EECS192 Lecture 4
Velocity and Line Sensor I
Feb. 11, 2020

Notes:
Check off-
- 2/14: Motor drive/stall, steering servo using LiPo
- Quiz 2: power MOSFET/motor drive Tues 2/18

Topics
- Driving MOSFETs and motor (conclusion)
- Battery Model
- Power wiring
- Driving MOSFETs and motor (conclusion)
- Quiz 1
- Latchup gotcha
- Speed sensing
- Line sensor

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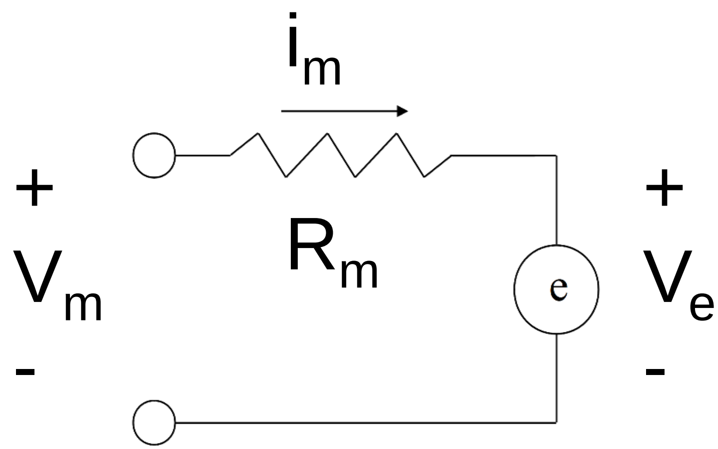
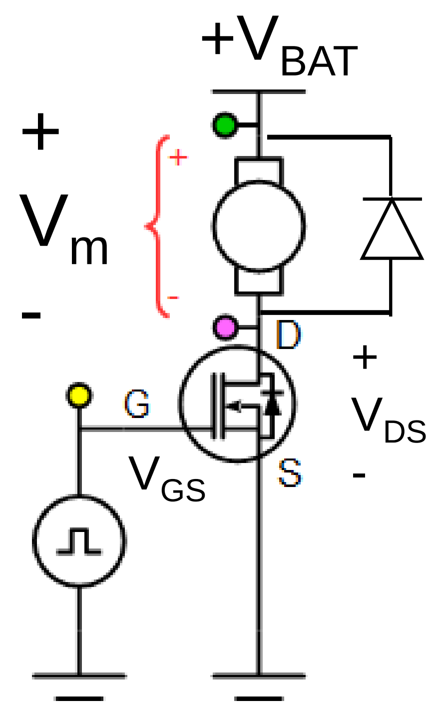
Motor Electrical Model



Motor Electrical Model
Back EMF
Motor electromechanical behavior

Also- see motor worksheet……



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

Motor Resistance?
Peak current?

Conclusion:
$\langle i_m \rangle = ?$

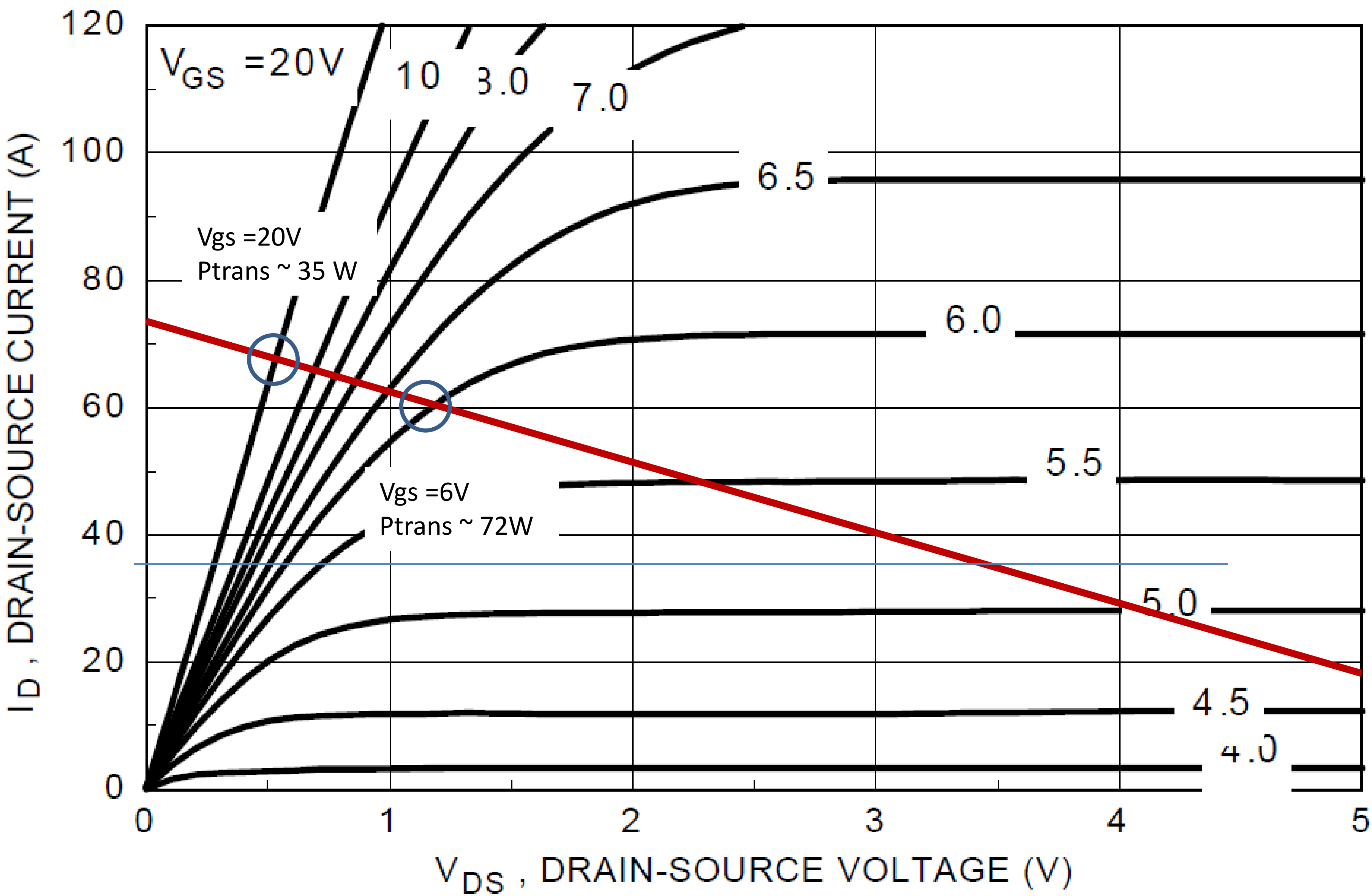
Driving MOSFETs and motor

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)



