EECS192 Lecture 8
Motor Modelling and Steering Introduction
Mar. 9, 2021

Topics
- Checkpoint 6: closed-loop control
- Checkpoint 7: Step+ telemetry
- Wiring Notes
- Quiz 2- motor model
- RC servo model
- Embedded Issues: deadlock
- HW 2 Simulation

CP6- Closed Loop Track with Velocity Control 3/12

Set up a figure 8* track. Use 1 meter string with chalk attached to make circles, and connect with tangent lines, and 60 degree crossing. Use white masking tape for figure 8 if on light background, or black tape if on light background.

C6.1 Show car driving the figure 8*, at speed of 1 m/sec or better. (May be lower for small circle.)

(You may use a wireless command to tell the car to start or stop running, but no other commands may be sent to the car.)

C6.2 Submit plots on one graph: steering angle command (degrees or radians), track error (cm), ESC command (% full speed), sensed velocity, all versus time axis in seconds.

C6.3 All members must fill out the checkpoint survey before the checkoff close. Completion is individually graded.

**** If you do not have space for a full size figure 8, use smaller than 1 m radius to fit. If you do not have room for a figure 8, use a circle of up to 1 m radius.***

(example Amazon tape): https://www.amazon.com/Removable-Painters-Painting-Labeling-Stationery/dp/B082R27TP6/ref=sr_1_7?dchild=1&keywords=1+inch+white+masking+tape&qid=1613947385&s=industrial&sr=1-7

Checkpoint 7: Telemetry+ Step Response

Set up a step track. Suggest 1 m before step, 1 m after step (0.5m+0.5m ok). The step should be 15 cm to the right or left.

C7.1 Demonstrate remote emergency stop.

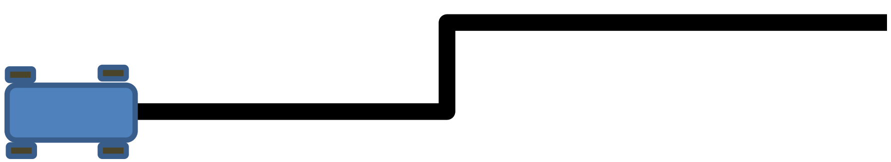
C7.2 Live demo: show car drive step by itself and stop.

C7.3 Live demo: show car drive step by itself and stop, while streaming data over UDP.

- i) timestep (seconds)
- ii) lateral error (cm or m)
- iii) estimated velocity (m/s)
- iv) commanded steering angle (rad or deg) and commanded ESC

C7.4 Plot telemetry data from the live demo (either live or from a file) with plots of lateral error, estimated velocity, commanded ESC, and commanded steering angle, all vs. time. Report % overshoot, and controller parameters used.

C7.5 All members must fill out the checkpoint survey before the checkoff close. Completion is individually graded.



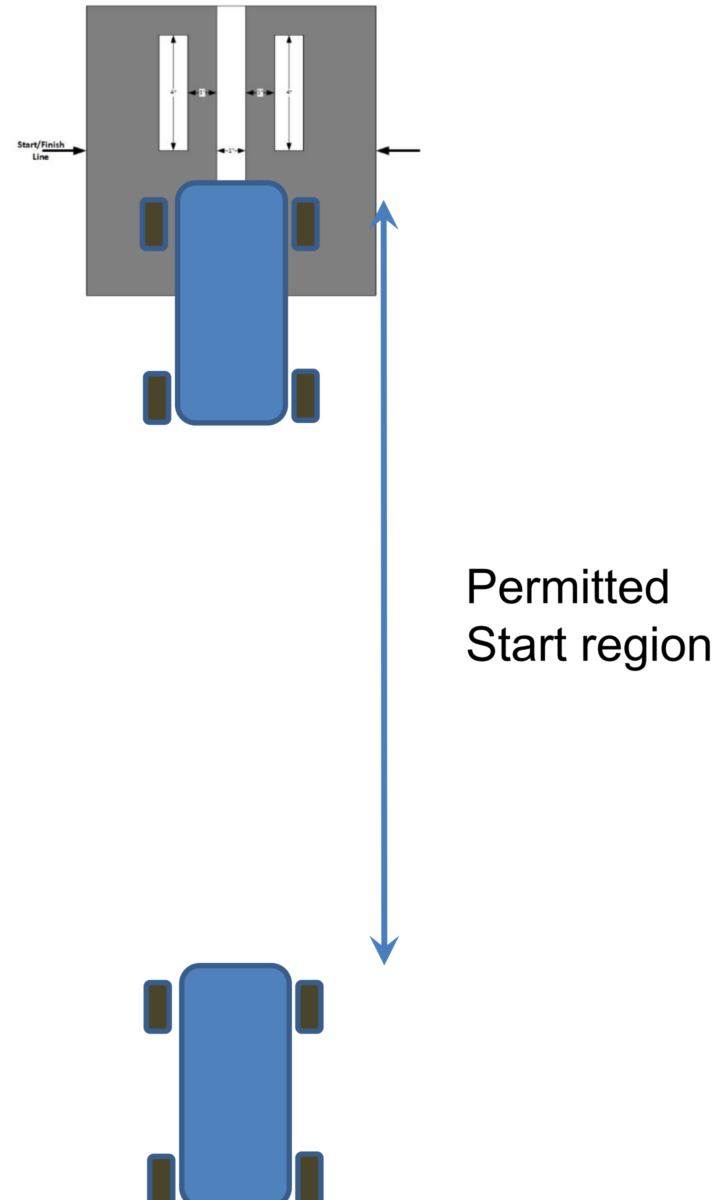
NATCAR Notes

1. Car can start in region shown (running start or avoid seeing stop line…) up to ``several feet” behind start/stop line

2. A running car can continue running for consecutive laps. If car is doing multiple laps without stopping, 4 second penalty is applied to intermediate laps.

The car must automatically stop within 6 feet of the finish line after finishing the race.

A penalty of 4 seconds will be added to the lap time for any car that does not automatically stop within the required region.



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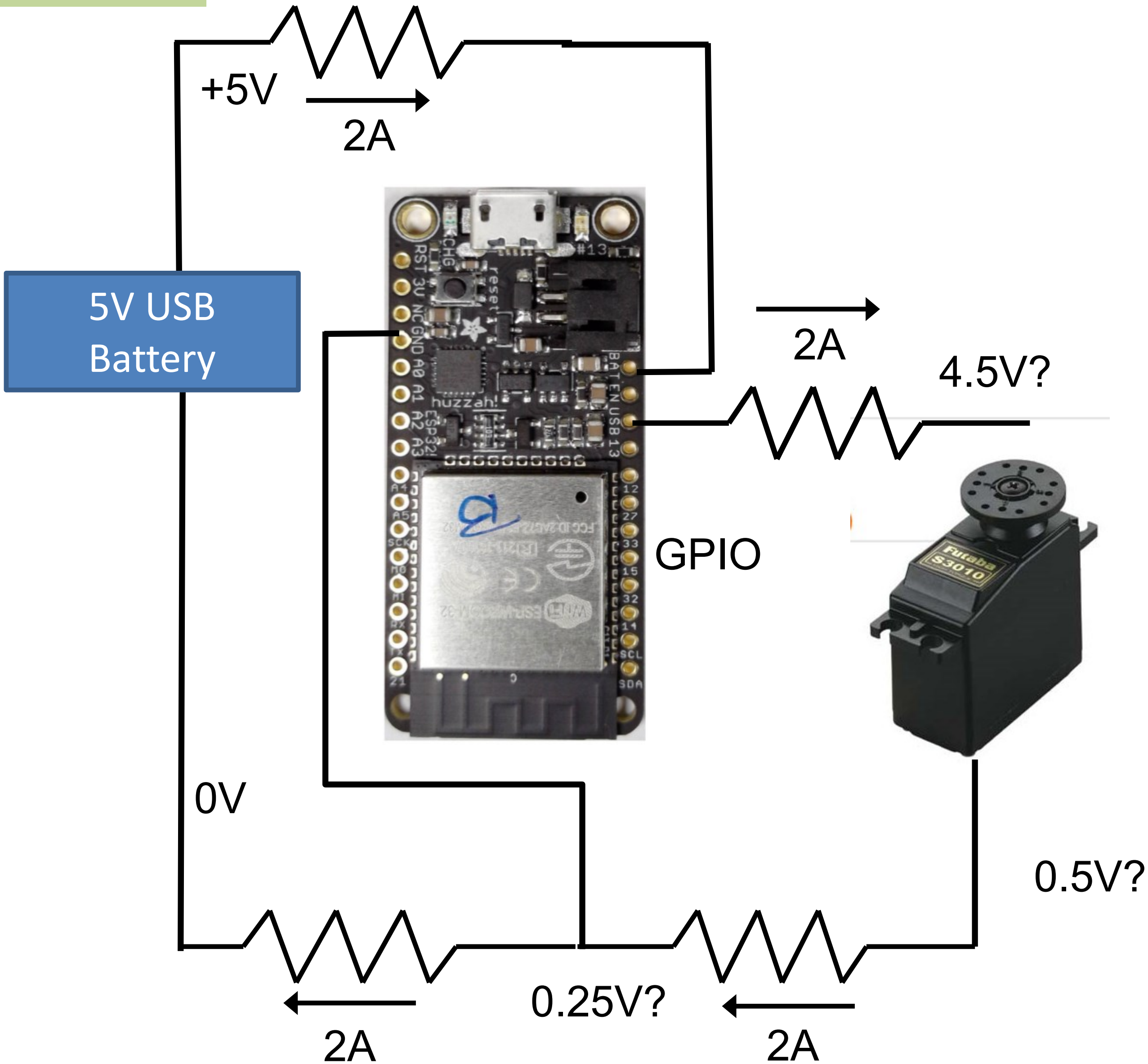
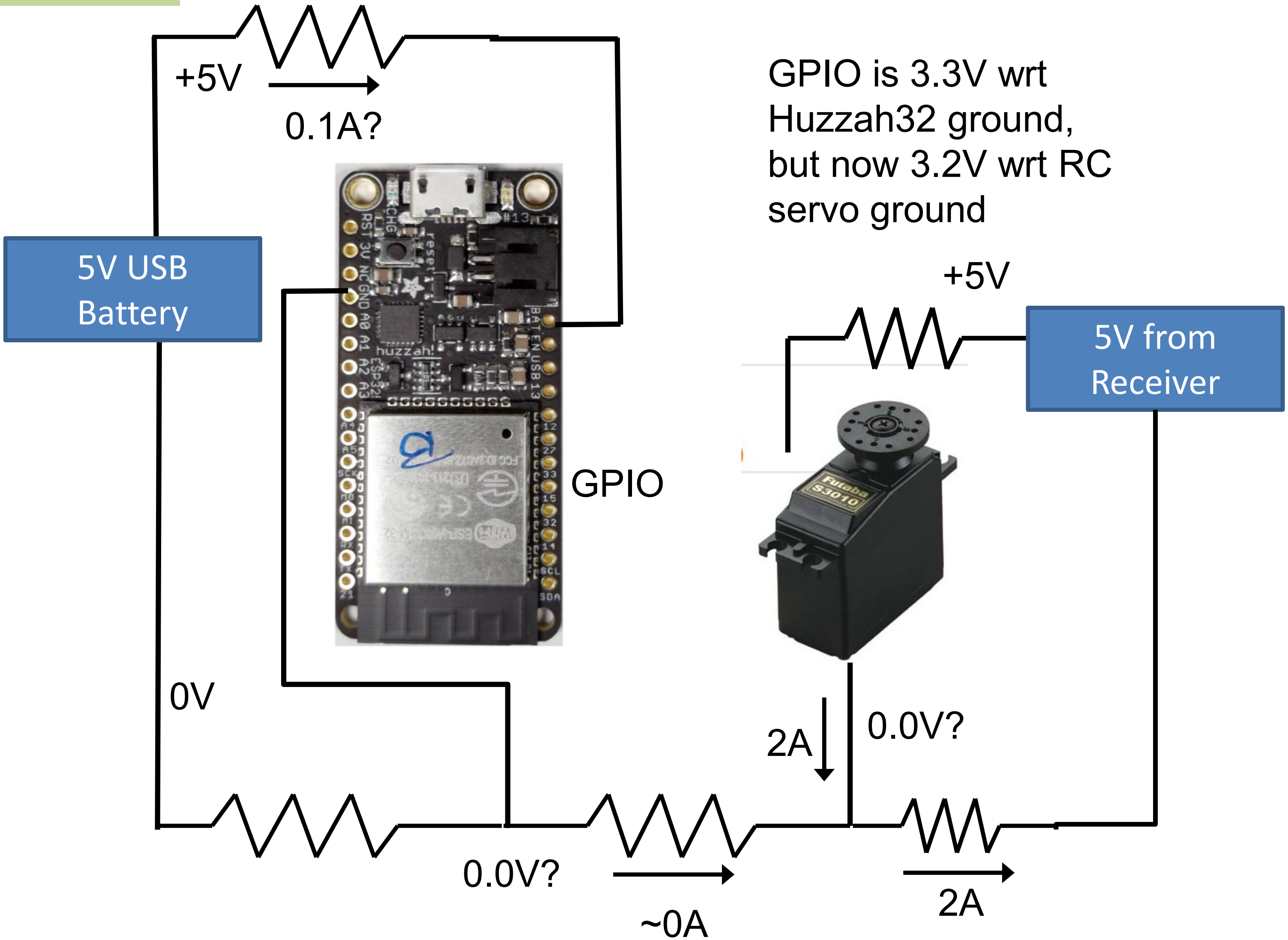
Power supply wiring issue?



