EECS192 Lecture 10
Mar. 31, 2020

Notes:

1. HW 2 due Fri Apr 3, 6 pm in bcourses
2. Progress Report due Tues 4/7 330 pm in bcourses

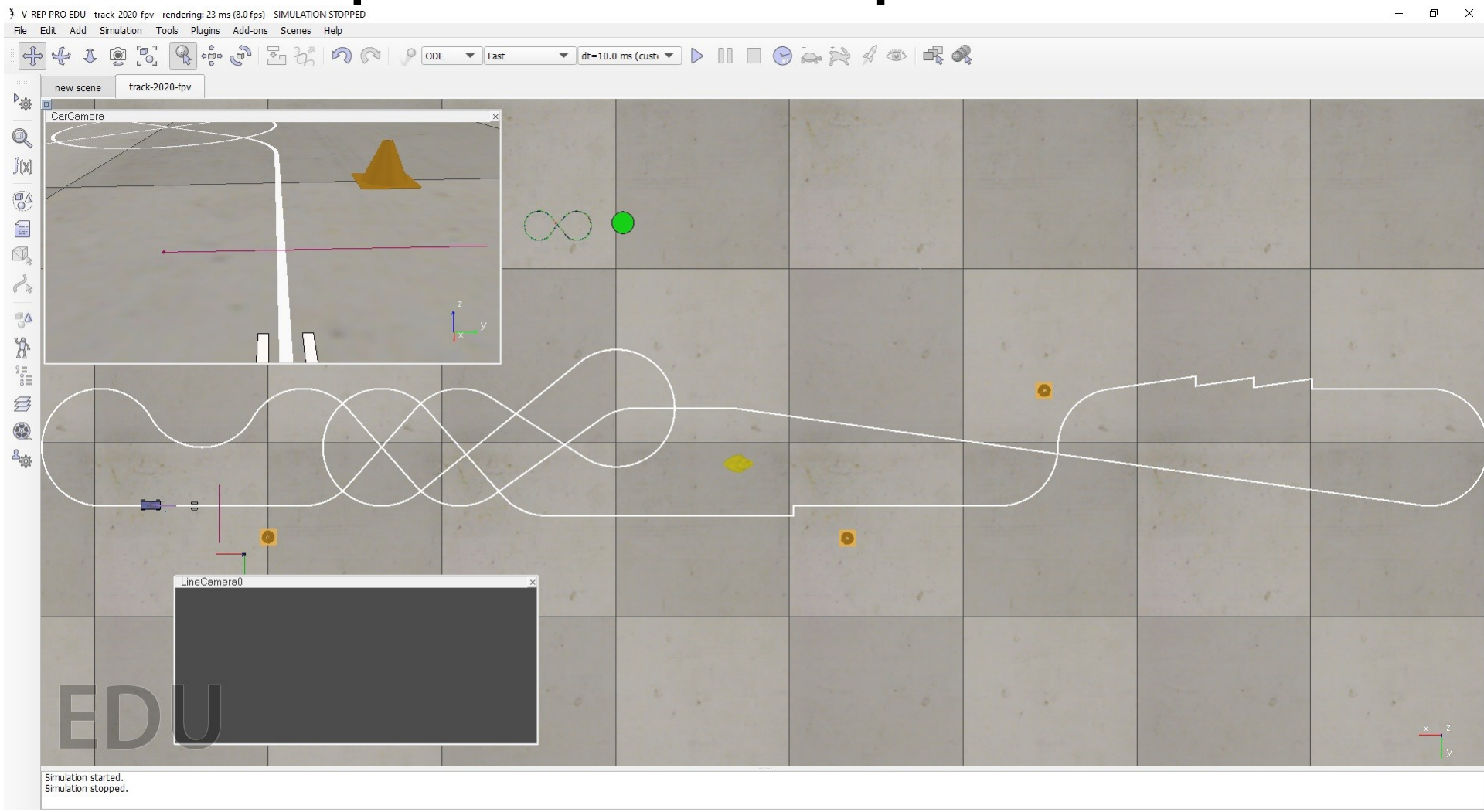
Tentative Grading changes

- Unchanged: community (3%), quiz (5%), round 1 10%, reports proposal + progress + oral (18%) Checkoffs 1-6 (15%) = (51%)
- C7 track run 10%
- C9 PCB 6%
- Round 2 12%
- HW 1+2+3 (15%)
- Oral final (10 min) %6
  - motor drive/H bridge
  - Buck converter
  - Steering control

Topics

- Upcoming checkpoints
- HW 2
- Progress Report
- Flyback Diode for Motor Inductor
- Q4
- Discrete Time control/timing
- Software Robustness

V-rep simulation update - FPV



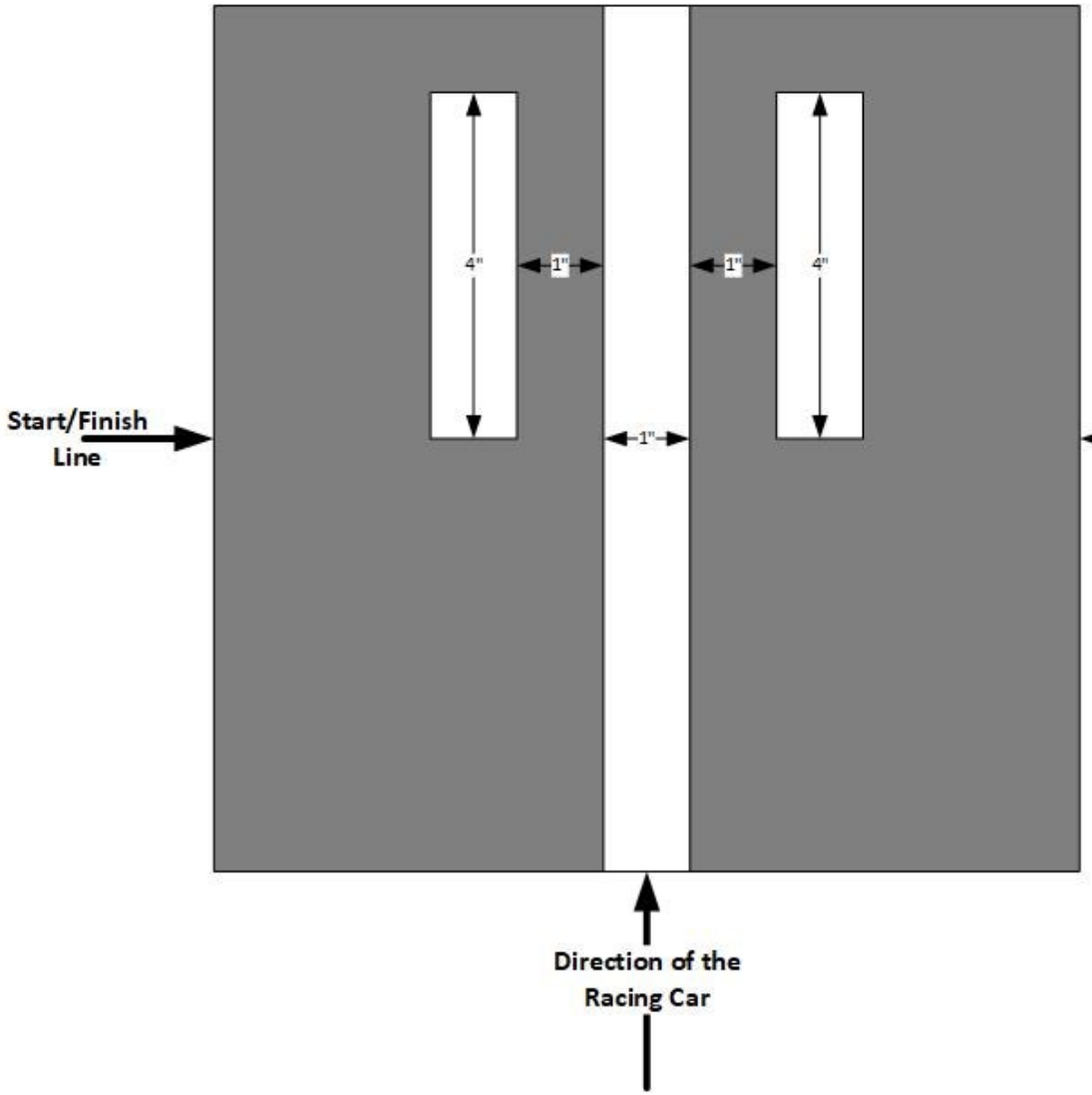
demo

NATCAR Notes

Cones +2 second
Finish line:The start/finish line will be marked with two 4-inch-long segments of 1-inch-wide white tape that are parallel to the track with 1-inch spacing, as shown in the figure below.