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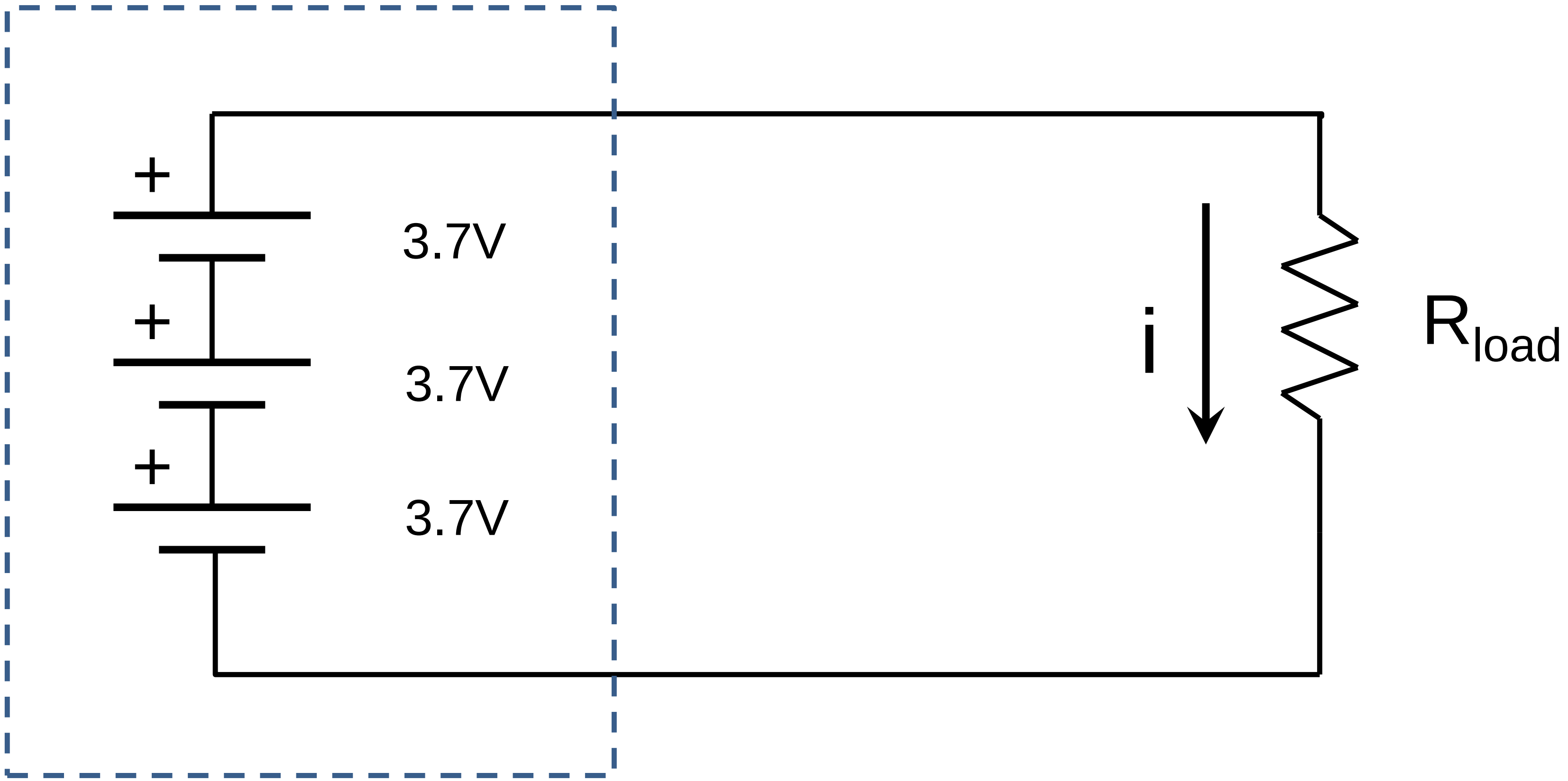
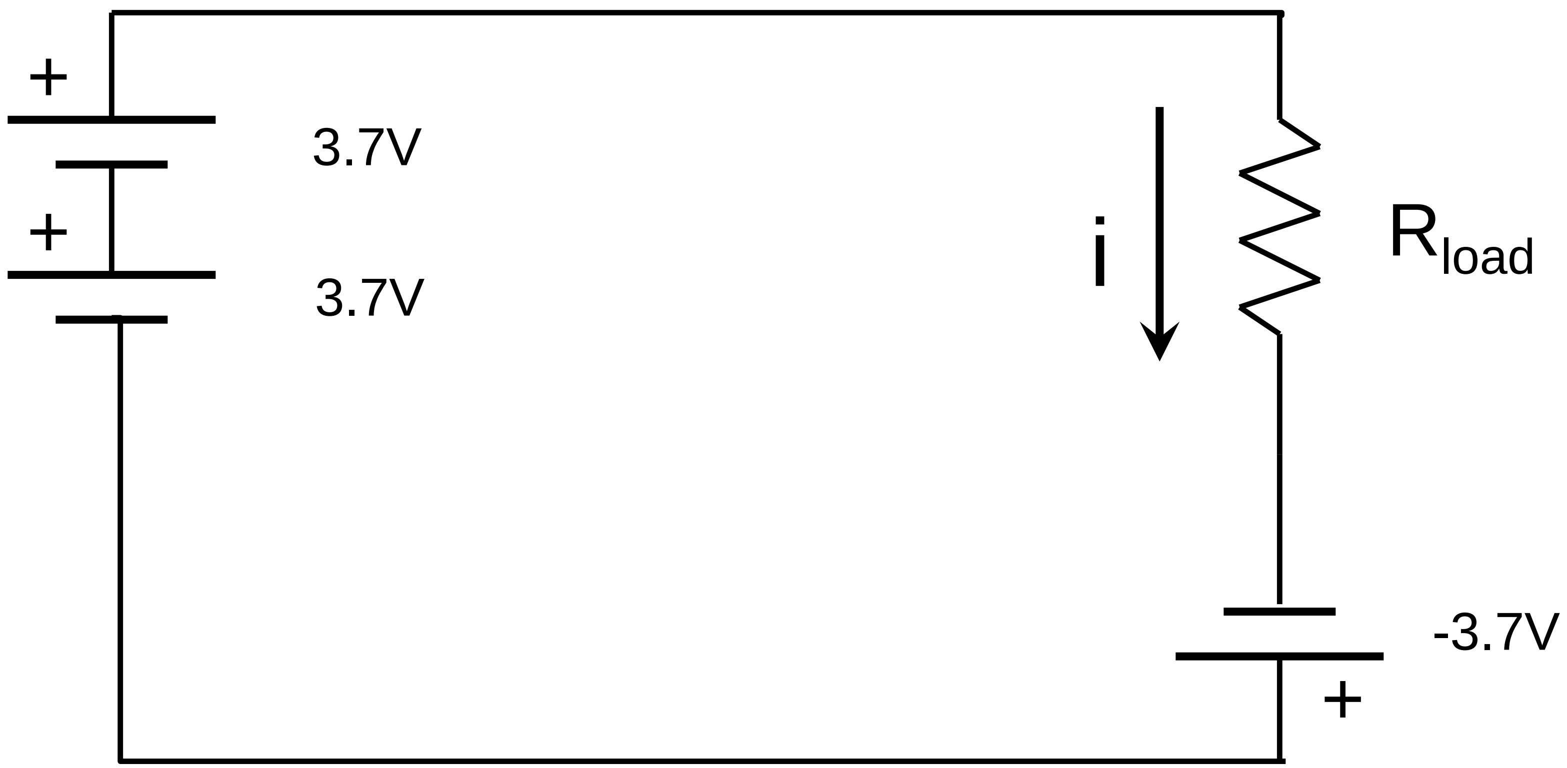
Battery Model- 3S