GPIO is 3.3V wrt Huzzah32 ground, but only 2.8V wrt RC servo ground

Wiring resistance effect?

Power supply wiring issue?



Wiring resistance effect?

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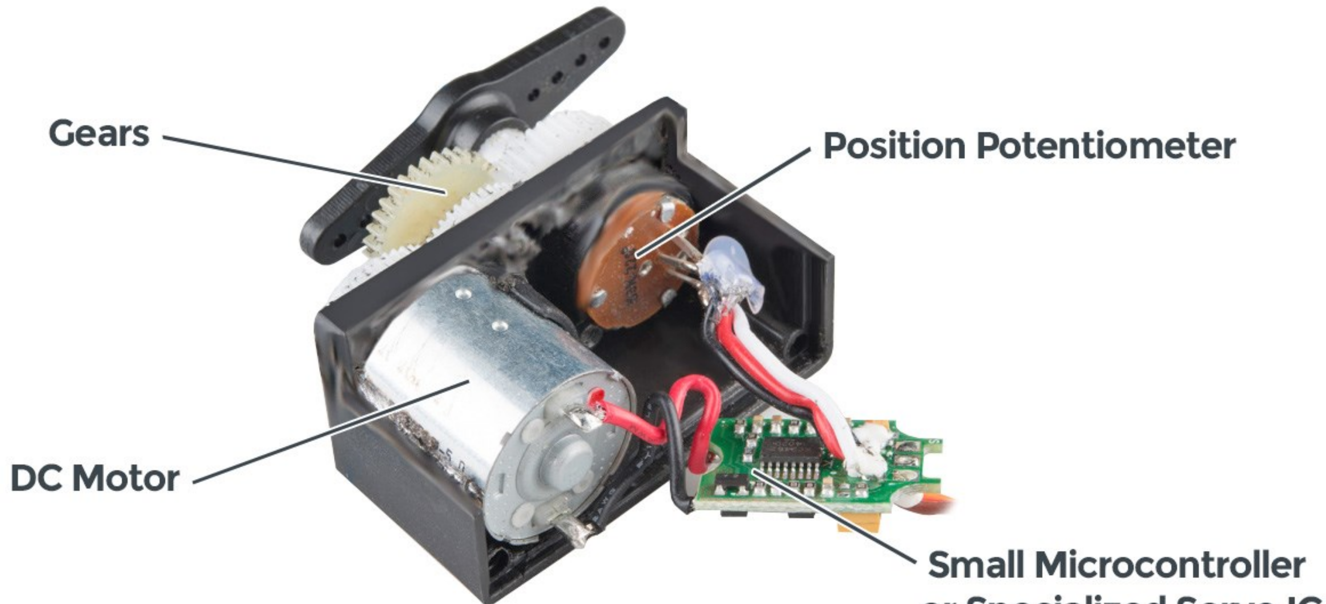
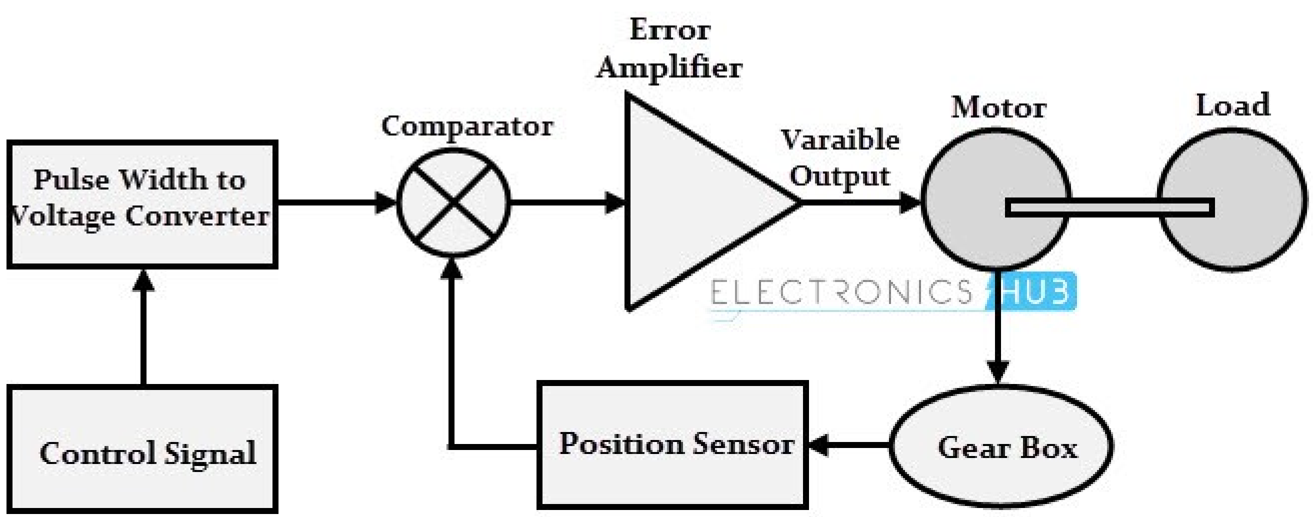
RC Servo Internals

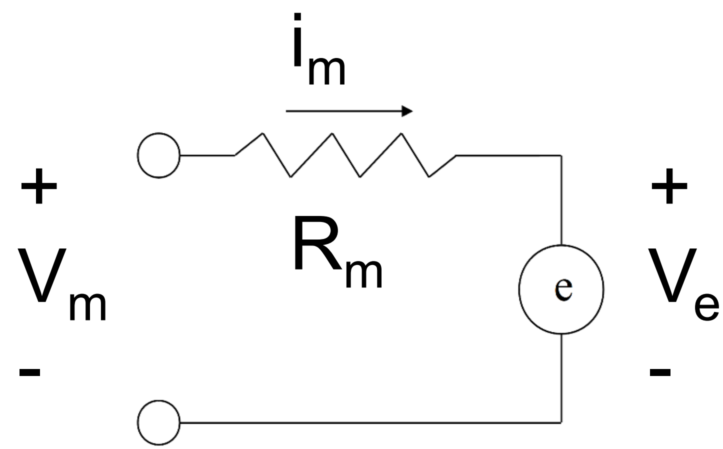


(image from sparkfun.com)



(image from electronicshub.org)

