varphi I_a$$

How to model friction?

- Coulomb friction/ viscous friction
- Transfer function

Motor Dynamics + load



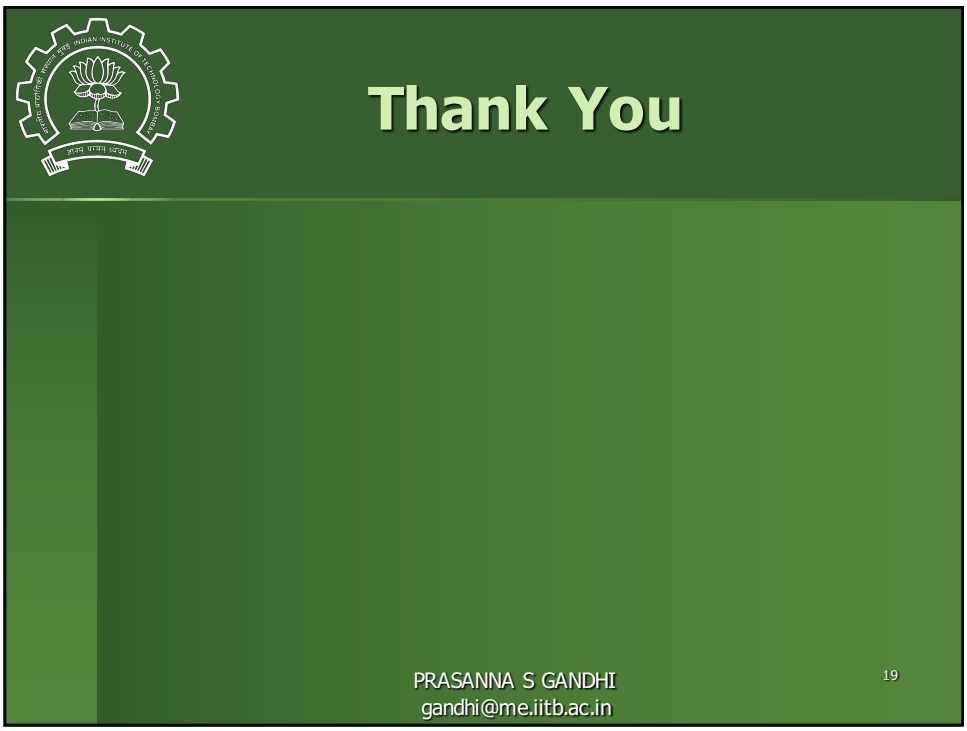
Armature free body diagram

Mechanical

$$J_m\ddot{\theta}_m + B_m\dot{\theta}_m + \frac{\tau_i}{N} = \tau_m$$

$$\tau_m = K_t\varphi I_a$$

How to account for load inertia (gear connection) ?


Thank You
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