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.



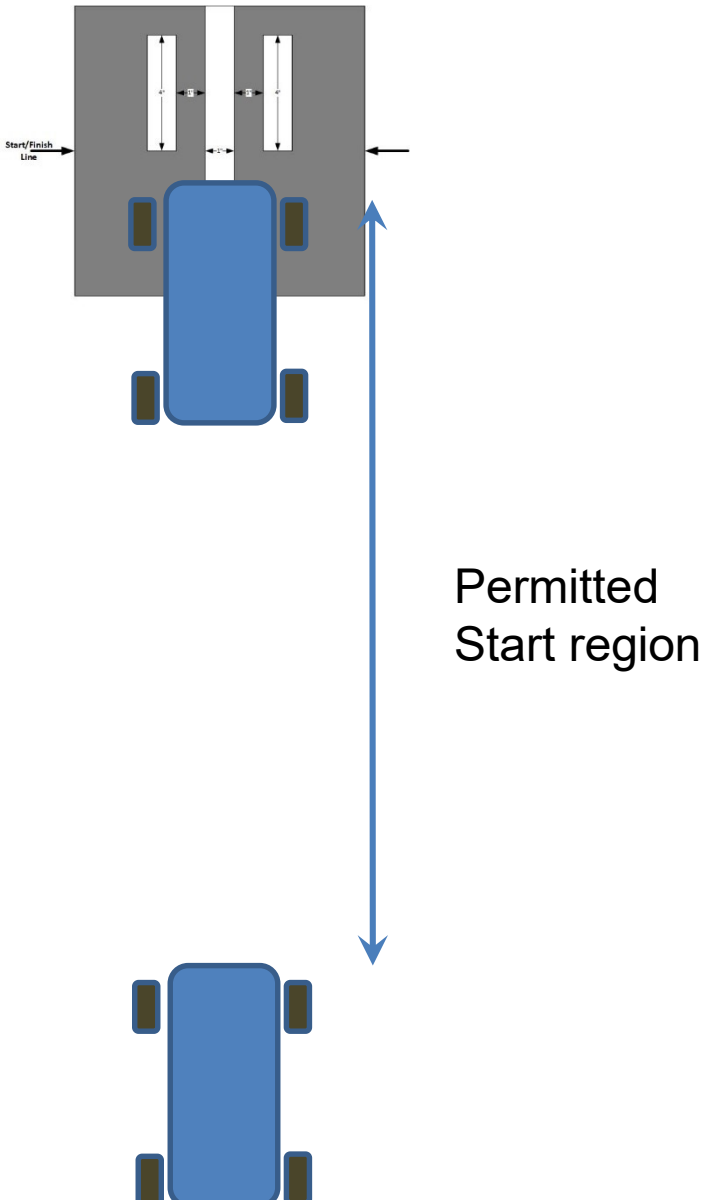
NATCAR Notes

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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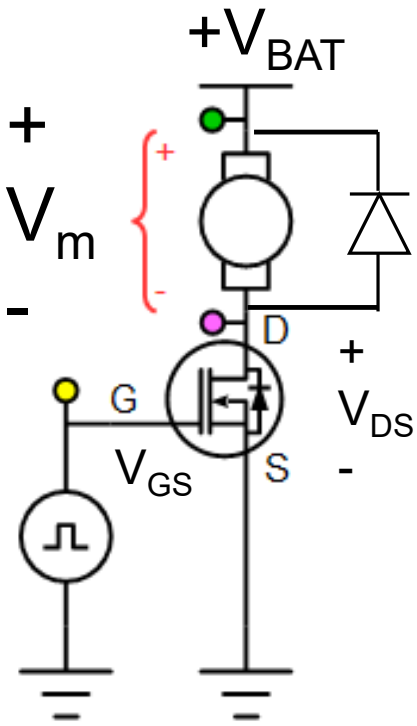
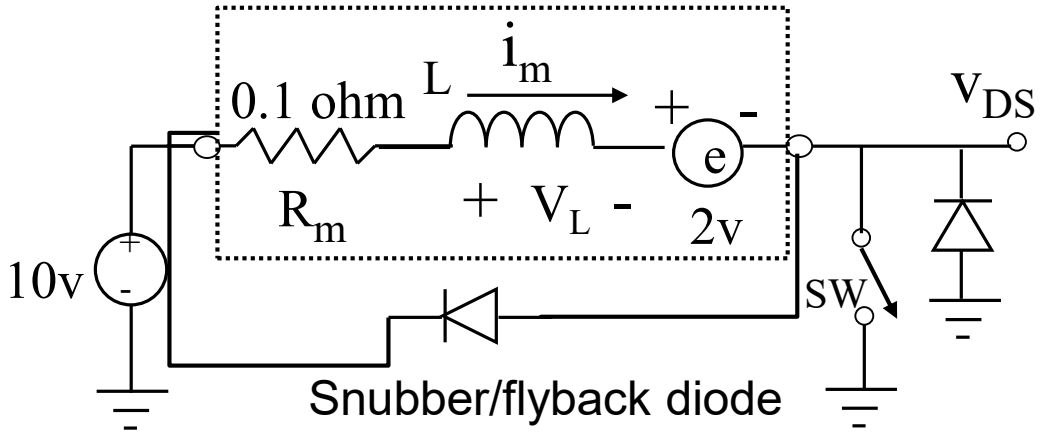
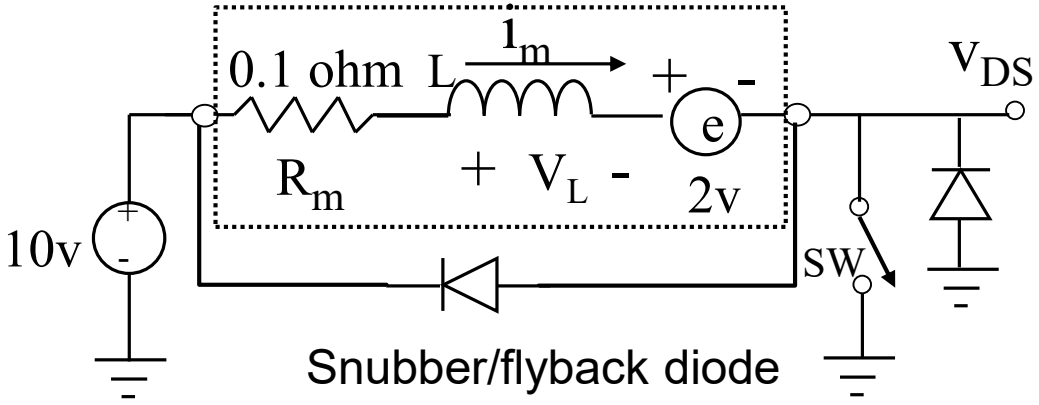
Low side motor drive