Motor Electrical Model



Motor Electrical Model
Back EMF
Motor electromechanical behavior

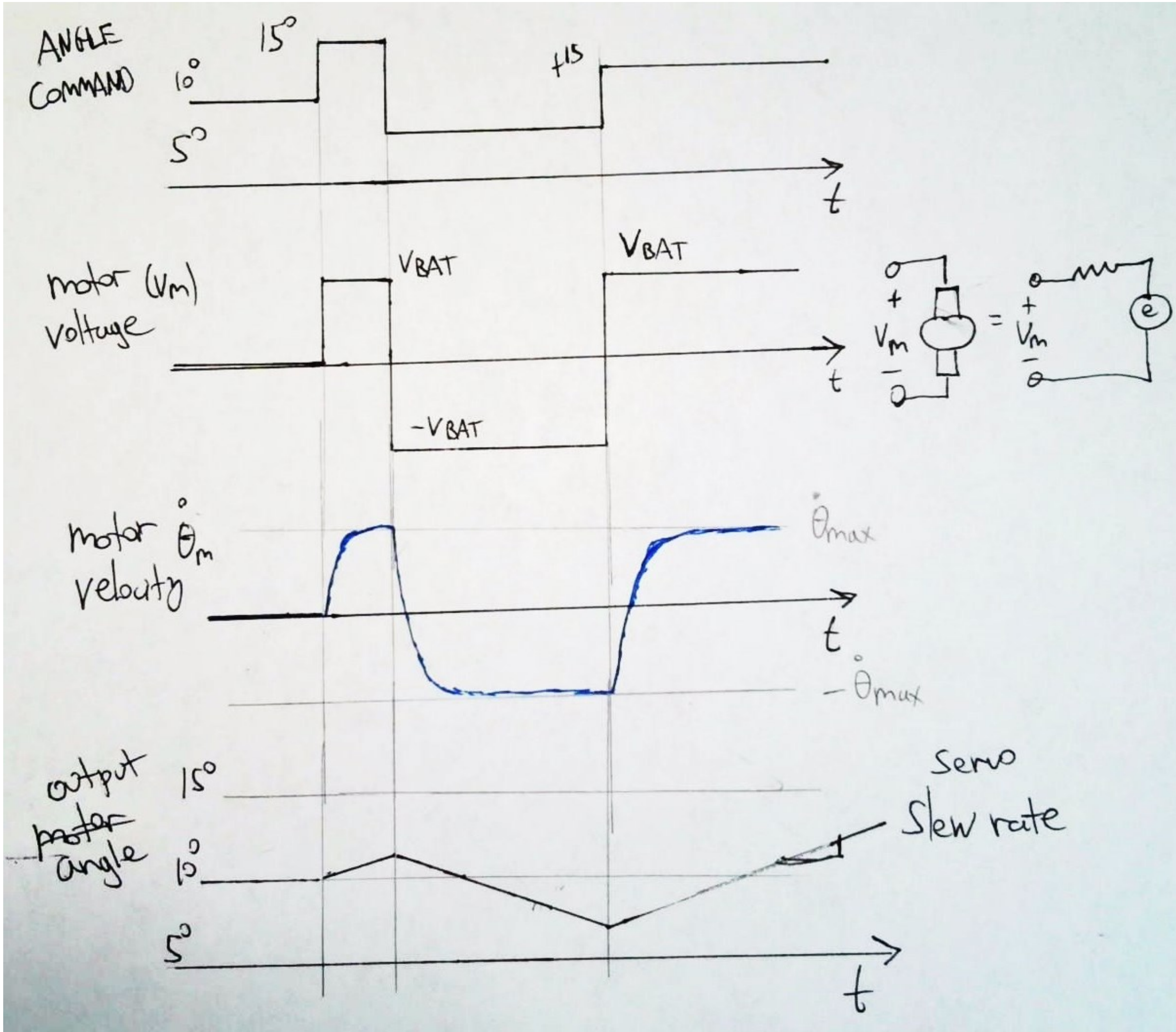
Also- see motor worksheet……
https://inst.eecs.berkeley.edu/~ee192/sp21/docs/motor-worksheet.pdf

$$i_m = \frac{V_{BAT} - k_e \dot{\theta}_m}{R_m}$$

Torque equation: $\tau = k_\tau \, i_m$

Back EMF equation: $V_e = k_e \dot{\theta}_m$

Servo gear motor response



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Timer mutex (mutual exclusion)

esp_err_t timer_spinlock_take(timer_group_t *group_num*)

Take timer spinlock to enter critical protect.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

esp_err_t timer_spinlock_give(timer_group_t *group_num*)

Give timer spinlock to exit critical protect.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

Timer interface- sharing

https://github.com/espressif/esp-idf/blob/release/v4.2/components/driver/timer.c

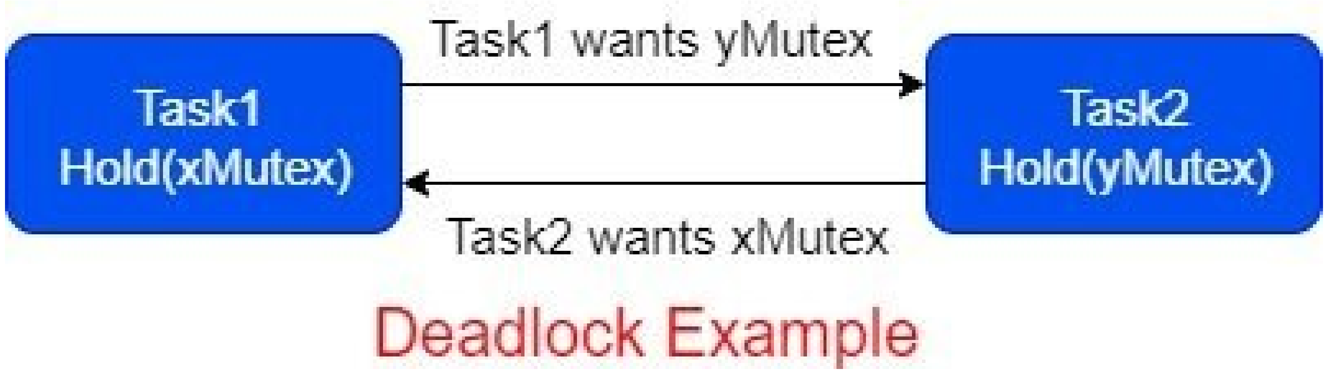
Vanilla FreeRTOS implements critical sections with taskENTER_CRITICAL()
which calls portDISABLE_INTERRUPTS()

Note: disabling interrupts is not sufficient – as other core can still interrupt

```
#define TIMER_ENTER_CRITICAL(mux) portENTER_CRITICAL_SAFE(mux);
#define TIMER_EXIT_CRITICAL(mux)  portEXIT_CRITICAL_SAFE(mux);
static portMUX_TYPE timer_spinlock[TIMER_GROUP_MAX] =
    {portMUX_INITIALIZER_UNLOCKED, portMUX_INITIALIZER_UNLOCKED};
```

```
esp_err_t timer_get_counter_value(timer_group_t group_num,
             timer_idx_t timer_num, uint64_t *timer_val)
{ …
TIMER_ENTER_CRITICAL(&timer_spinlock[group_num]);
 timer_hal_get_counter_value(
             &(p_timer_obj[group_num][timer_num]->hal),
             timer_val);
TIMER_EXIT_CRITICAL(&timer_spinlock[group_num]);
 return ESP_OK;
}
```

Deadlock

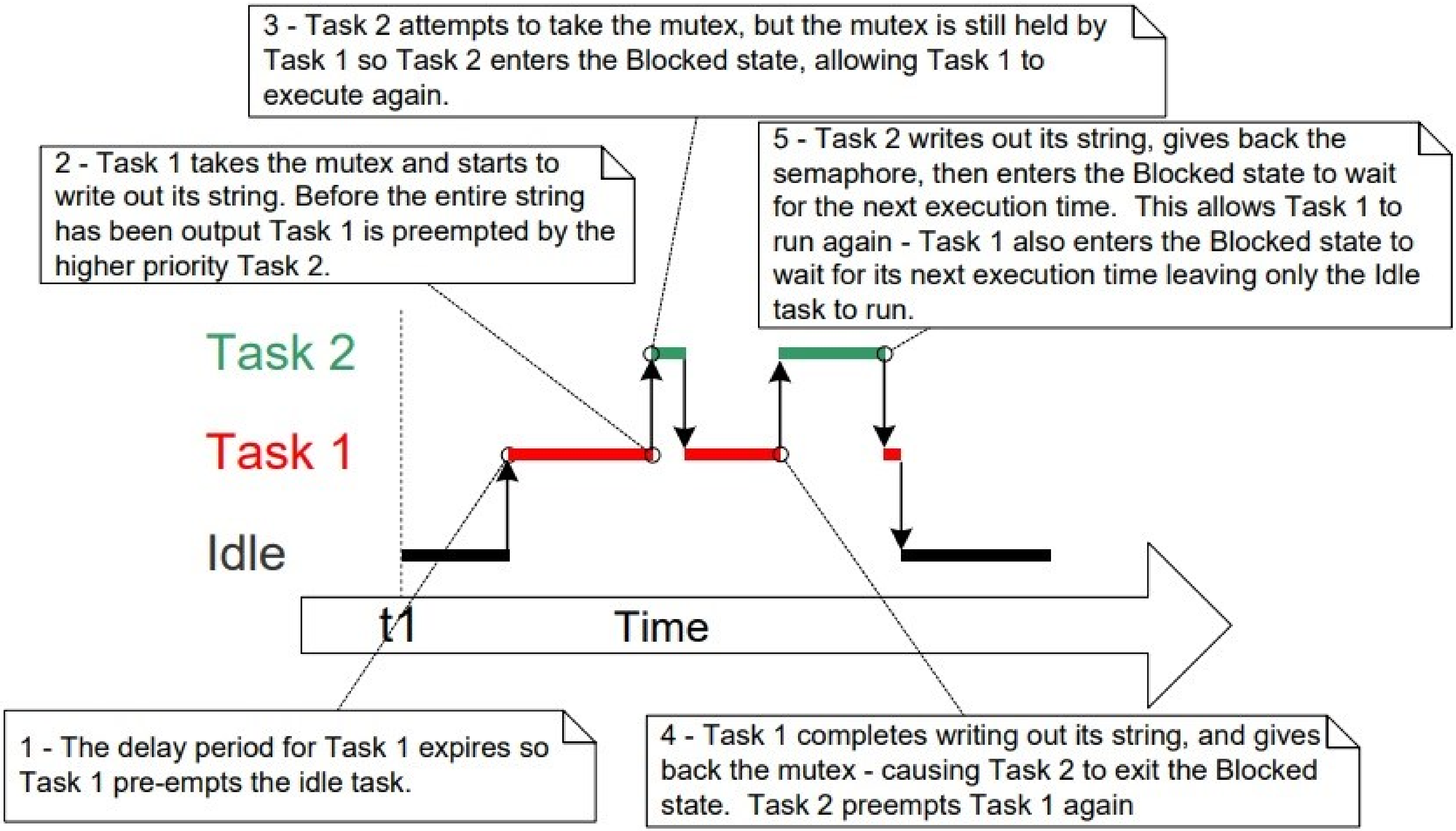


Possible Task1 and Task2 both block
(May be safer to use interrupt if only a single processor…)

Example: xSemaphoreCreateBinary()
See https://docs.espressif.com/projects/esp-idf/en/latest/esp32/
api-reference/system/freertos.html?highlight=priority%20inheritance

Deadlock/Priority Inversion- print example

(from Mastering_the_FreeRTOS_Real_Time_Kernel-A_Hands-On_Tutorial_Guide.)