Battery Model- 3S
avoid weakly charged cell



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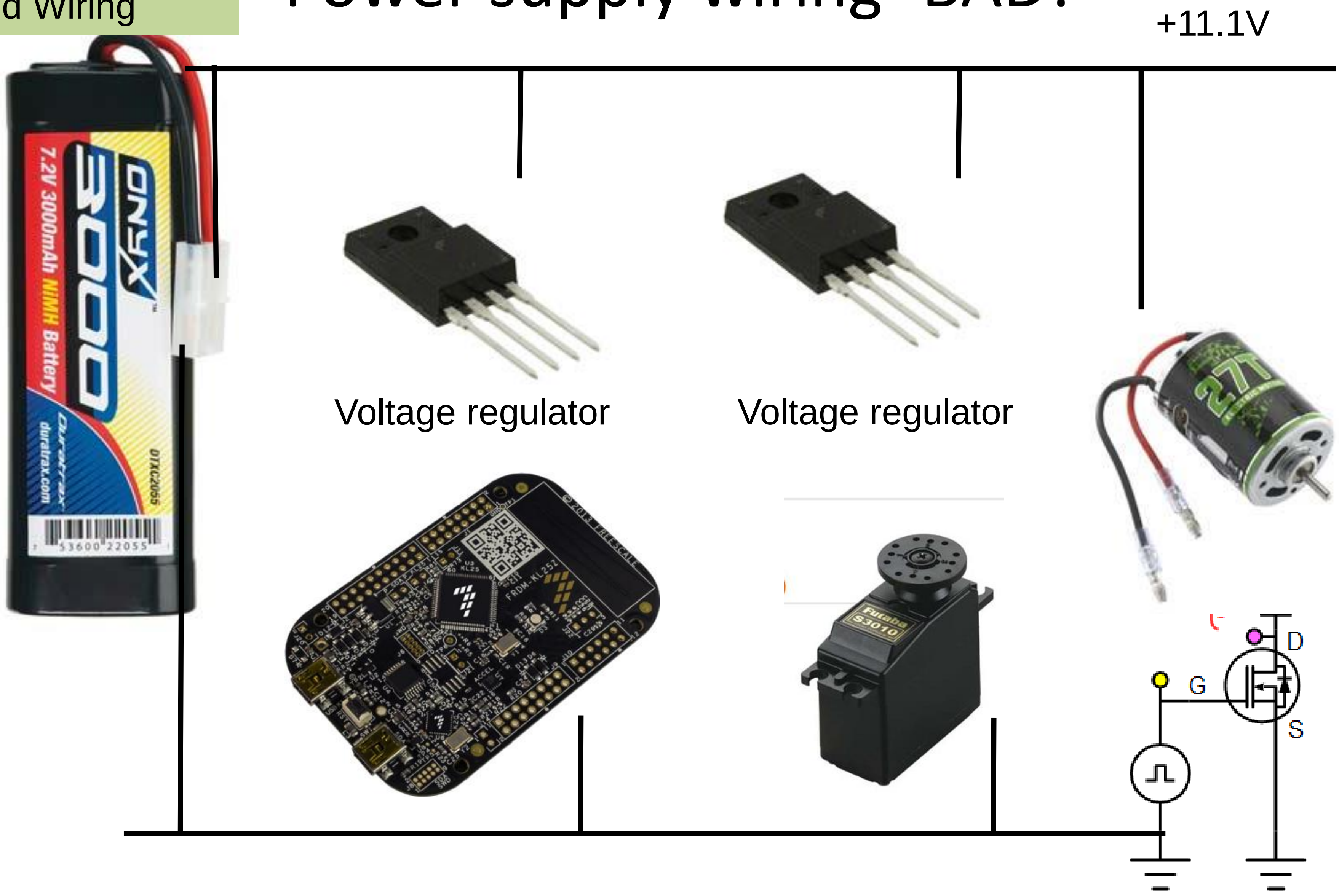
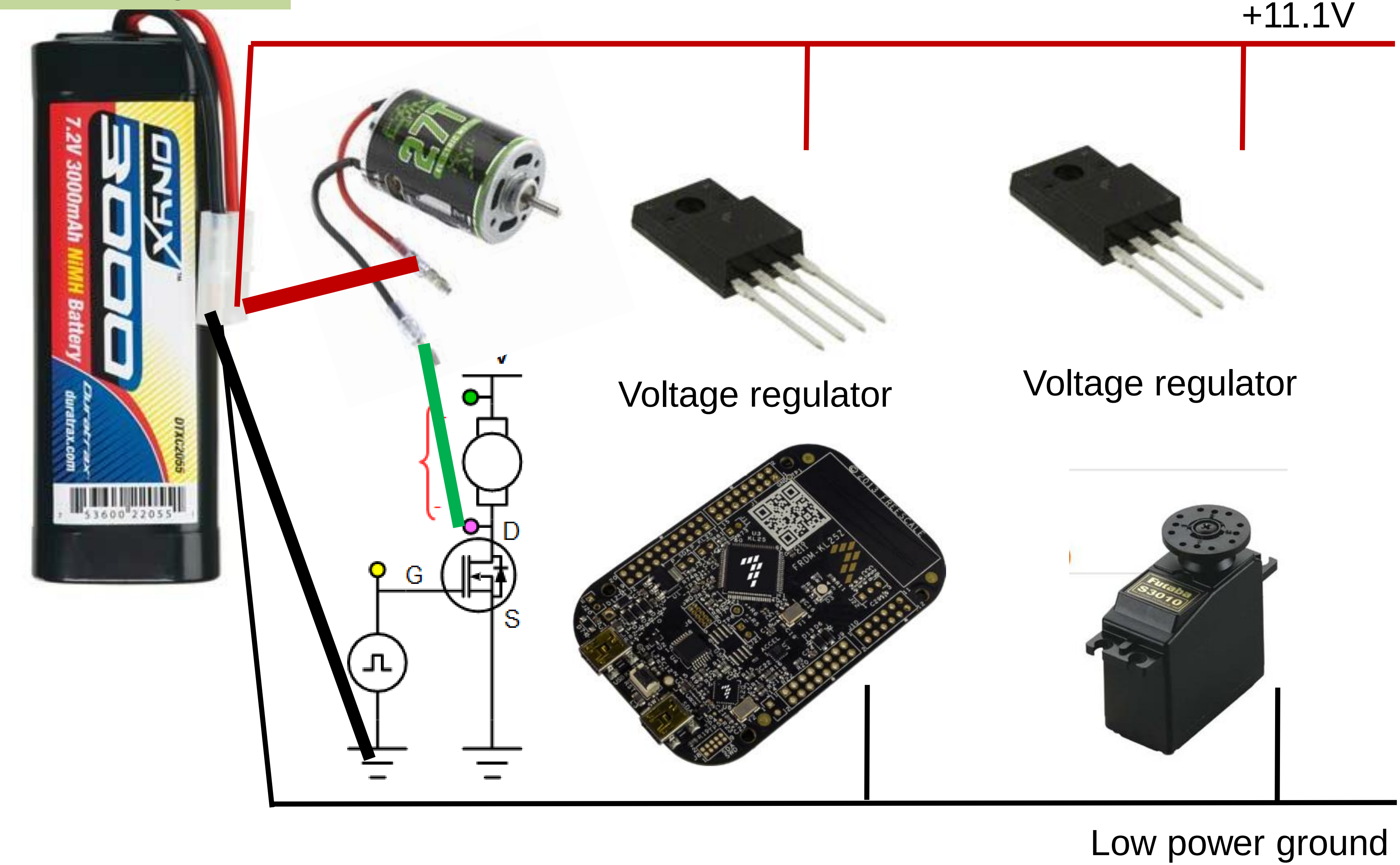
Power supply wiring- BAD!