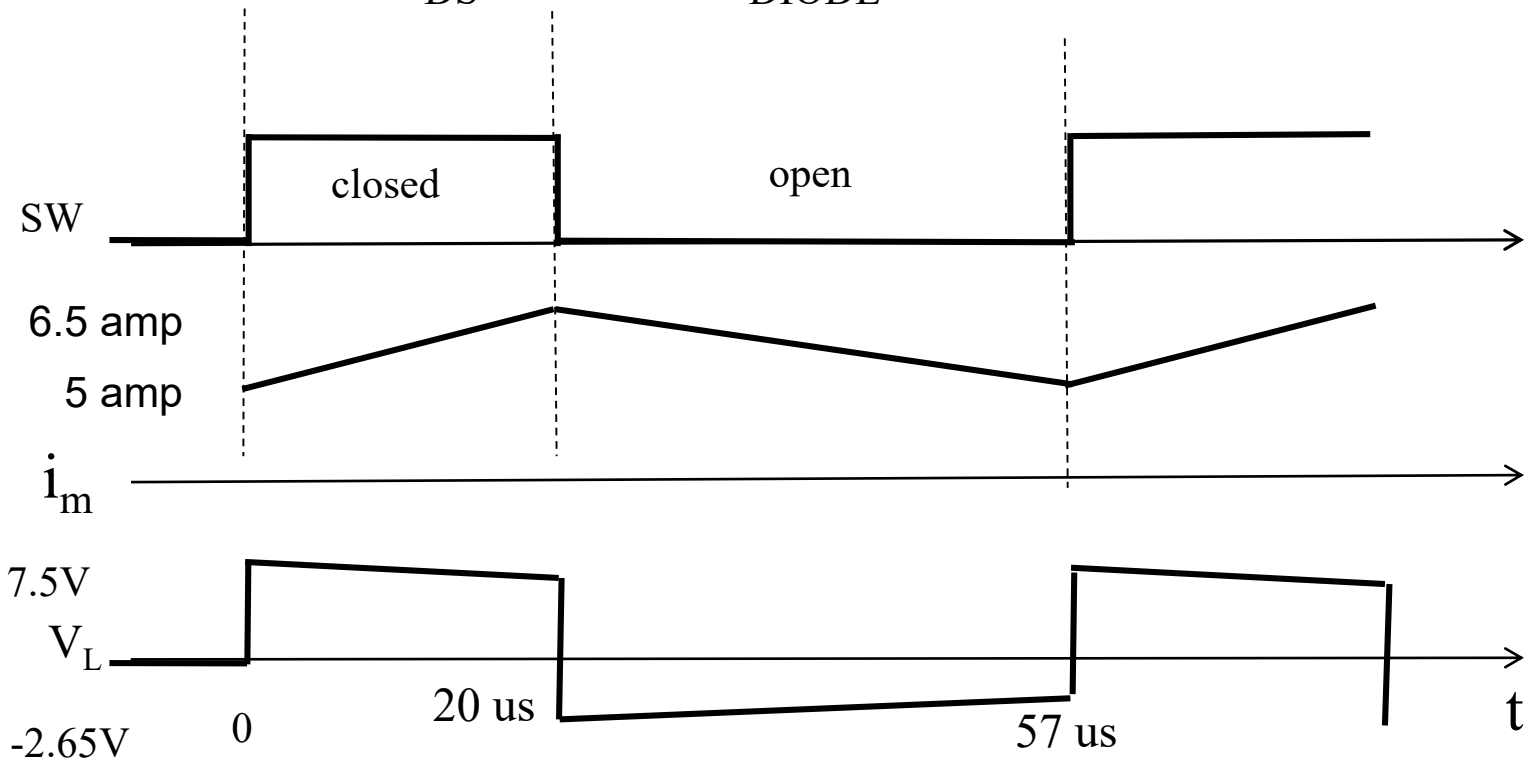
What about motor inductance?





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

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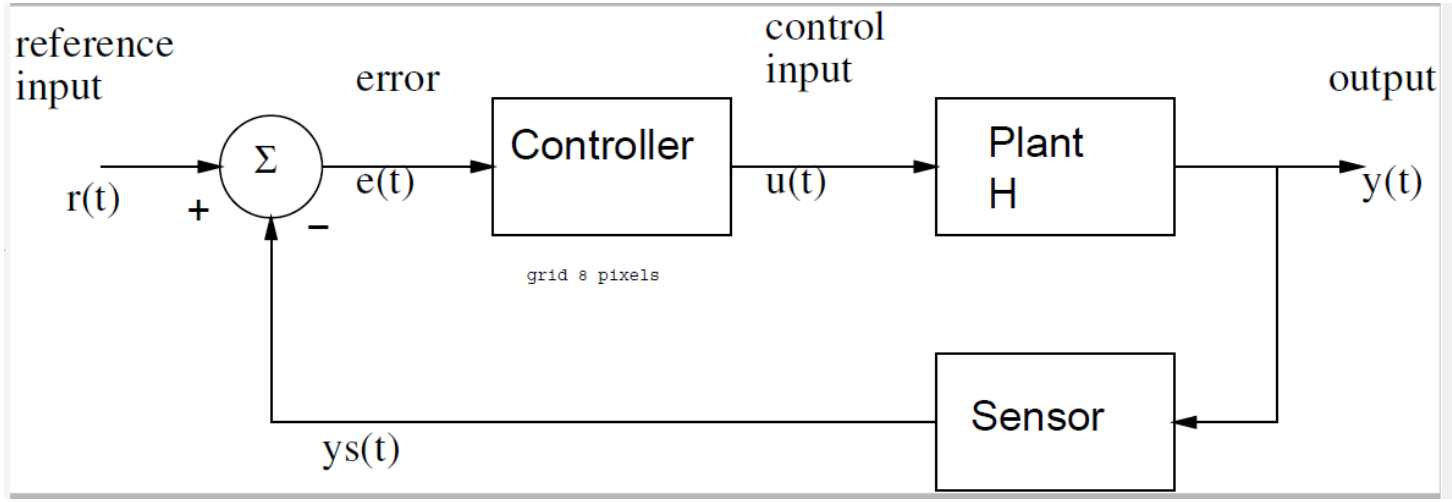
Control Synopsis



State equations: $$\dot{x}(t) = ax(t) + bu(t)$$

Output equations: $$y(t) = cx(t) + du(t)$$

Control Law (P): $$u(t) = k_p e(t) = k_p(r(t) - y(t)).$$

Control Synopsis

Control Law (P): $u(t) = k_p e(t) = k_p(r(t) - y(t)).$

New state equations:

$$\dot{x} = ax + bk_p e(t) = ax + bk_p(r - x) = (a - bk_p)x + bk_p r.$$

Zero Input Response (non-zero init condx):

$$x(t) = x(0)e^{(a-bk_p)t} \quad for \quad t \geq 0.$$

$a' = a - b\,k_p$ $\quad$ $b' = b\,k_p$

Total Response (non-zero init condx) by convolution:

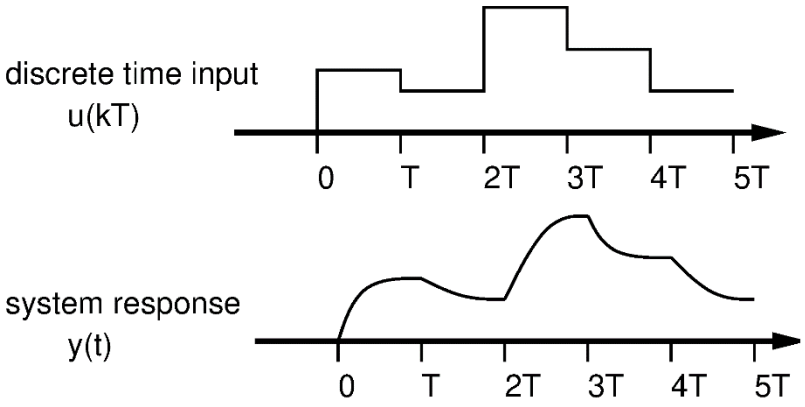
$$x(t_o) = e^{a't_o}x(0) + \int_0^{t_o} e^{a'(t_o-\tau)}b'r(\tau)d\tau \ . \qquad (10)$$

Step Response (zero init condx) by convolution:

$$x(t_o) = b' \int_0^{t_o} e^{a't_o}e^{-a'\tau}d\tau \ = \ \frac{-b'e^{a't_o}}{a'}e^{-a'\tau}|_0^{t_o} \ = \frac{b'}{a'}(1 - e^{-a't_o}) \ . \qquad (11)$$

Control Synopsis- Discrete Time

Superposition of Step Responses



$$x((k+1)T) = e^{a(k+1)T}x(0) + e^{a(k+1)T}\int_0^{(k+1)T} e^{-a\tau}bu(\tau)d\tau \ . \qquad (15)$$

$$x(kT) = e^{akT}x(0) + e^{akT}\int_0^{kT} e^{-a\tau}bu(\tau)d\tau \ . \qquad (14)$$

$$x((k+1)T) = e^{aT}x(kT) + e^{a(k+1)T}\int_{kT}^{(k+1)T} e^{-a\tau}bu(\tau)d\tau \ = e^{aT}x(kT) + \int_0^{T} e^{a\lambda}bu(kT)d\lambda \ , \ (16)$$

Control Synopsis- Discrete Time

$$G(T) \equiv e^{aT} \quad \text{and} \quad H(T) \equiv b \int_0^T e^{a\lambda} d\lambda \ . \tag{17}$$