Deadlock/Priority Inversion

(from Mastering_the_FreeRTOS_Real_Time_Kernel-A_Hands-On_Tutorial_Guide.

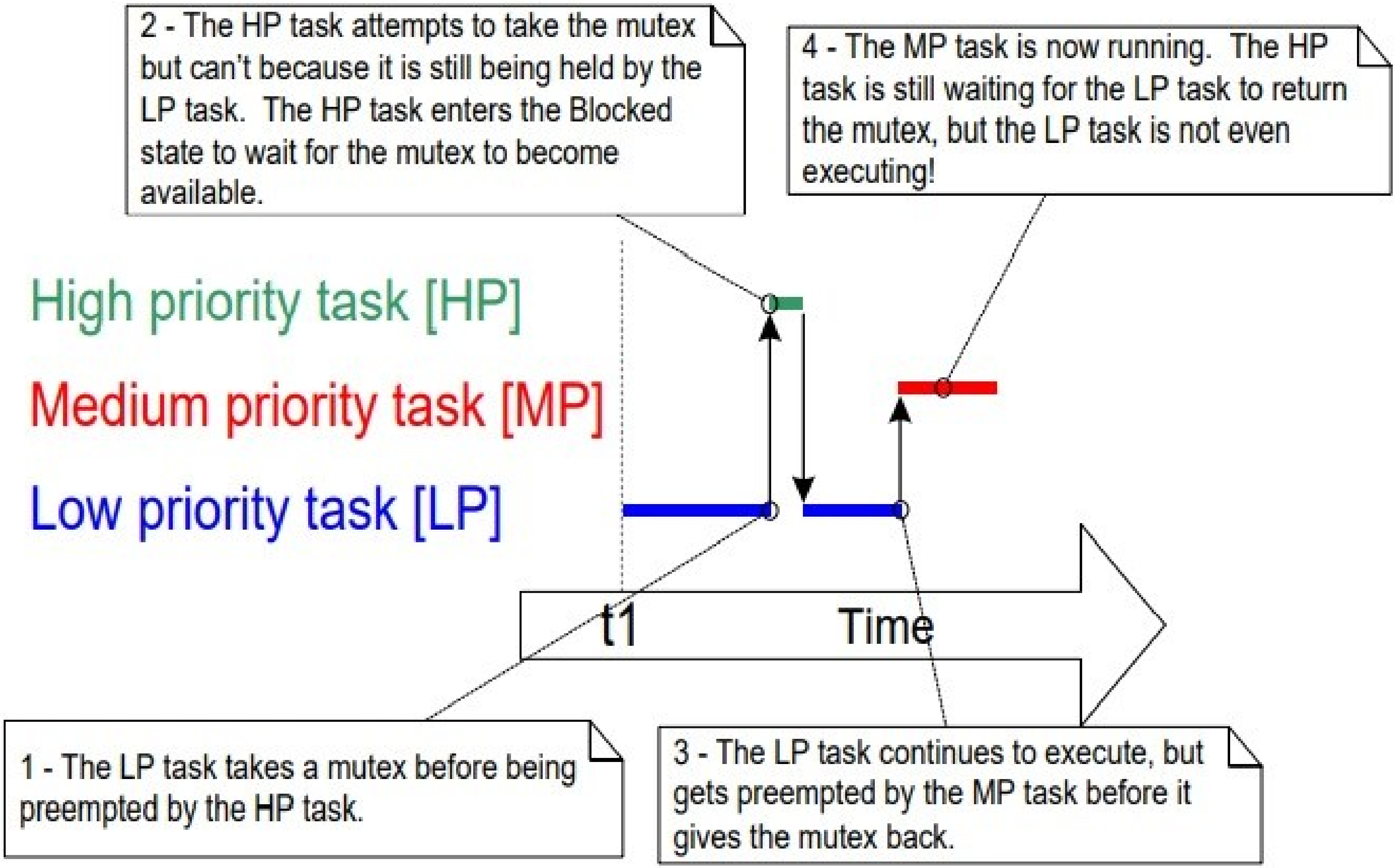


Figure 66. A worst case priority inversion scenario

Deadlock/Priority Inheritance

(from Mastering_the_FreeRTOS_Real_Time_Kernel-A_Hands-On_Tutorial_Guide.

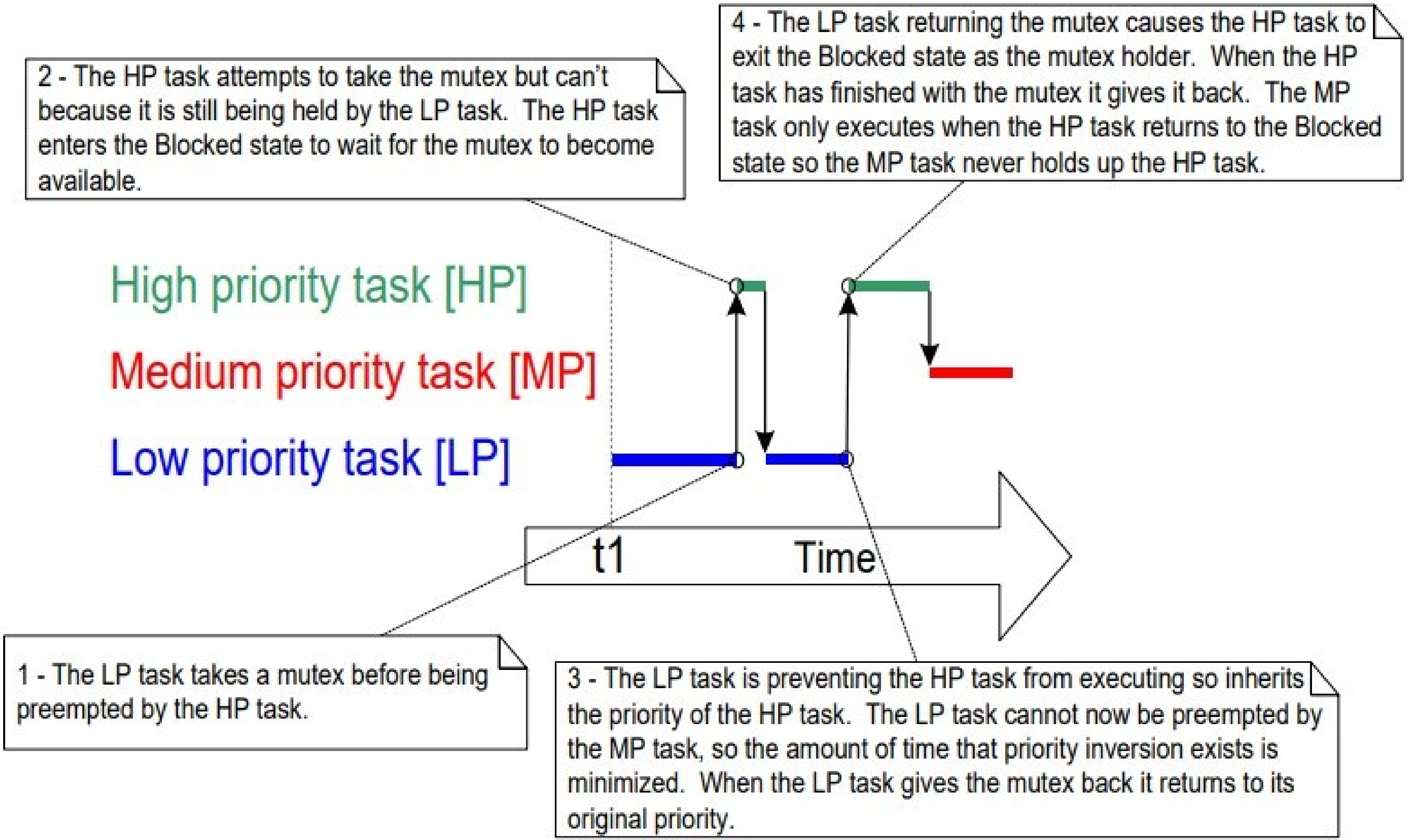


Figure 67. Priority inheritance minimizing the effect of priority inversion

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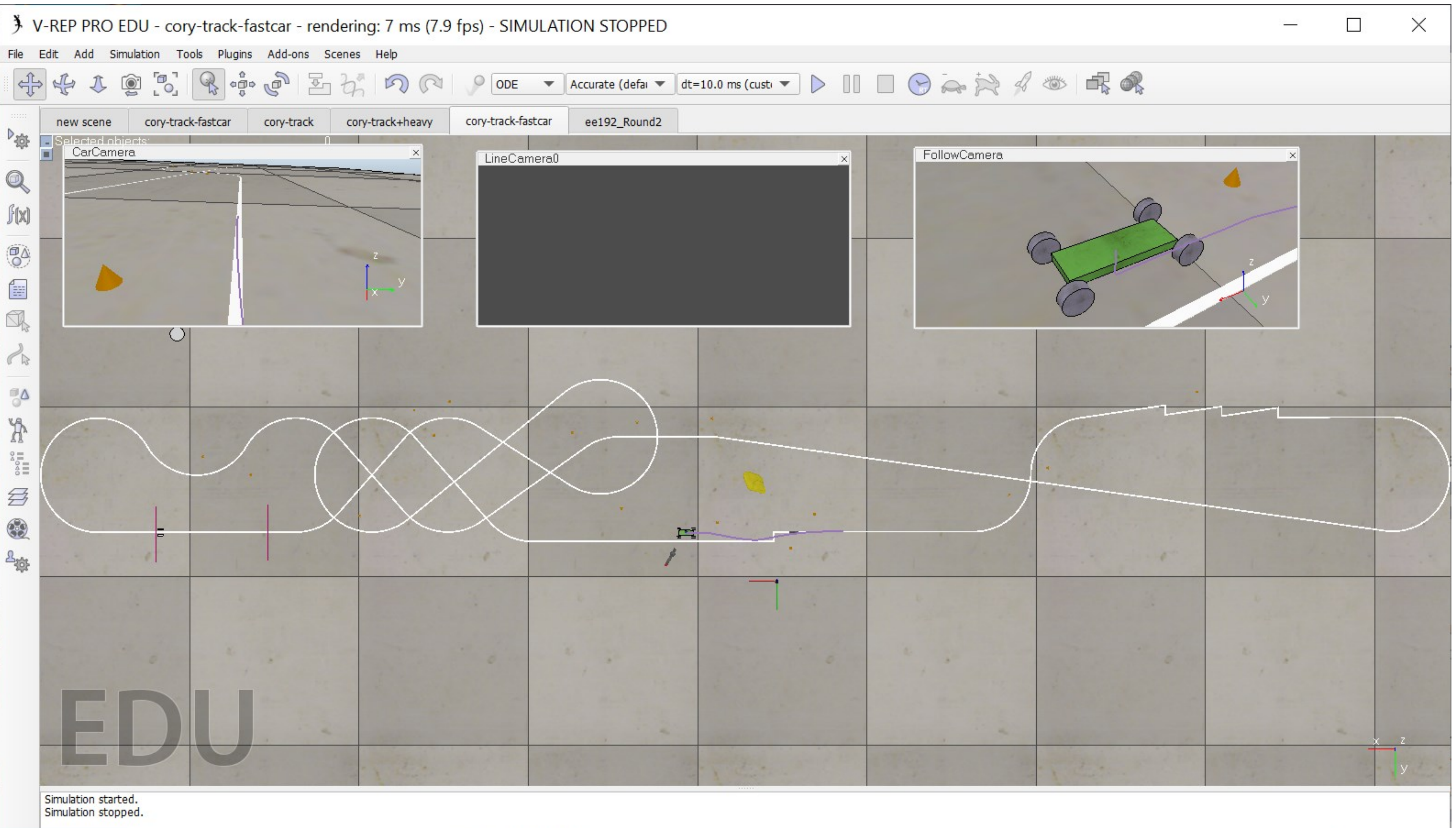
V-REP sim for step