On board: what does this look like electrically (as a schematic)?

Power supply wiring- Star is better!



On board: what does this look like electrically (as a schematic)?

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1.4 Voltage and current operating ratings

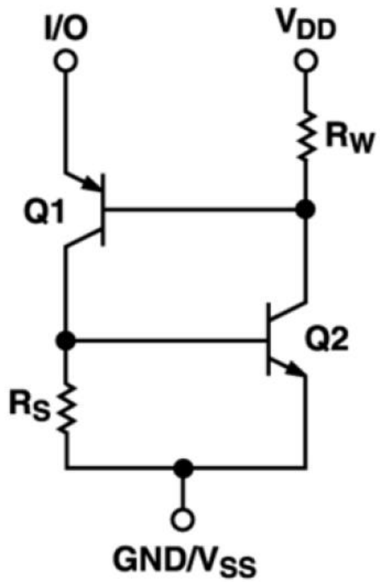
Table 4. Voltage and current operating ratings

LATCHUP!

Symbol	Description	Min.	Max.	Unit
V_{DD}	Digital supply voltage	–0.3	3.8	V
I_{DD}	Digital supply current		1[illegible]0	mA
V_{IO}	IO pin input voltage	–0.3	V_{DD} + 0.3	V

Caution: input voltage from sensor may be greater than 0.3V when CPU is off
VDD = 0!

Latchup phenomena:
make sure Vin always less than Vdd



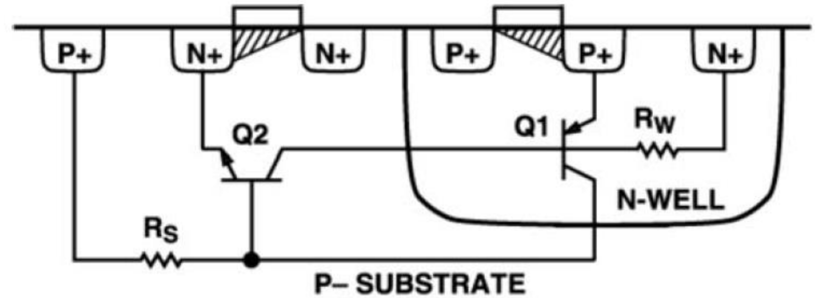
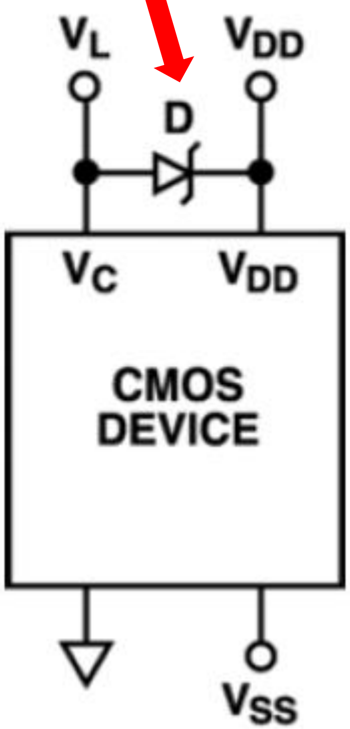