State equations:

$$x((k+1)T) = G(T)x(kT) + H(T)u(kT) \tag{18}$$

Output equations:

$$y(kT) = Cx(kT) + Du(kT) \ . \tag{19}$$

Total Response (non-zero init condx) by convolution:

$$x(k) = G^k x(0) + \sum_{j=0}^{k-1} G^{k-j-1} H u(j) \ . \tag{23}$$

Control Synopsis- Discrete Time

Control Law (P):

$$U(kT) = k_p\,[r(kT) - x(kT)]$$

New state equations:

$$x((k+1)T) = G(T)x(kT) + H(T)k_p(r(kT) - x(kT)) = [G - Hk_p]x(kT) + Hk_p r(kT)\ . \quad (24)$$

$$x((k+1)T) = [e^{aT} + \frac{k_p}{a}(1 - e^{aT})]x(kT) + Hk_p r(kT) \ = \ G'x(kT) + Hk_p r(kT) \quad . \qquad (25)$$

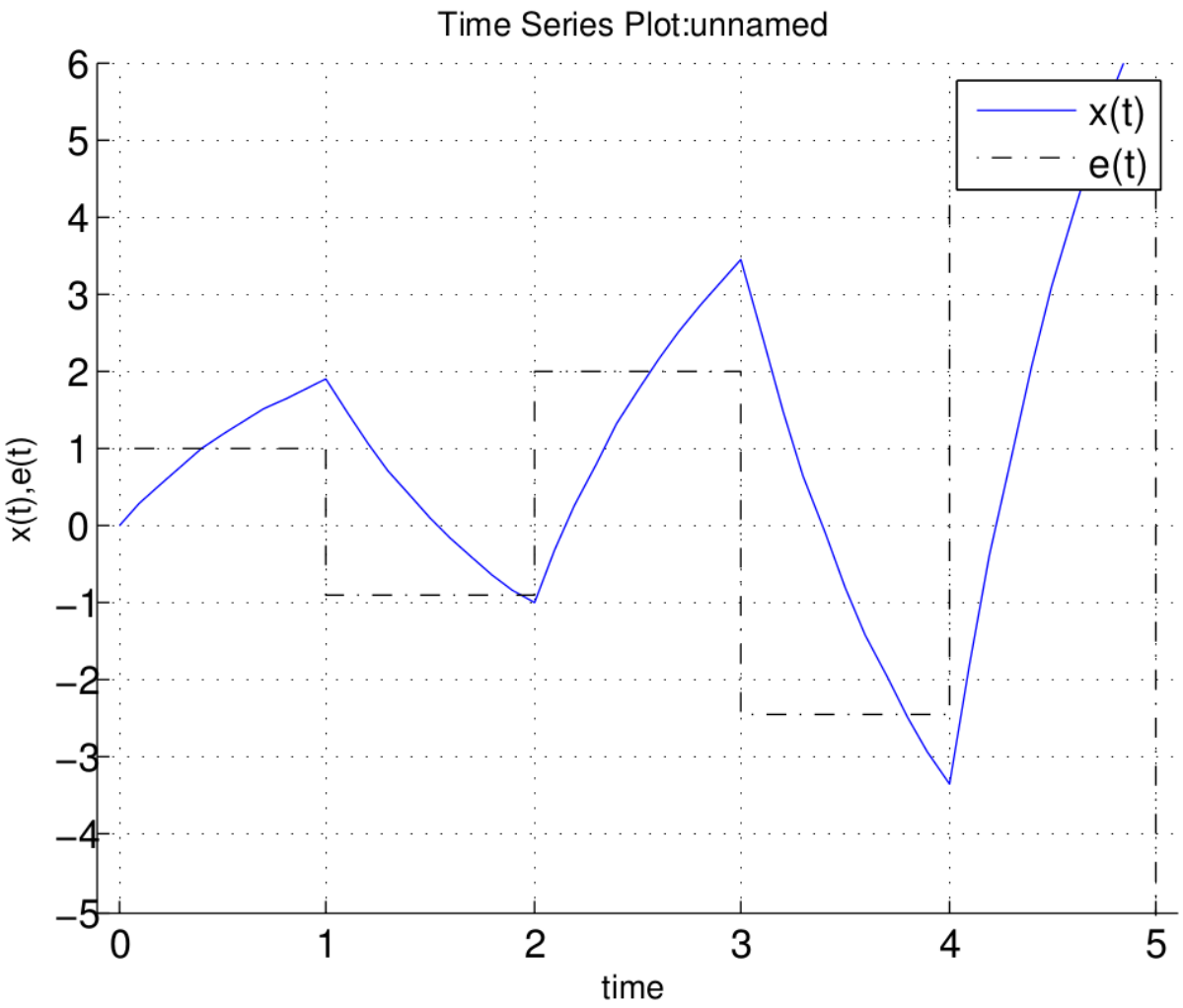
For stability:

$$|e^{aT} - \frac{k_p}{a}(e^{aT} - 1)| < 1. \qquad (26)$$

Notes: stability depends on gain **and** T!

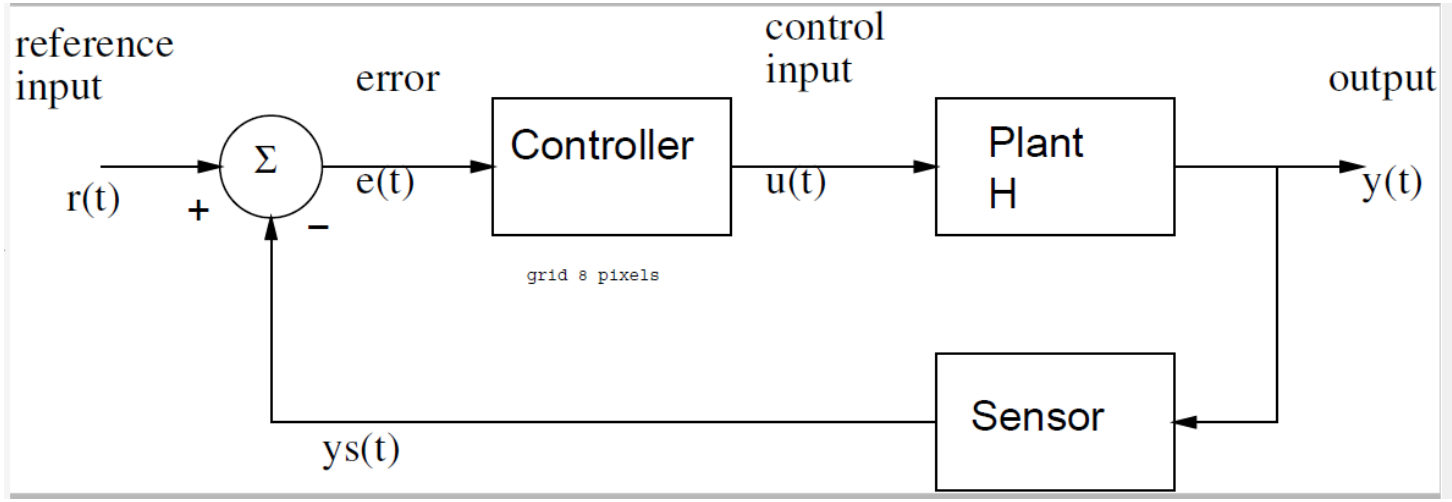
Discrete Time Control

u[k] = kp*(r[k]-x[k])



On board

Control Synopsis



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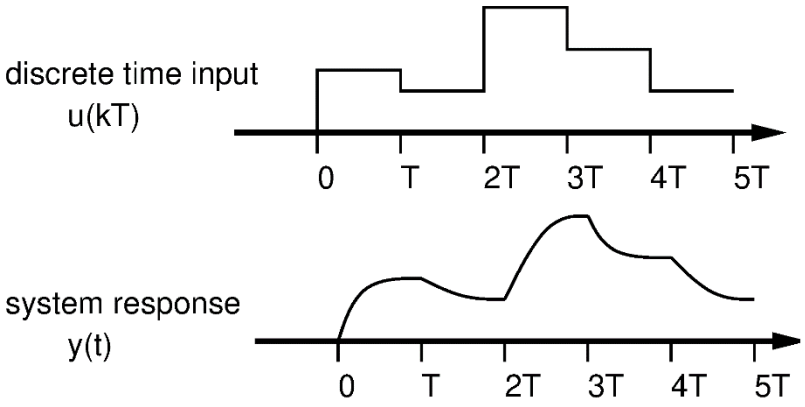