Repo for HW2:

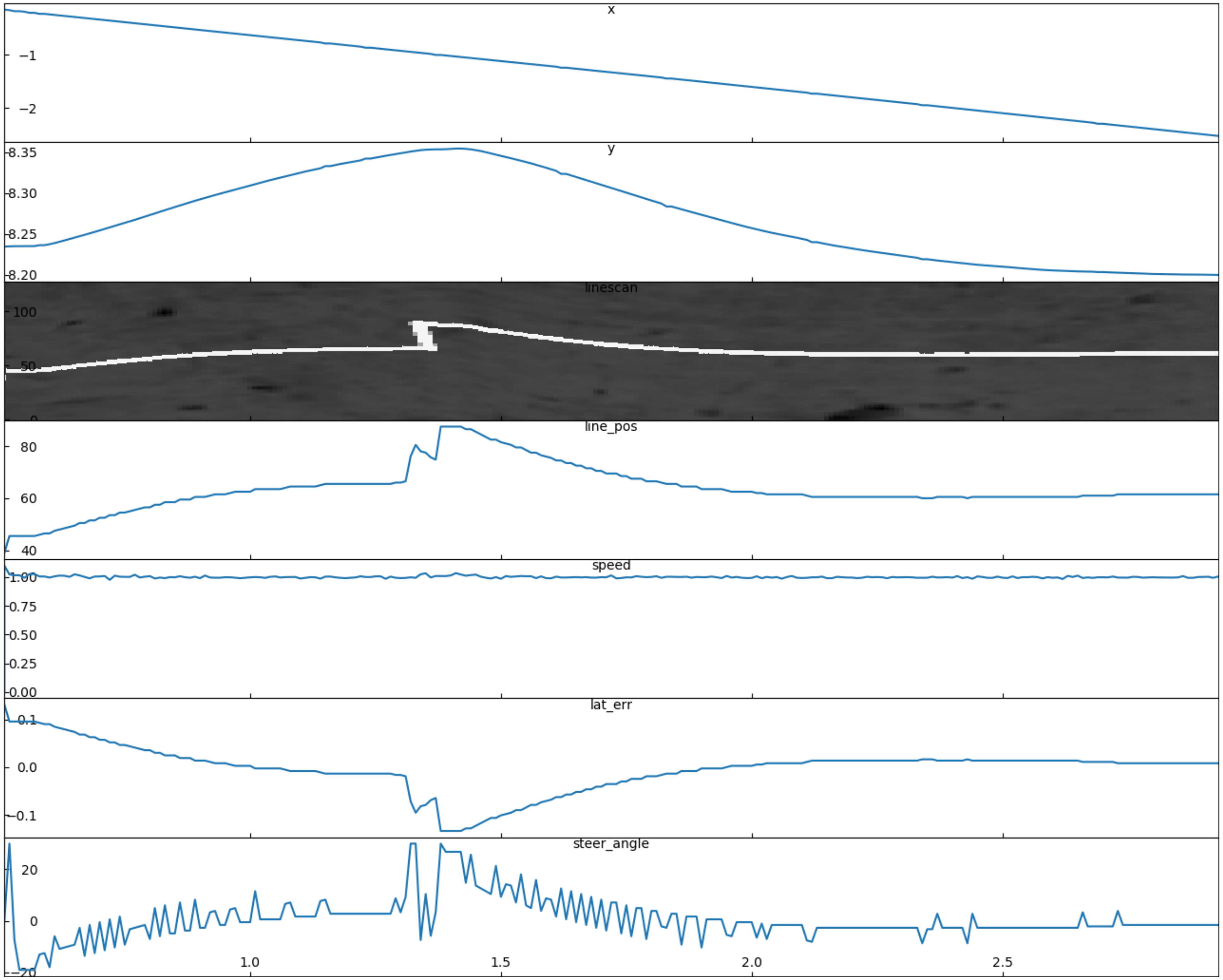
https://github.com/ucb-ee192/simulator-pub

- tracks
- .gitignore
- README.md
- carInterface.py — Should not need to change
- carInterface4wd.py
- controller.py — Edit to change controller and track finder
- controller4wd.py
- log-visualizer.py — For plotting waterfall and state
- simpleCsvDict.py
- vrep.py
- vrepConst.py
- vrepInterface.py
- xyplot.py — For plotting just car path

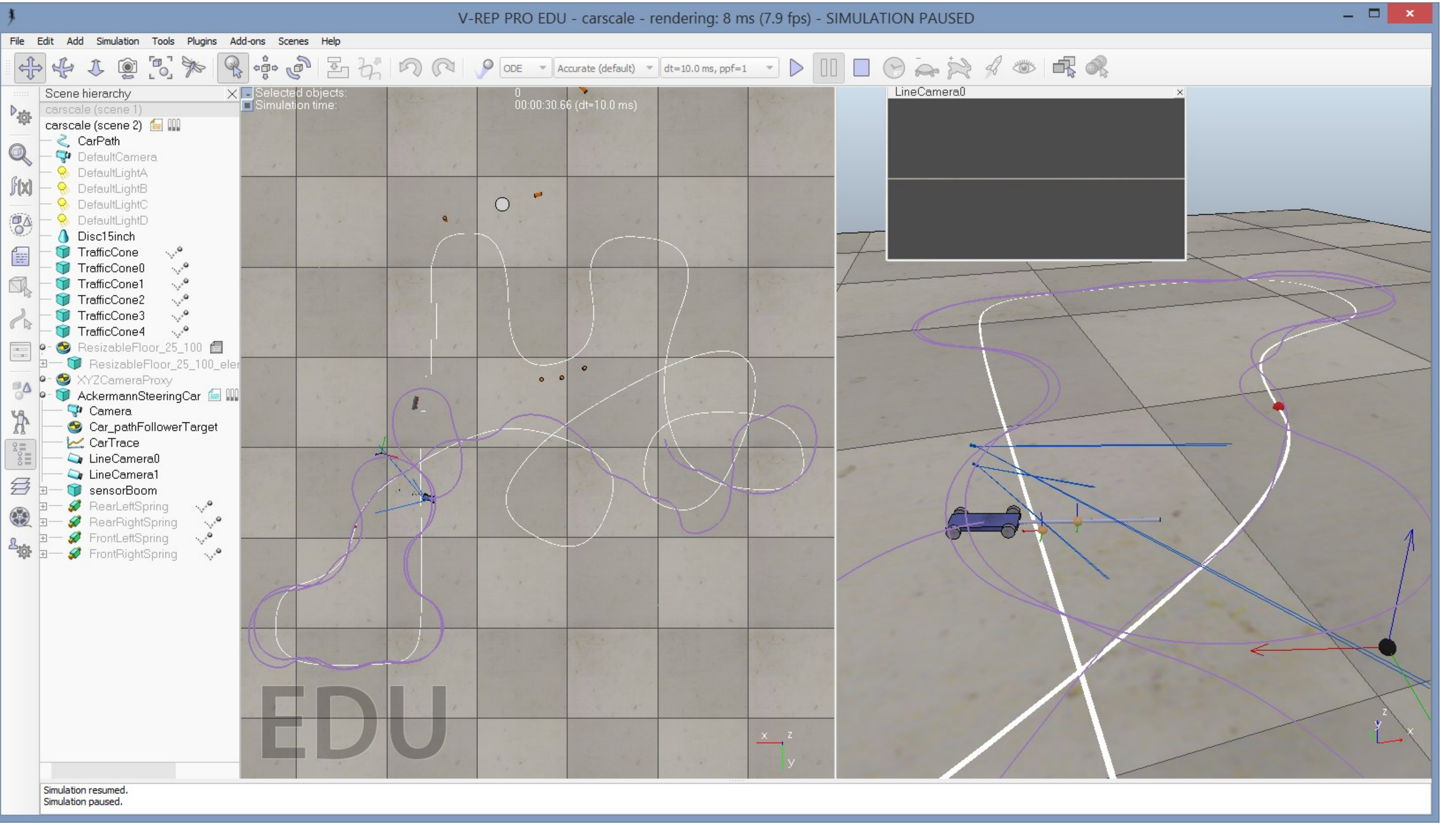
V-Rep Simulator Demo

Telemetry plotting from V-REP

```
python log-visualizer.py car_data_lap0.csv
```