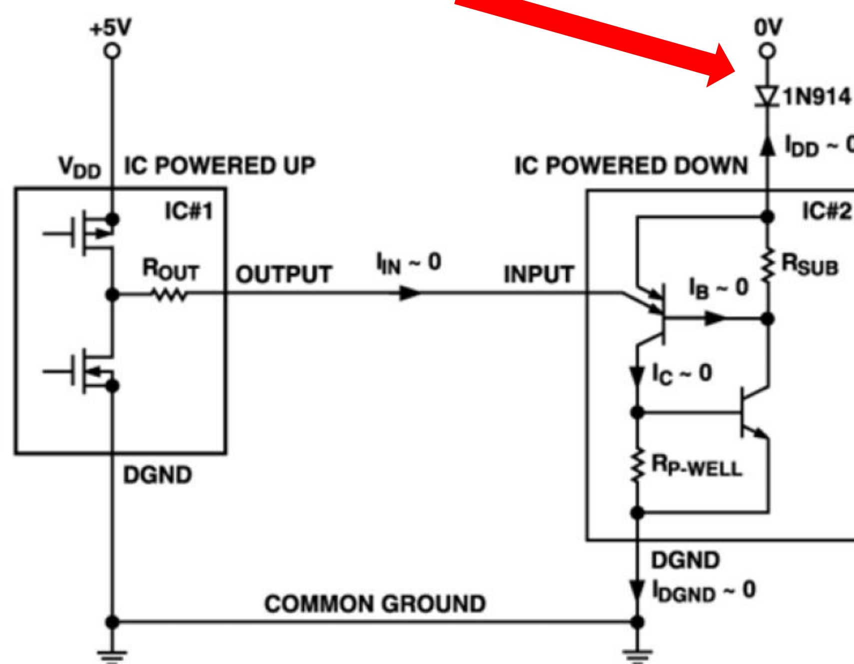
Figure 2. Cross-section of PMOS and NMOS devices, showing parasitic transistors Q1 and Q2.

Protection circuit



Schottky diode

Protection circuit



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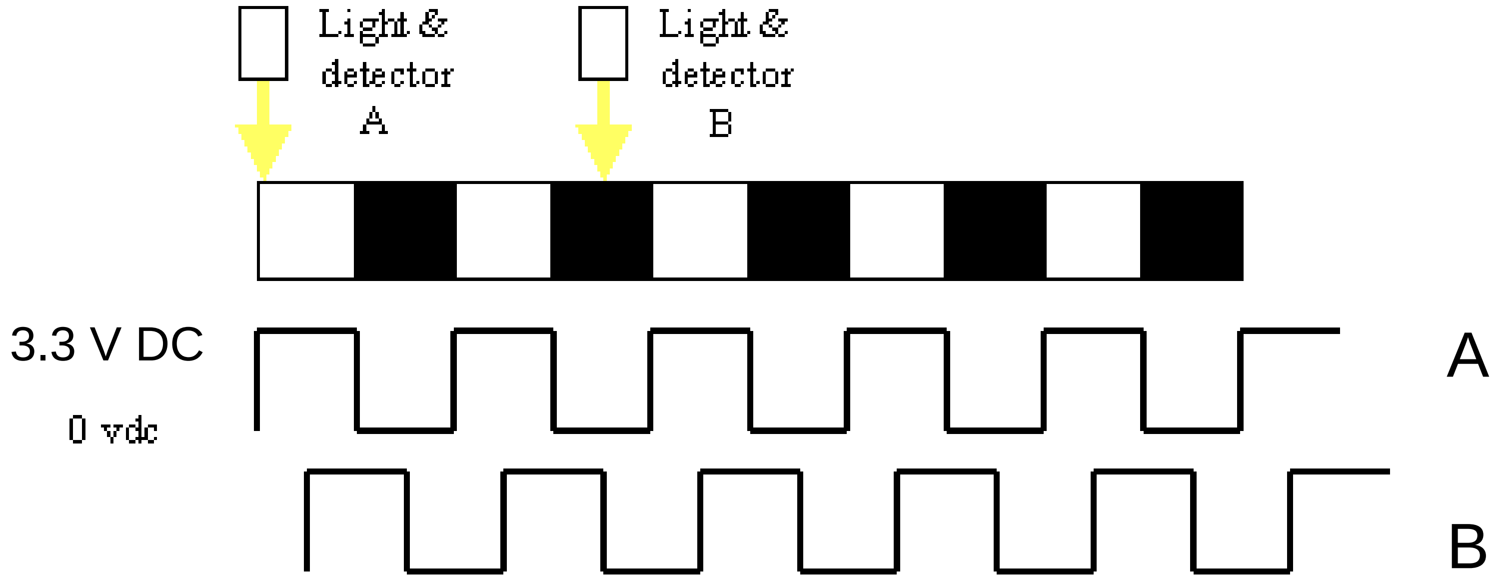
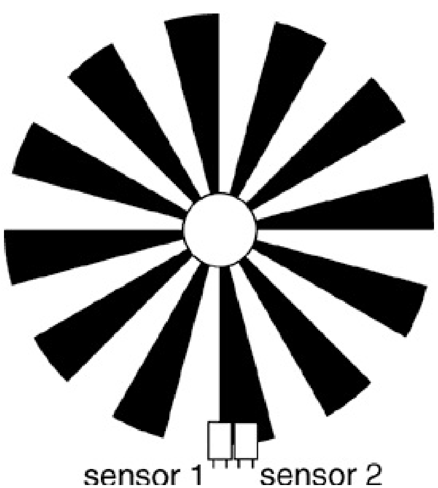
Quadrature Encoder



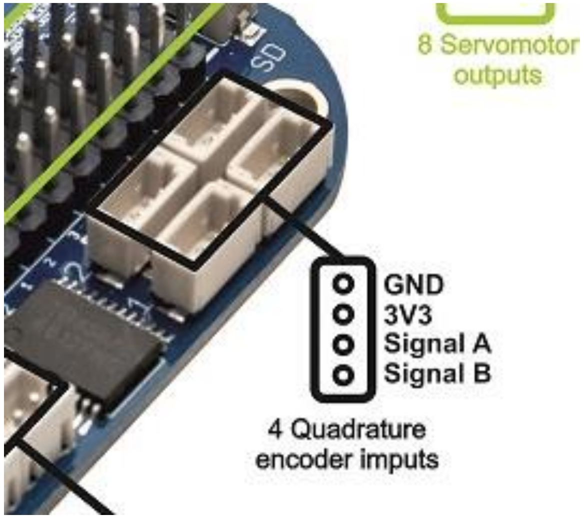
https://www.sinotech.com/wp-content/uploads/quadrature-encoder.gif



Fab suggestion: aluminum foil covered with black paper with slots. 4 slots probably enough. Note: sensors can be placed where convenient- don’t need to look at same slot.

http://codeforfree.weebly.com/uploads/1/0/1/6/10160088/5858962_orig.png

Beagle Bone Blue Quad Encoder




```
int rc_encoder_read  (int ch)
```

Returns
The current position (signed 32-bit integer)
or -1 and prints an error message is there is a problem.
Ch 1-3 are available
Examples:
rc_test_encoders.c.