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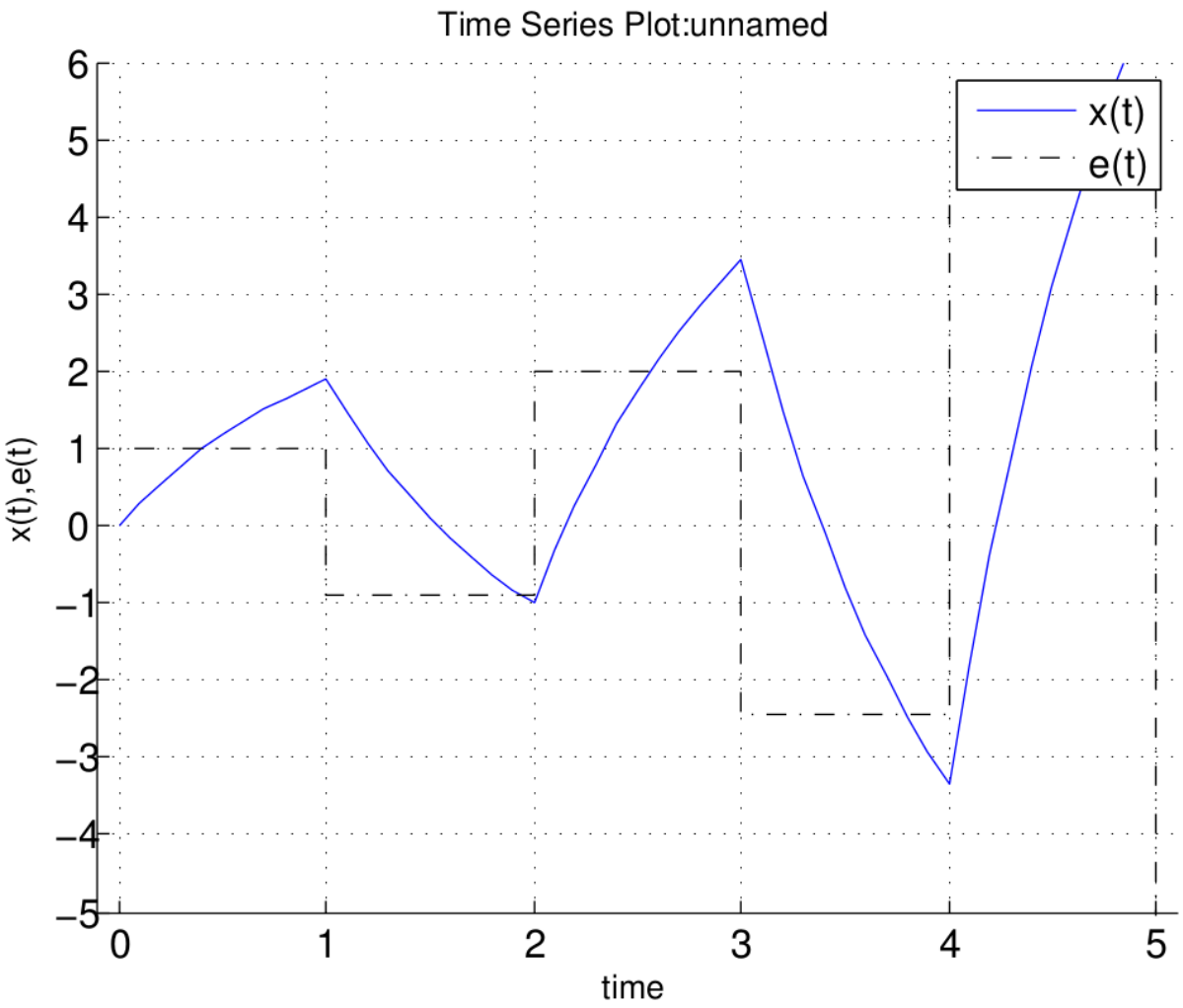

On board

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10 Questions to Consider when Reviewing Code

Jacob Beningo

Embedded Systems Conference -2017

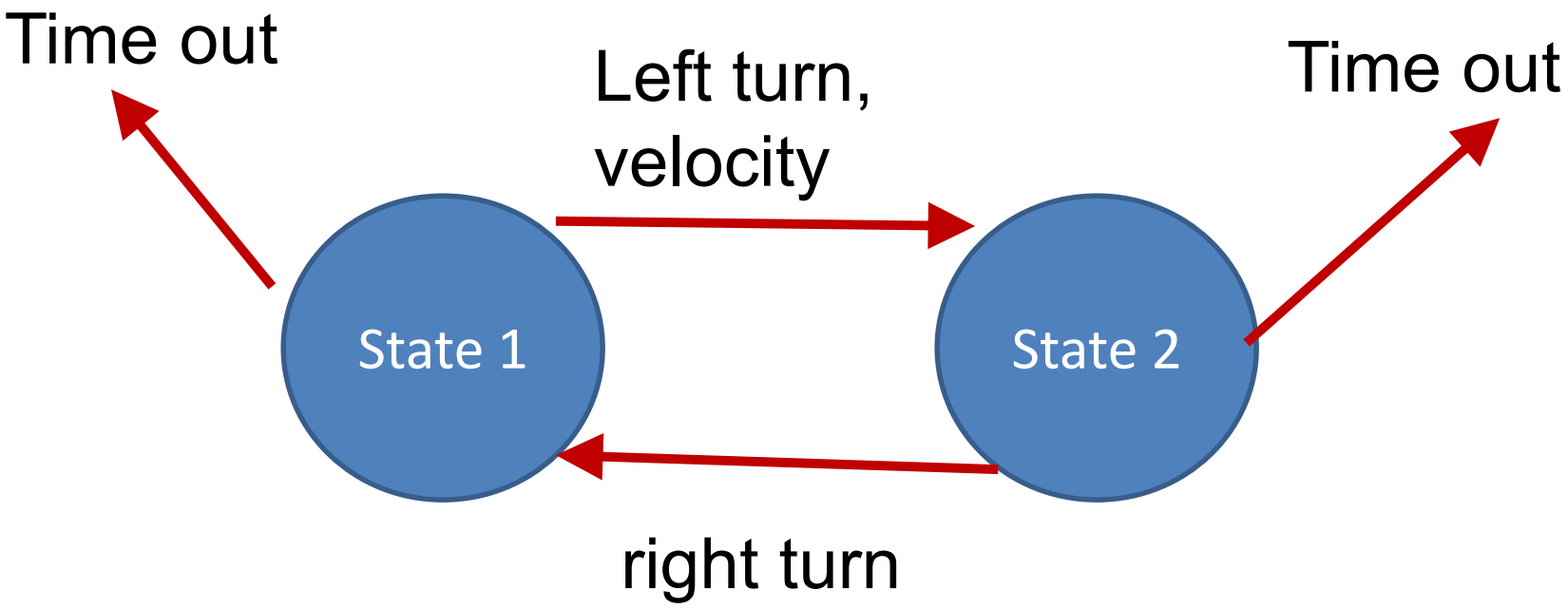
https://www.designnews.com/electronics-test/10-questions-consider-when-reviewing-code/143583201956491?cid=nl.x.dn14.edt.aud.dn.20170329

1. Does the program build without warnings?
2. Are there any blocking functions?
3. Are there any potential infinite loops?
4. Should this function parameter be const?
6. Has extern been limited with a liberal use of static?
7. Do all if … else if … conditionals end with an else?
8. Are assertions and/or input/output checks present?
9. Are header guards present? The guard prevents double inclusion of the #include directives.
10. *Is floating point mathematics being used?*

Software Robustness

- Checksums for bit rot
- Watch dog timer/computer operating properly COP
- Lost track detection
- Autocalibration at startup
  - (sanity check for steering angle vs line error)
  - AGC
- State Observer/estimator
- Discrete State observer

FSM Recognizer (generalized WDT)