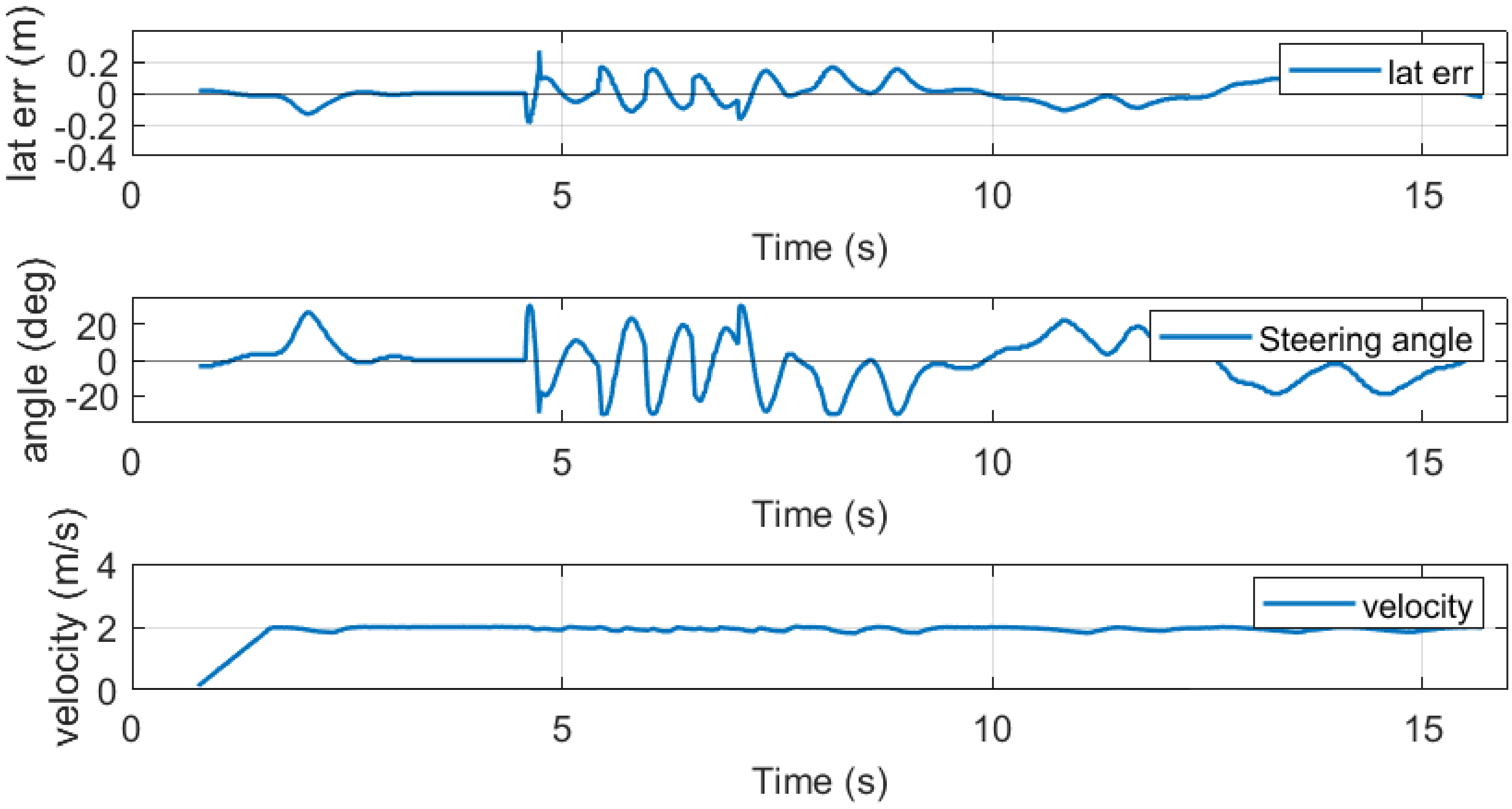


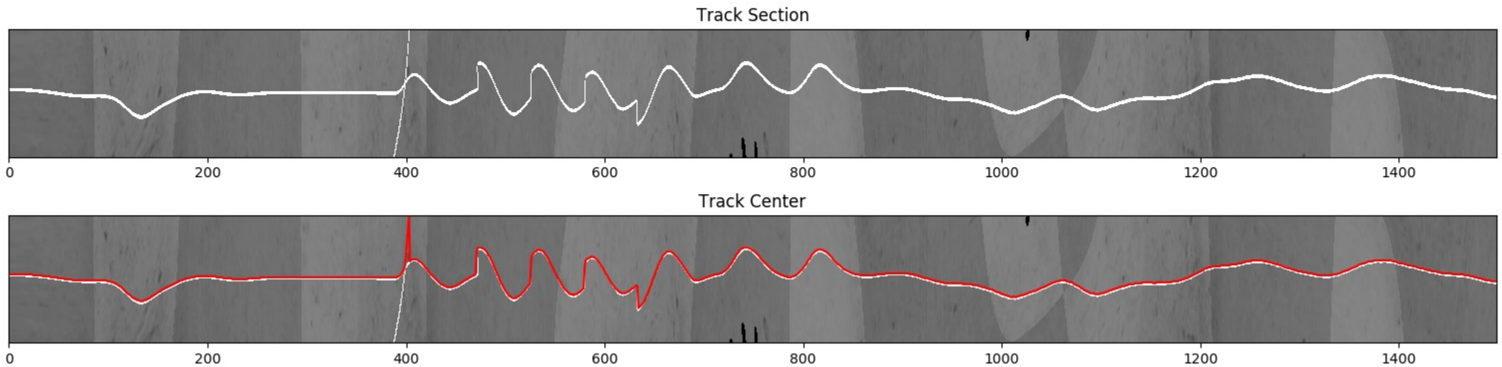
V-rep simulation



demo

V-rep simulation





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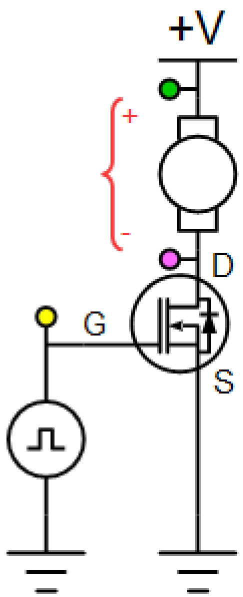
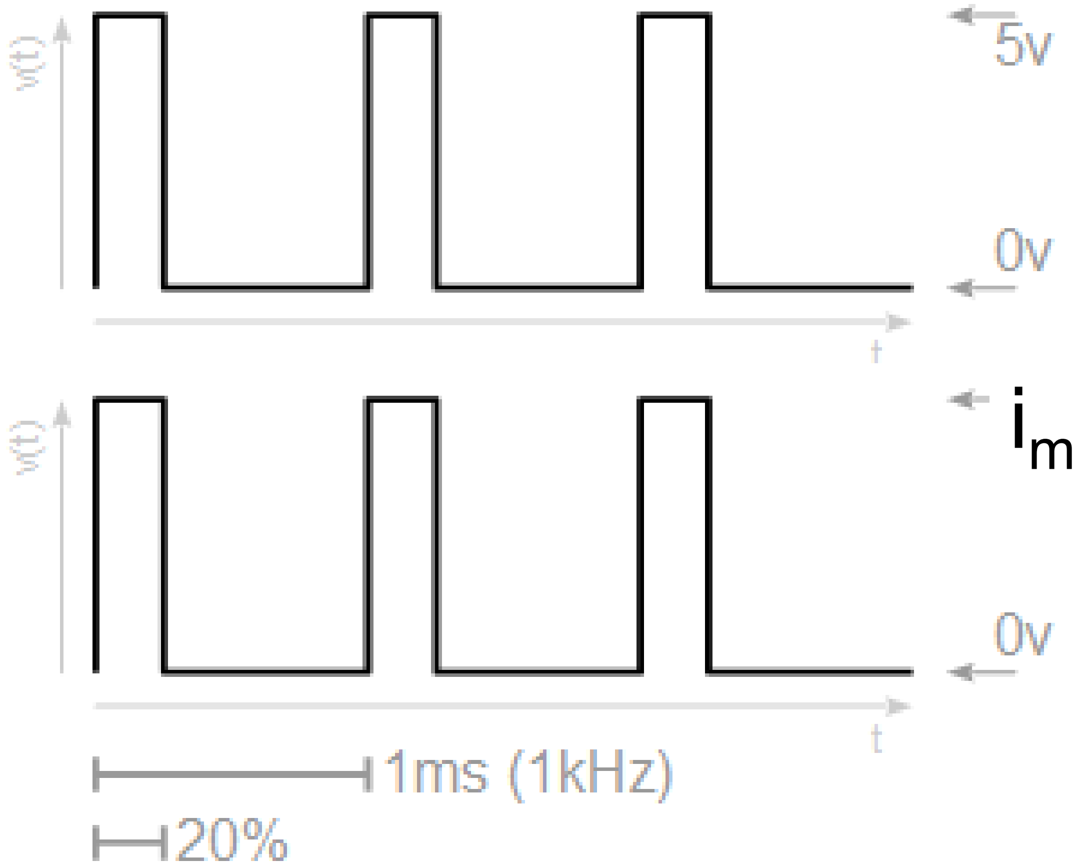
Extra Slides

Extra Slides

PWM for Main Motor control

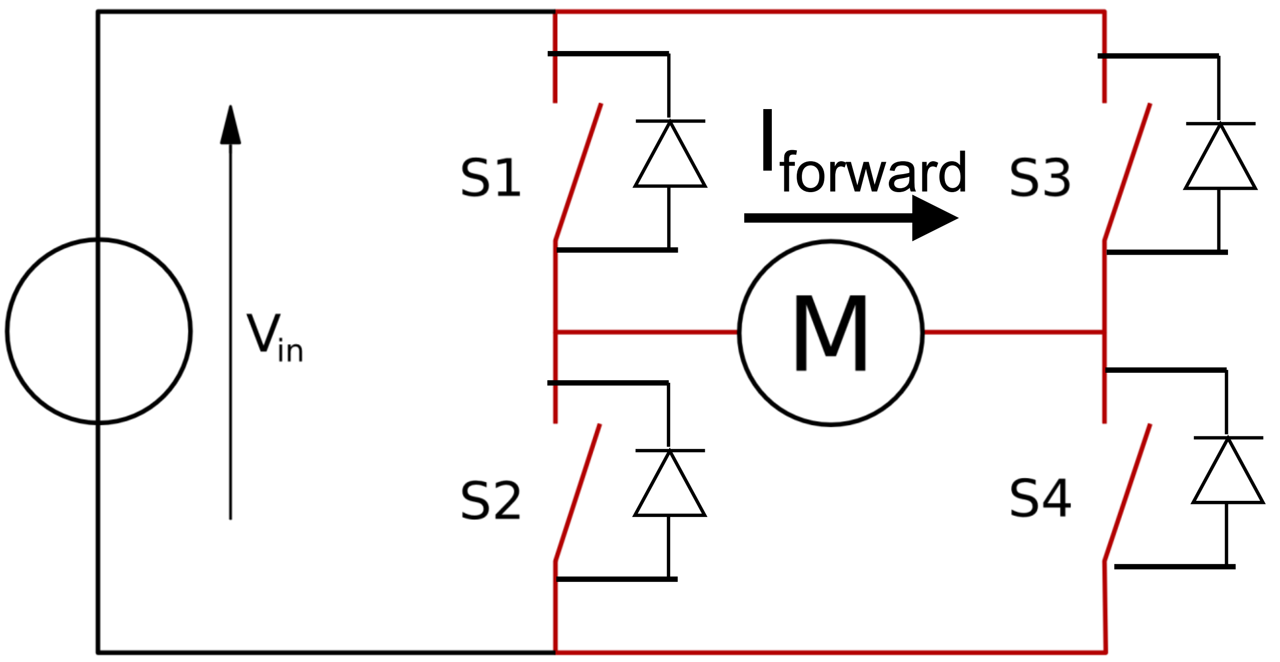




$<i_m> = (T/T_o)\ i_{max}$

Is i_{max} constant?