Sharp GPS260

Fig.9 Test Circuit for Response Time

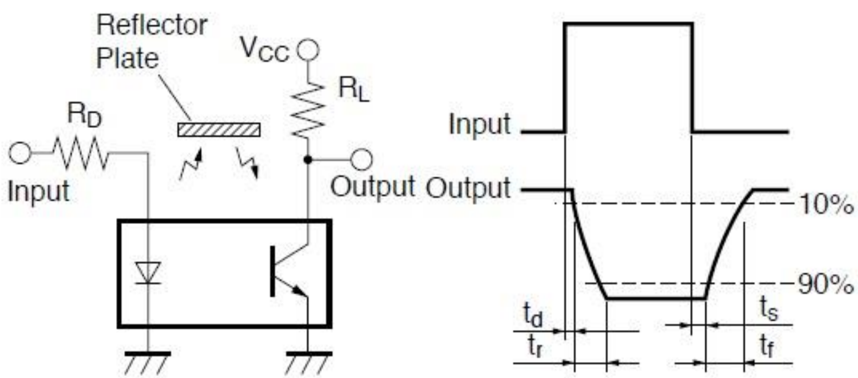
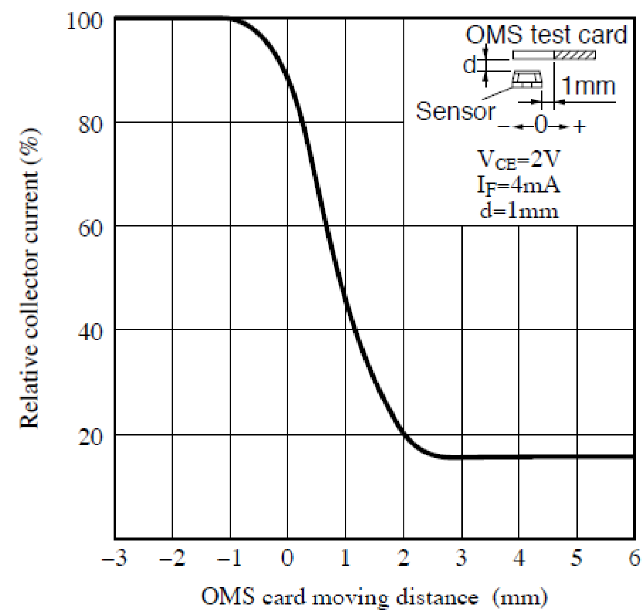
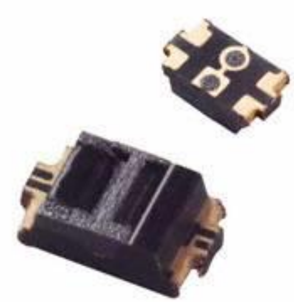


Fig.13 Detecting Position Characteristics (2)



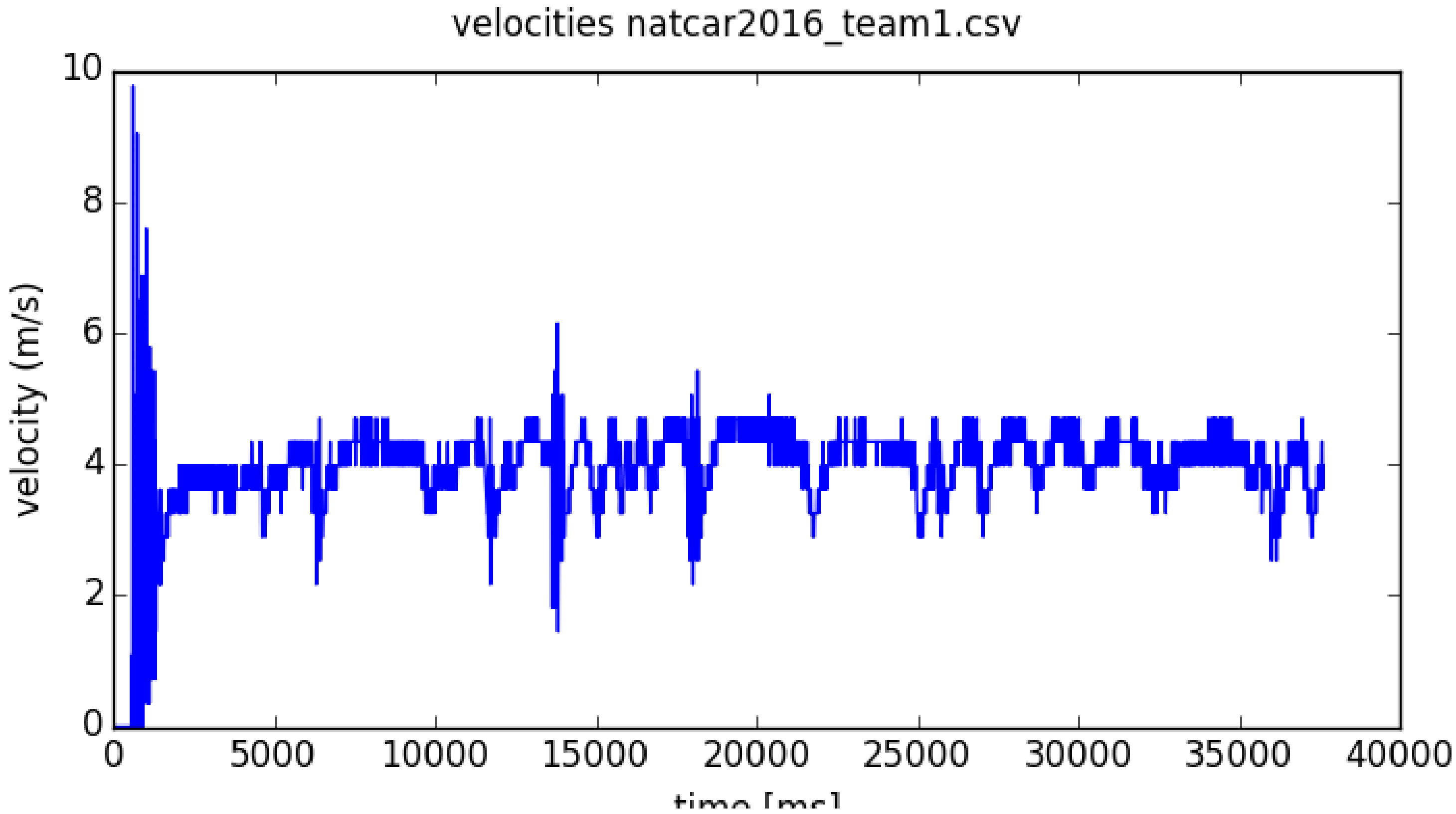
- Choose current 4 mA in LED
- Vcc = 3.3 V
- May want regulated/clean voltage for Vcc