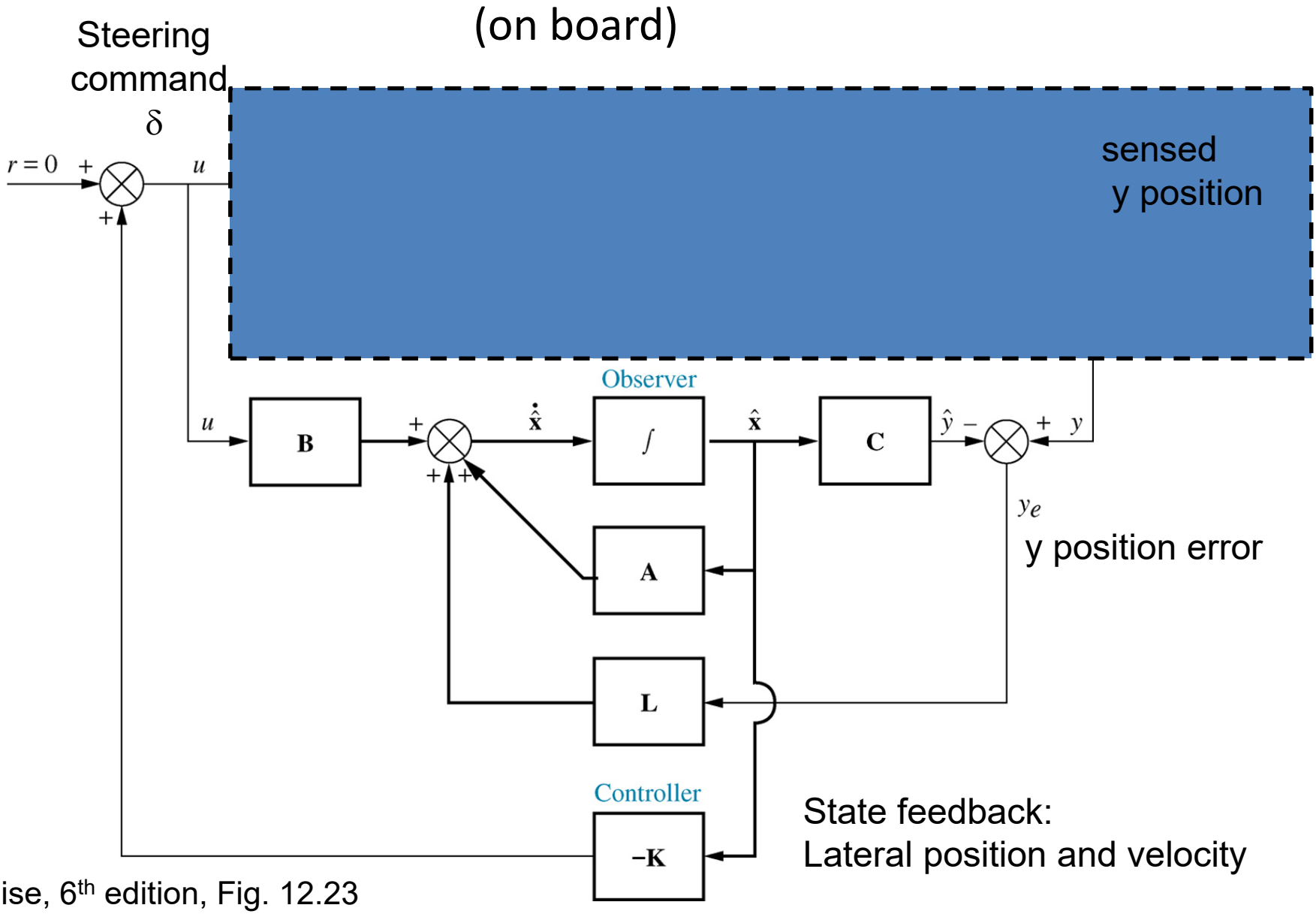


Digital Filtering

- Moving average
  - $y1[n] = (y[n-2]+y[n-1]+y[n])/3$
- Median filter (outlier rejection)
- Notch filter (mechanical vibration)
  - $y[n] = (x[n-2]+2x[n-1]+x[n])/4$
- Model based filtering (or Kalman filter)

(on board)

Software Robustness: Observer



N. Nise, 6th edition, Fig. 12.23

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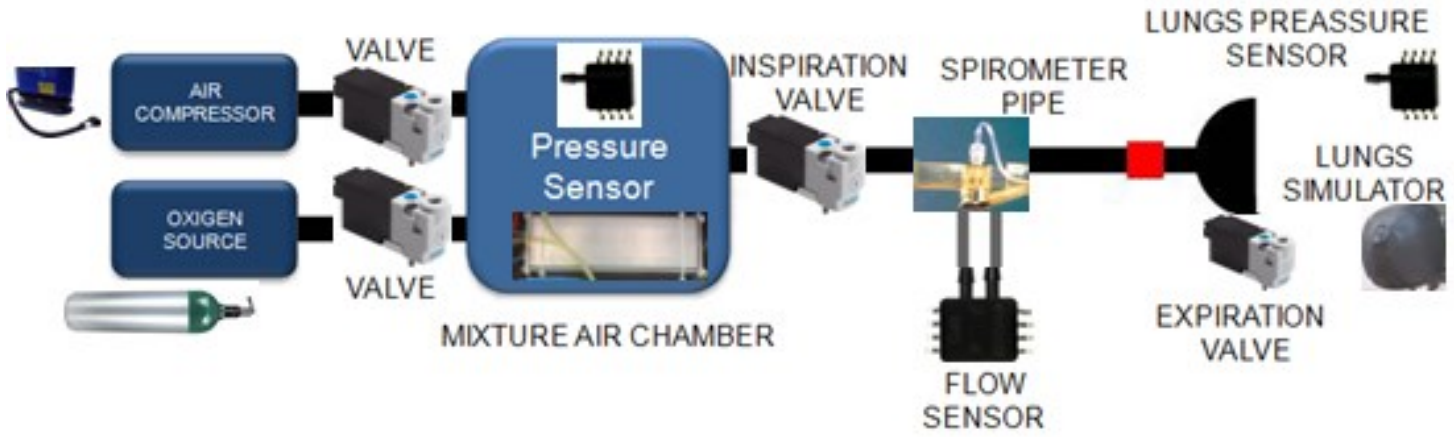
- Mechatronics System Example