H Bridge Concept

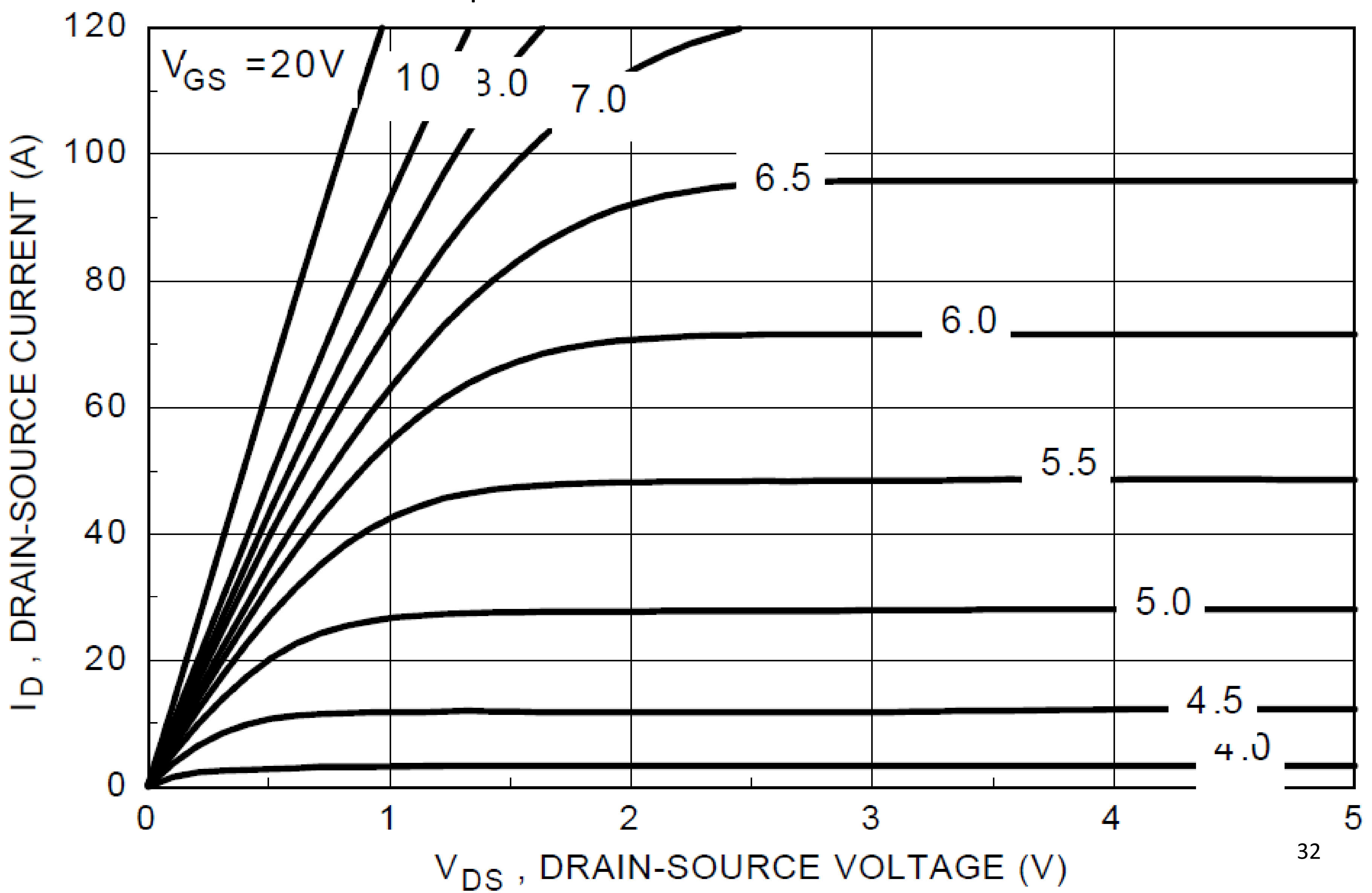


S1	S2	S3	S3	Function?
Off	Off	Off	Off	
On	Off	Off	On	
Off	On	On	Off	
On	On	Off	Off	
On	Off	On	off	
Off	On	Off	on	

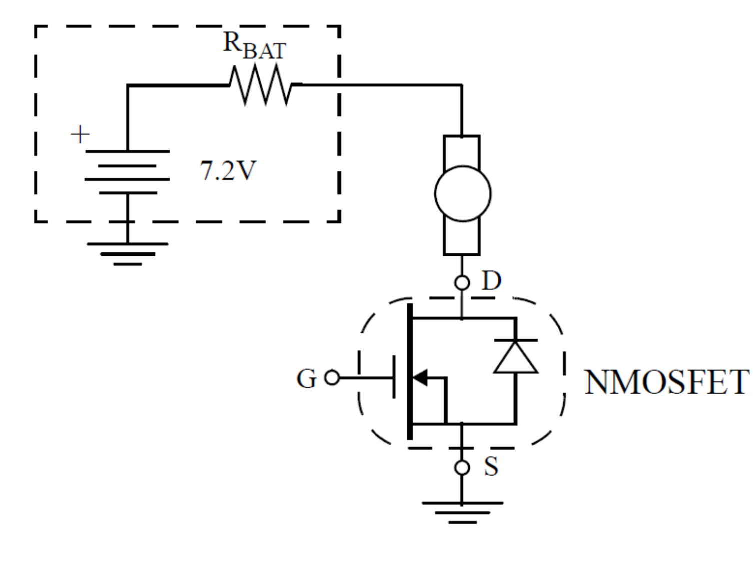
MOSFETs and motor drive

Given: Rm = 0.1 ohms, Vbatt = 7.2 V, Rbat = 0.
Vds = ? ➔ Ids = ? amps

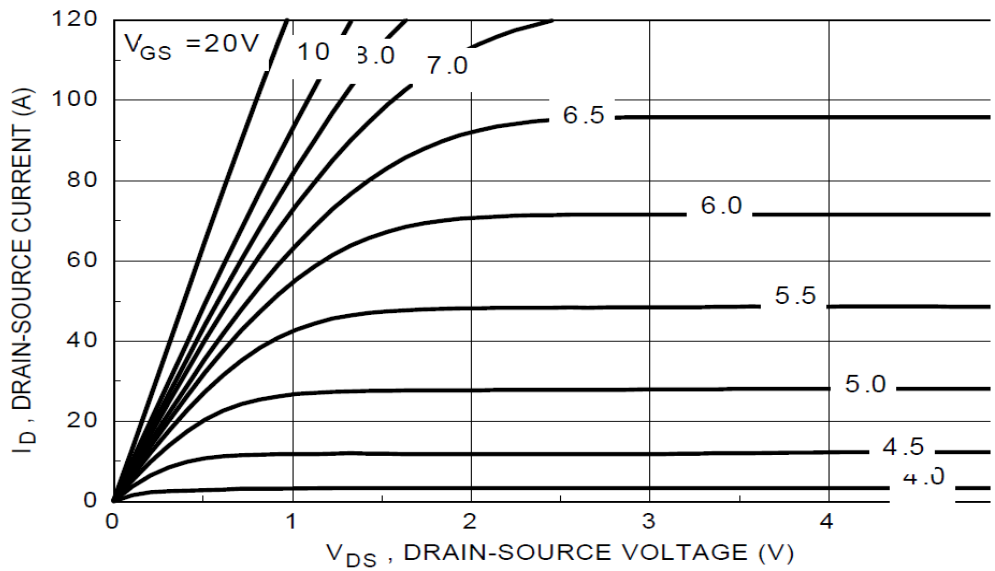
(LiPo 11 V!)



Low-side MOSFET drive



Motor and Battery



MOSFET On region Characteristic

Given: R_{BAT} = 0.00 Ohms, Rm=0.1 ohms.

Neglect motor inductance, assume static case.(Motor is stalled).