100 us response time

Velocity Sensing

- On board: estimating $\Delta x/\Delta T$



Note: care about velocity sensing usually at cruise speed (also stopping)

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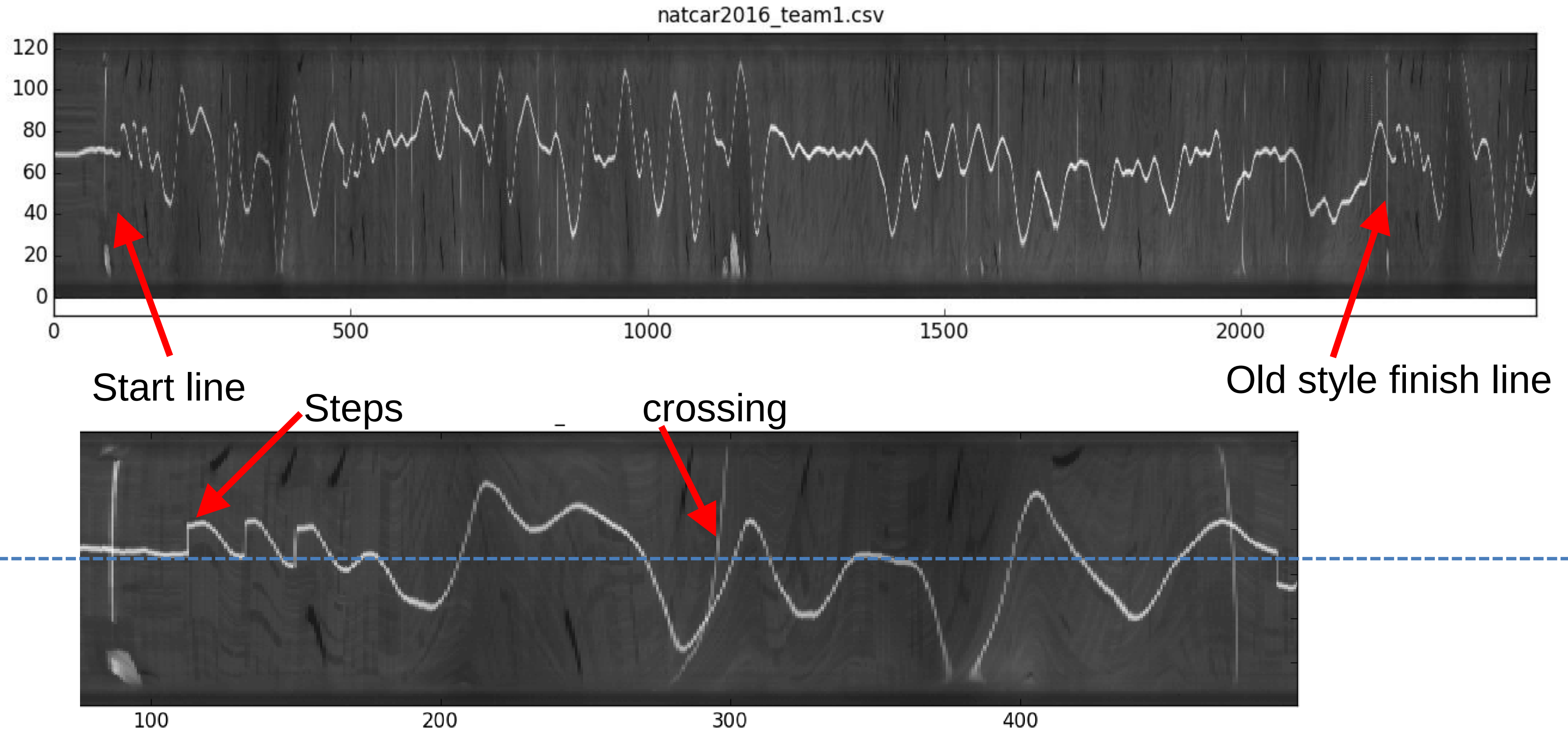
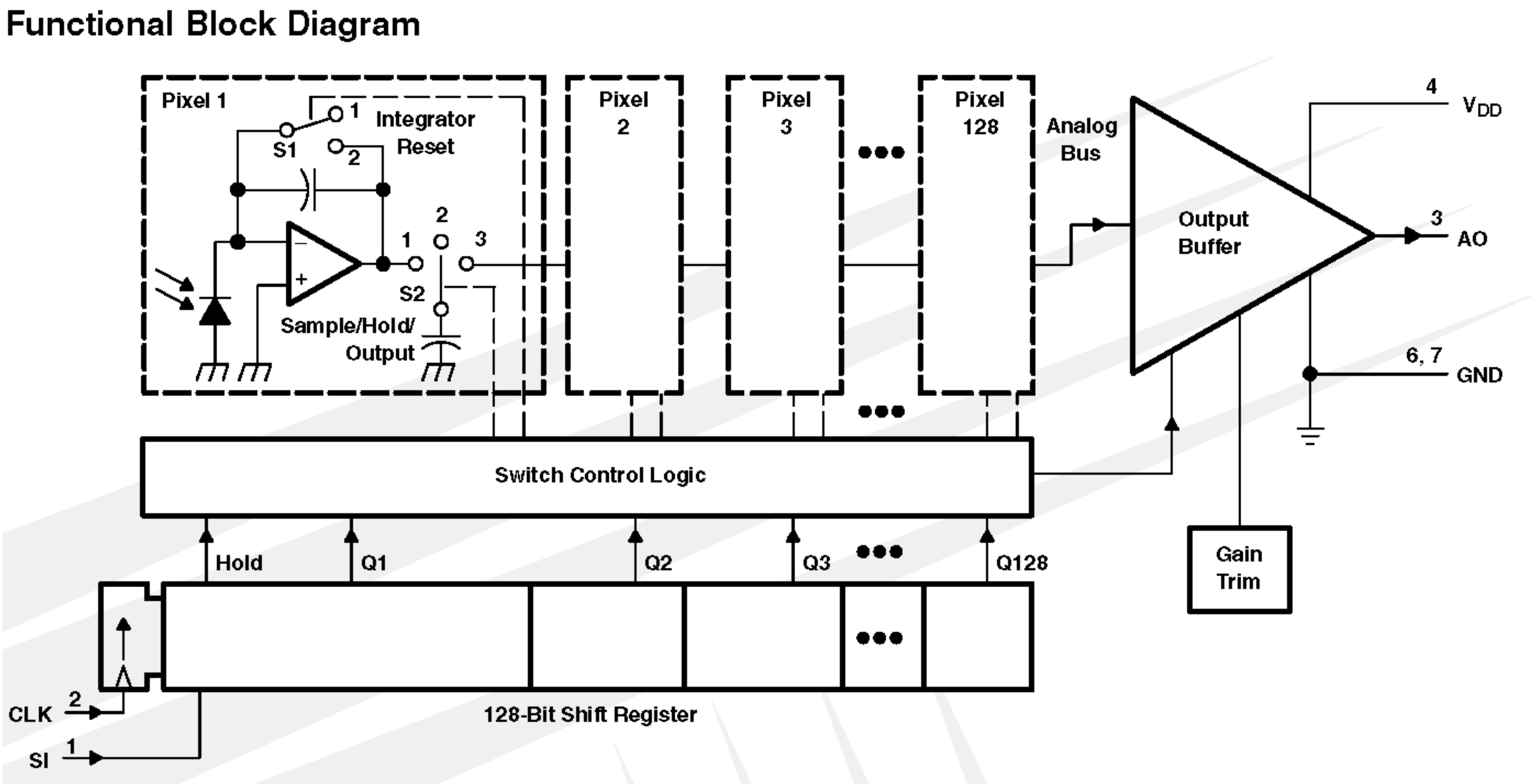
Example Line camera data