Mechatronics system example: ventilator



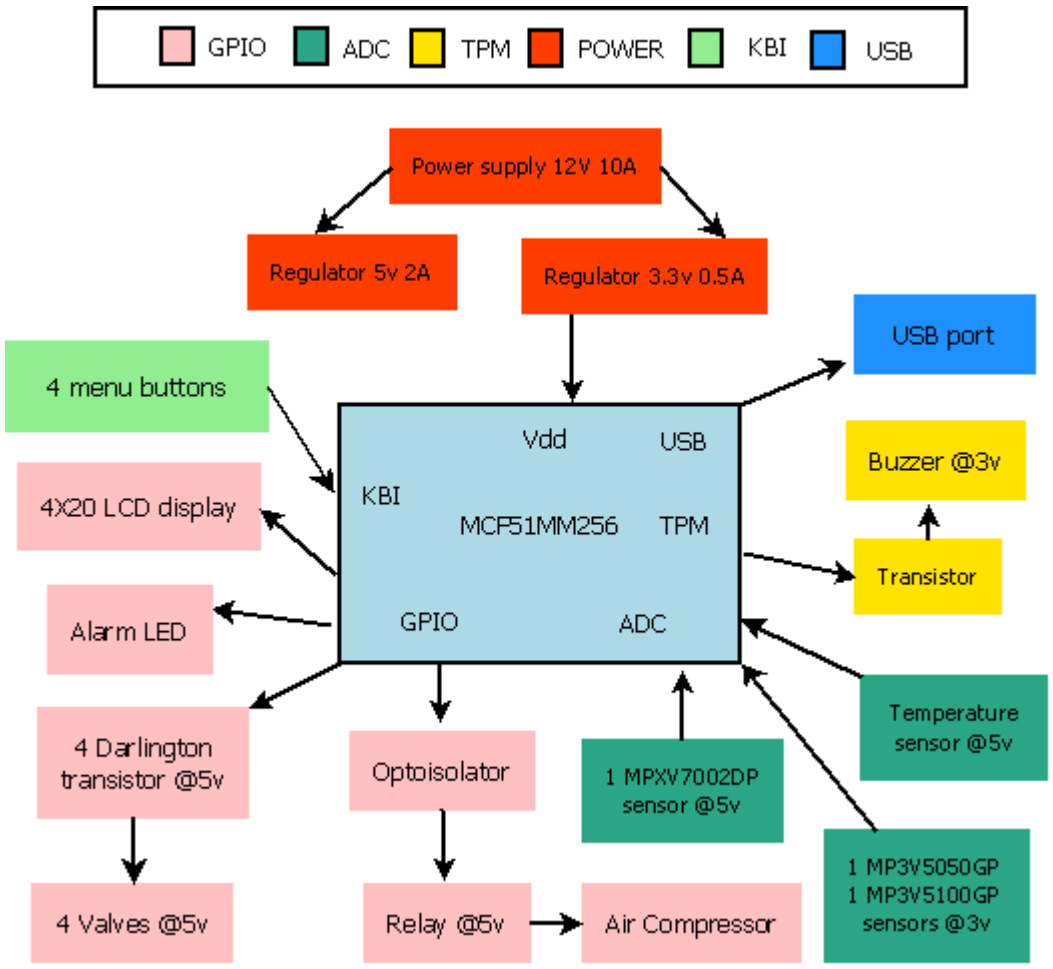
Mechatronics System Example: Ventilator

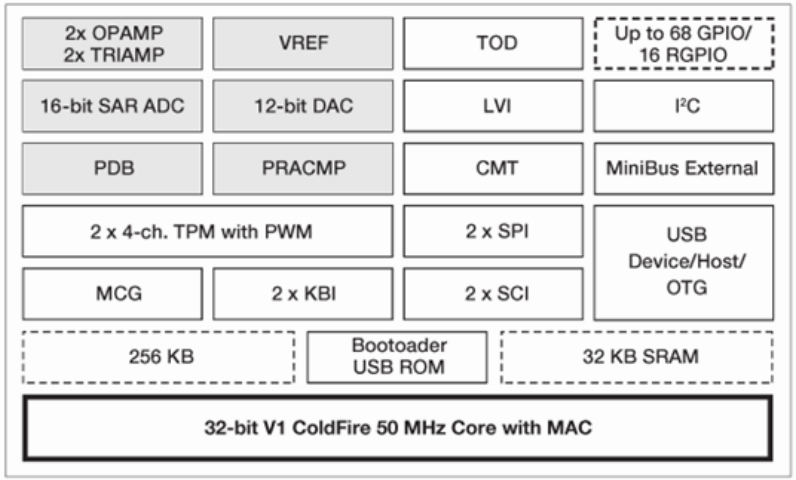
Ventilator/Respirator Hardware and Software Design Specification

https://www.nxp.com/docs/en/application-note/DRM127.pdf

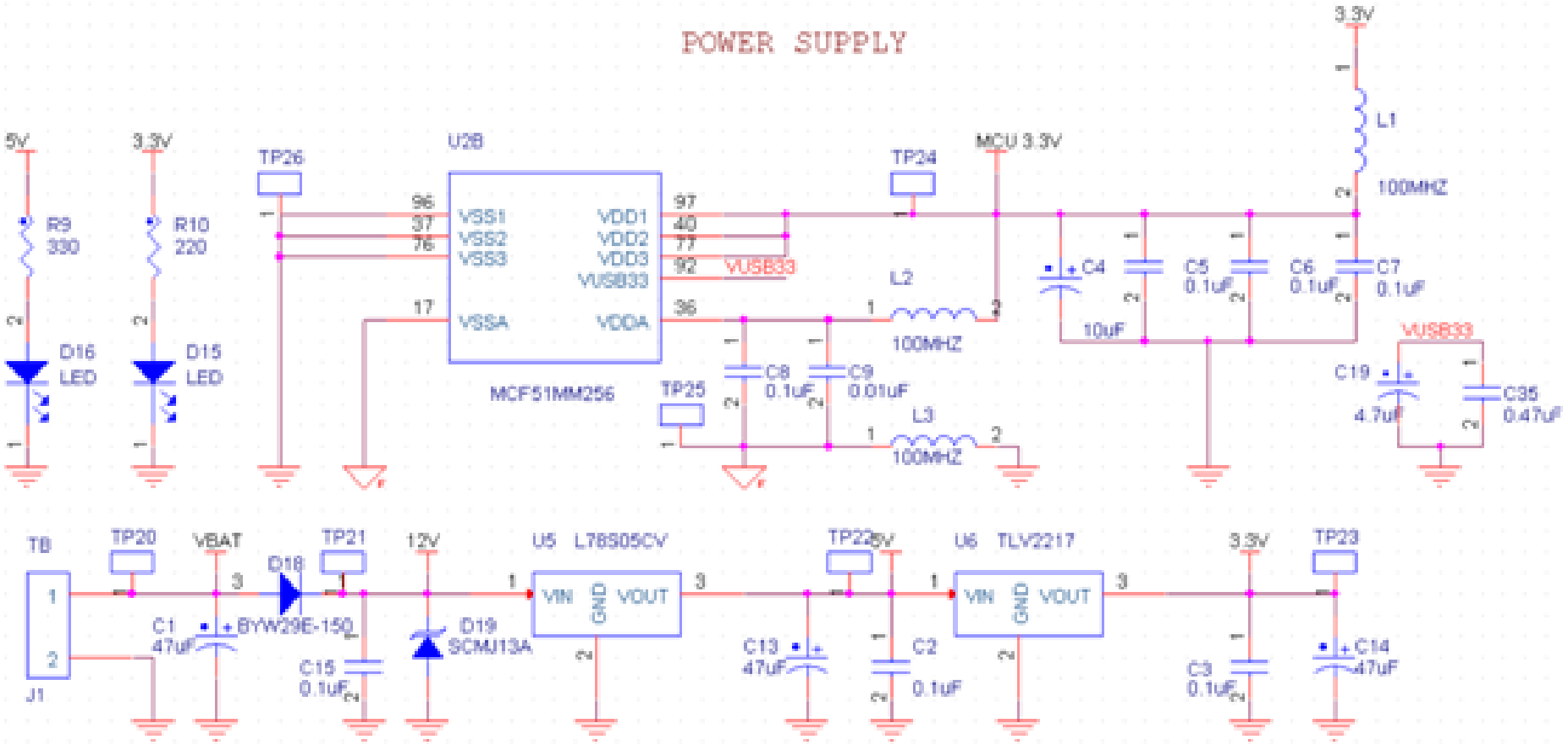
Note: only to be used as an illustrative example of mechatronic system design, not intended for clinical use.