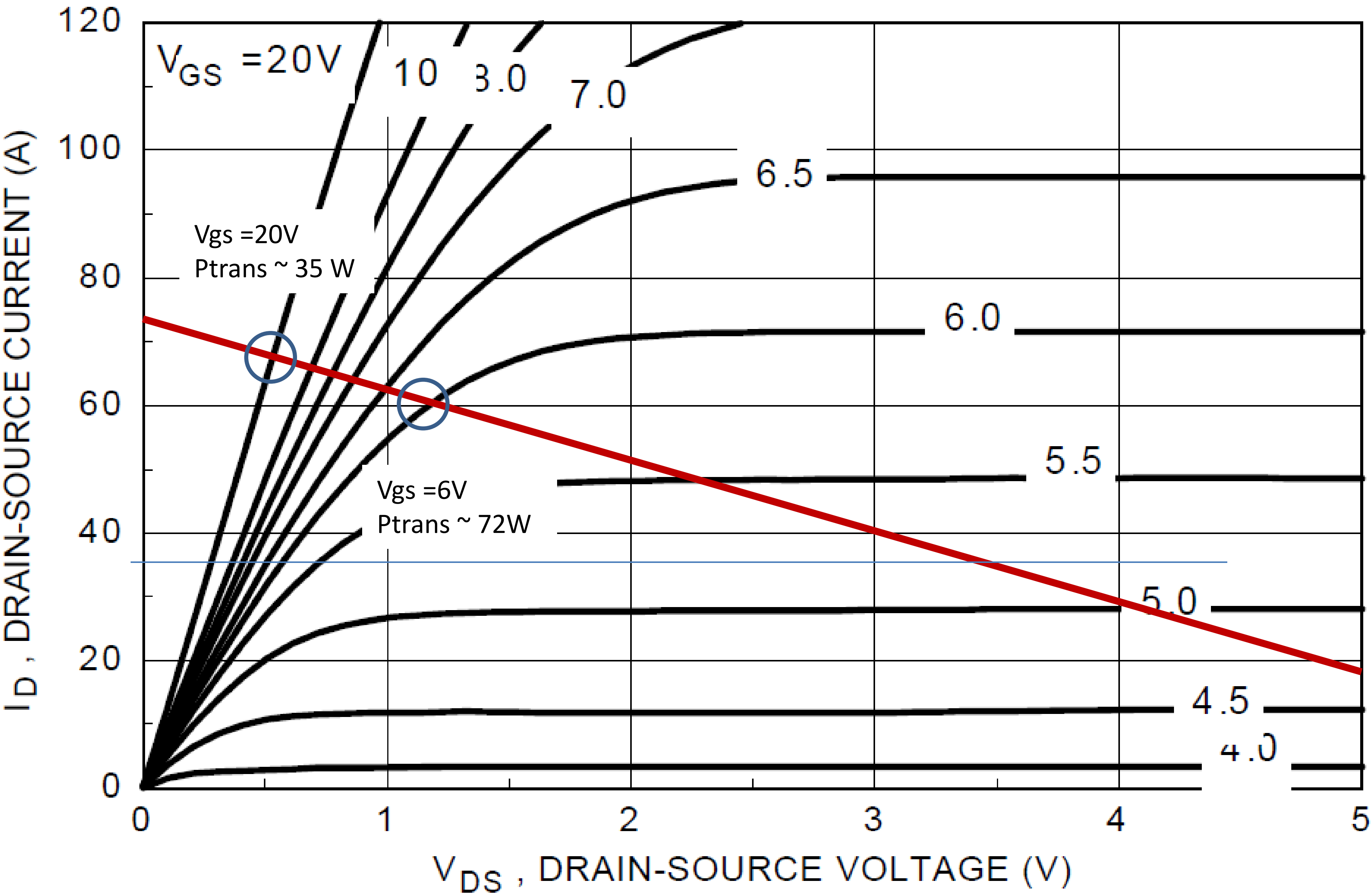
Driving MOSFETs and motor

Rm = 0.1 ohms, Vbatt = 7.2 V, Rbat = 0.

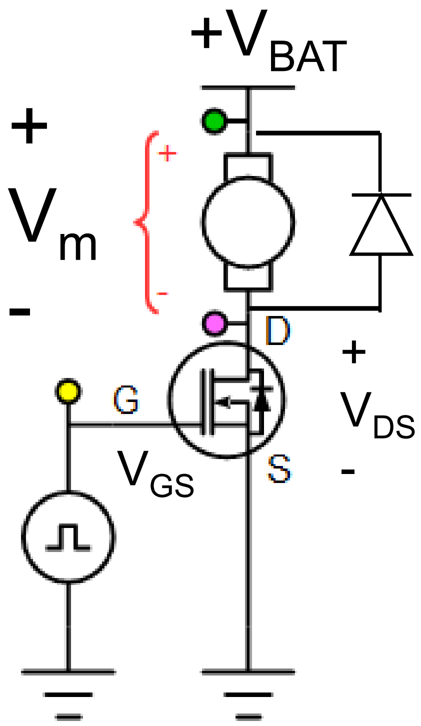
Vds = 3.6V ➔ Ids = (7.2-3.6V)/(0.1 ohm) = 36 amps

Key design points:

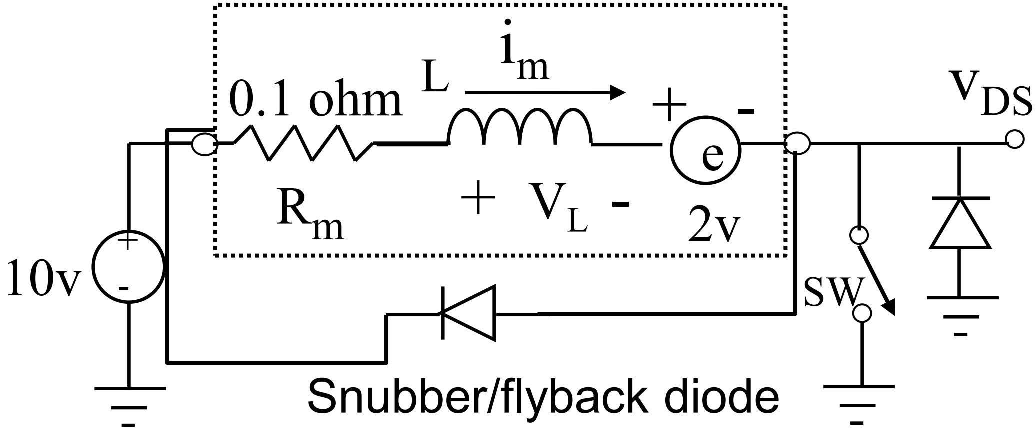
1) High Vgs better than low Vgs
2) Switch quickly
3) Make sure Vs=0 (big ground)



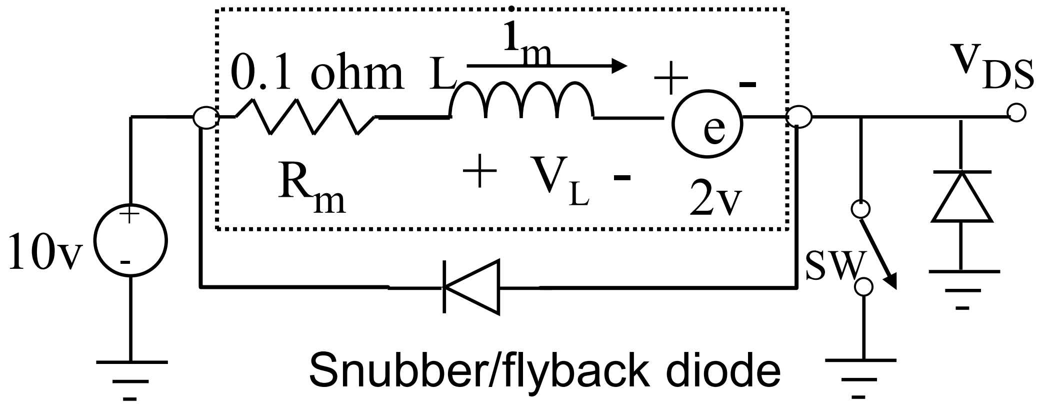
Low side motor drive



What about motor inductance?

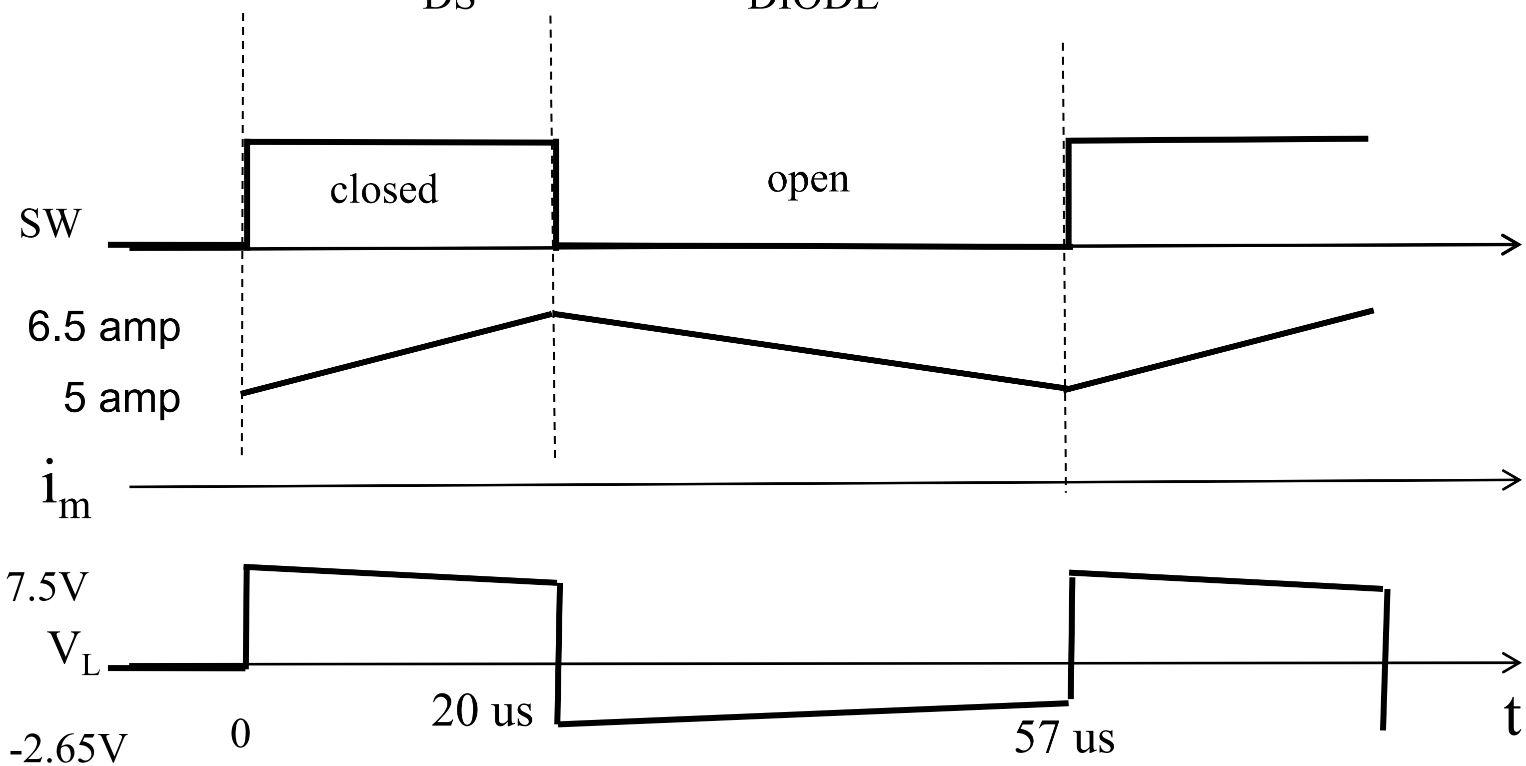


Snubber/flyback diode



Motor inductance~100 uH (?)
Time constant?
L/R= 10^{-4}H / 0.1 ohm = 1 ms

$$V_{DS} = 10V - V_{DIODE}$$



Flyback diode with motor model