Hardware Block Diagram

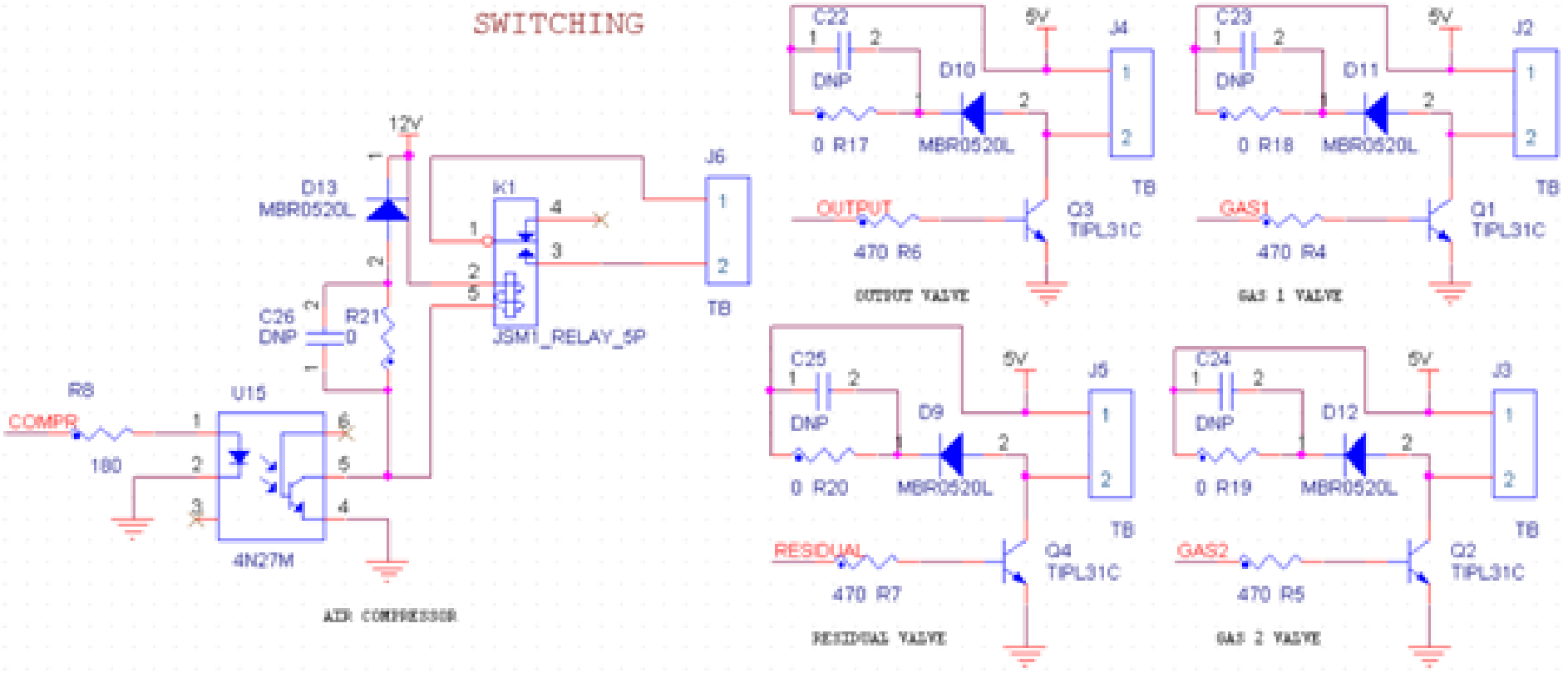




Power Supply

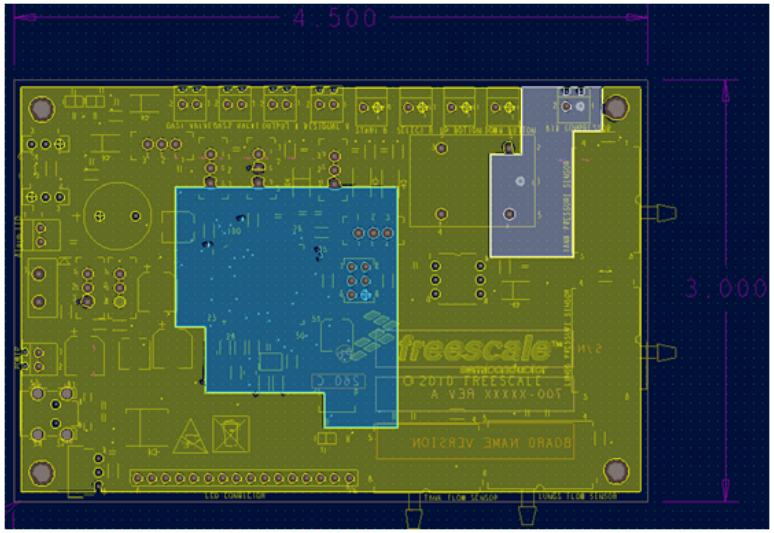


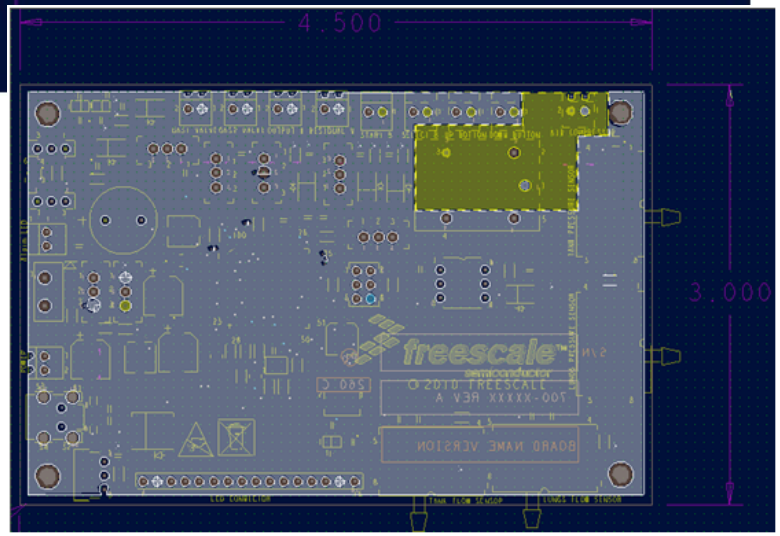
Actuator drive



4 layer PCB


4.500
3.000
VIEW FROM PRIMARY SIDE
PRIMARY DATUM
GRID ORIGIN
0
freescale


4.500
3.000
freescale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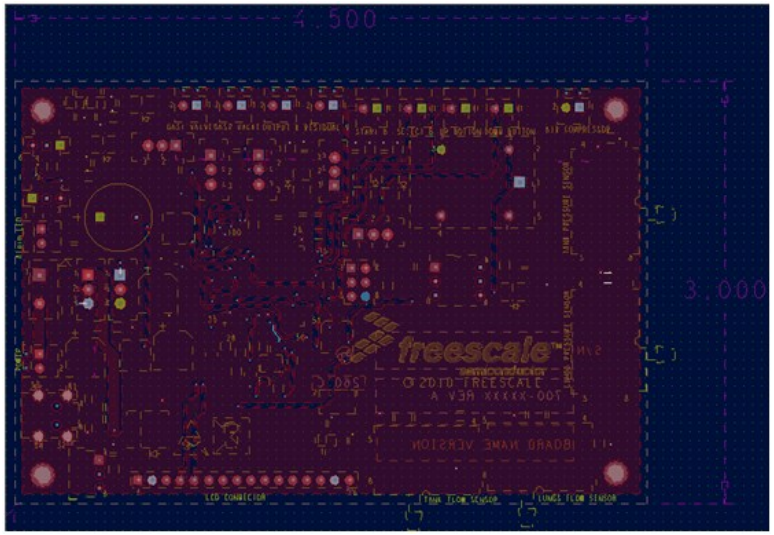
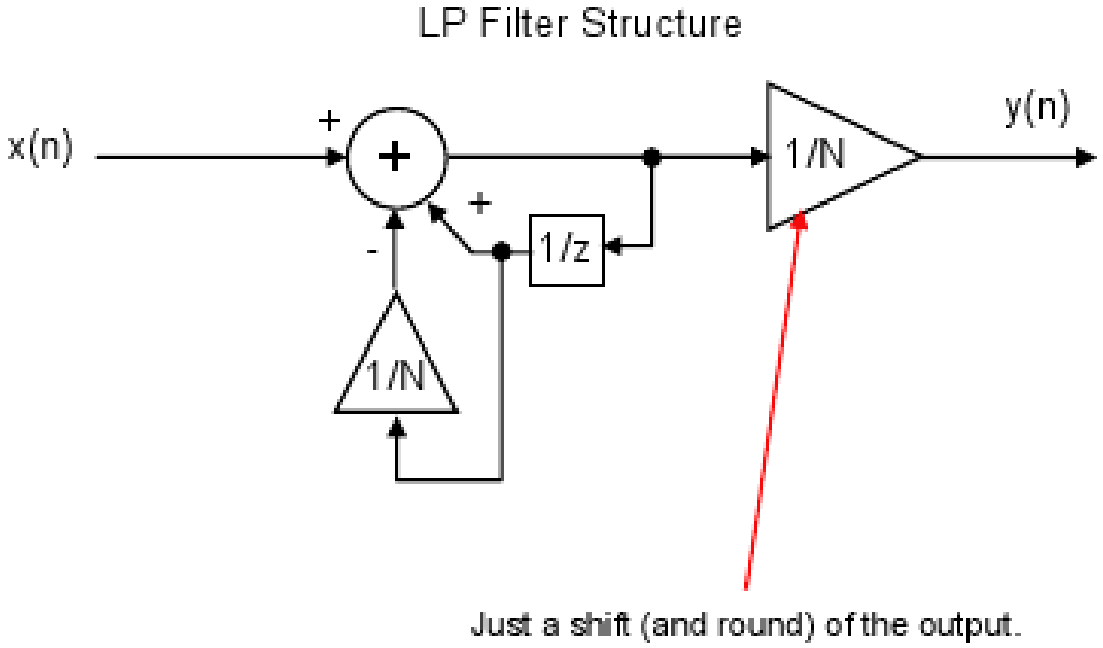

3.000
freescale

Populated Board

Sensor Processing



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