TSL 1401 line sensor



TSL 1401 line sensor

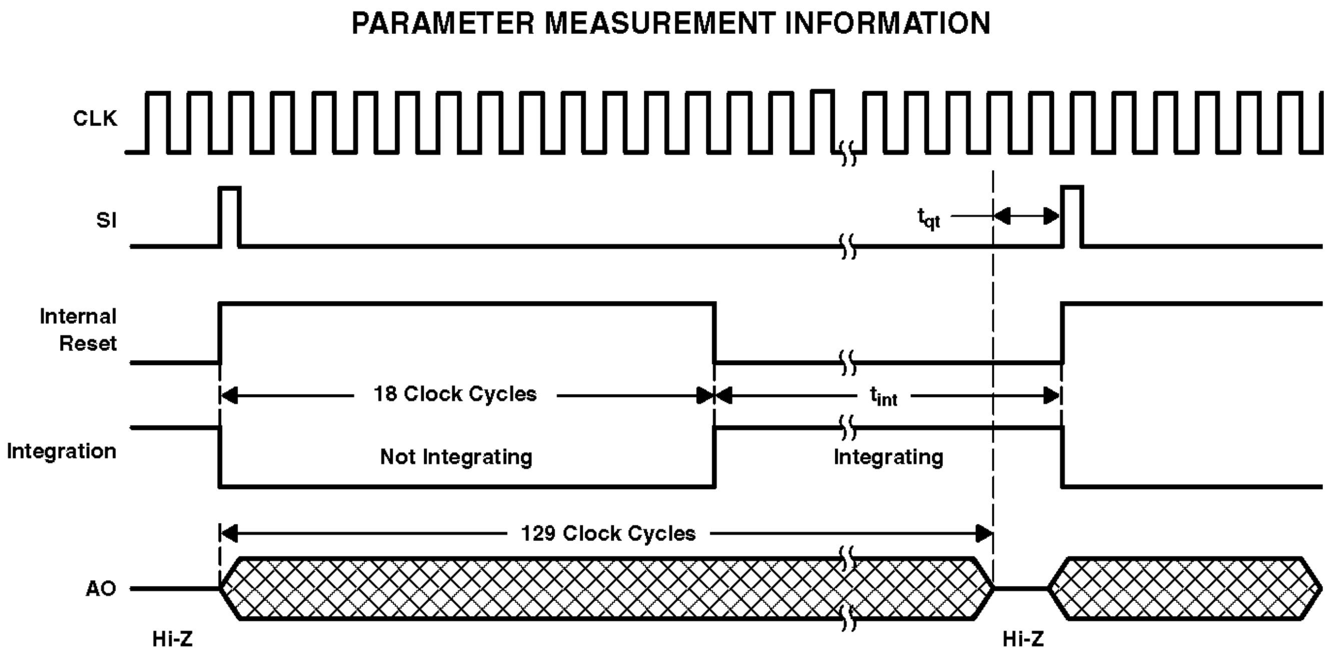


Figure 1. Timing Waveforms

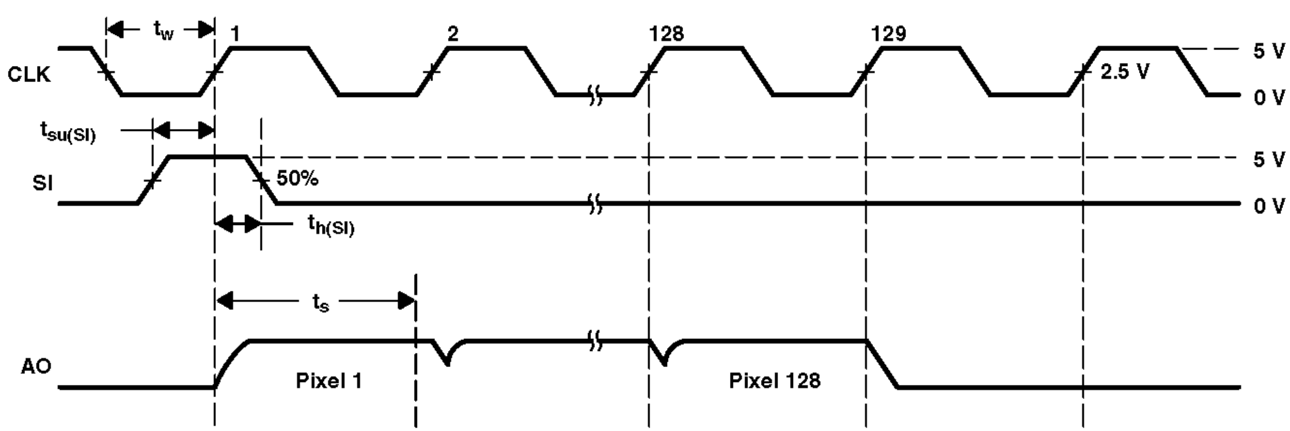


Figure 2. Operational Waveforms

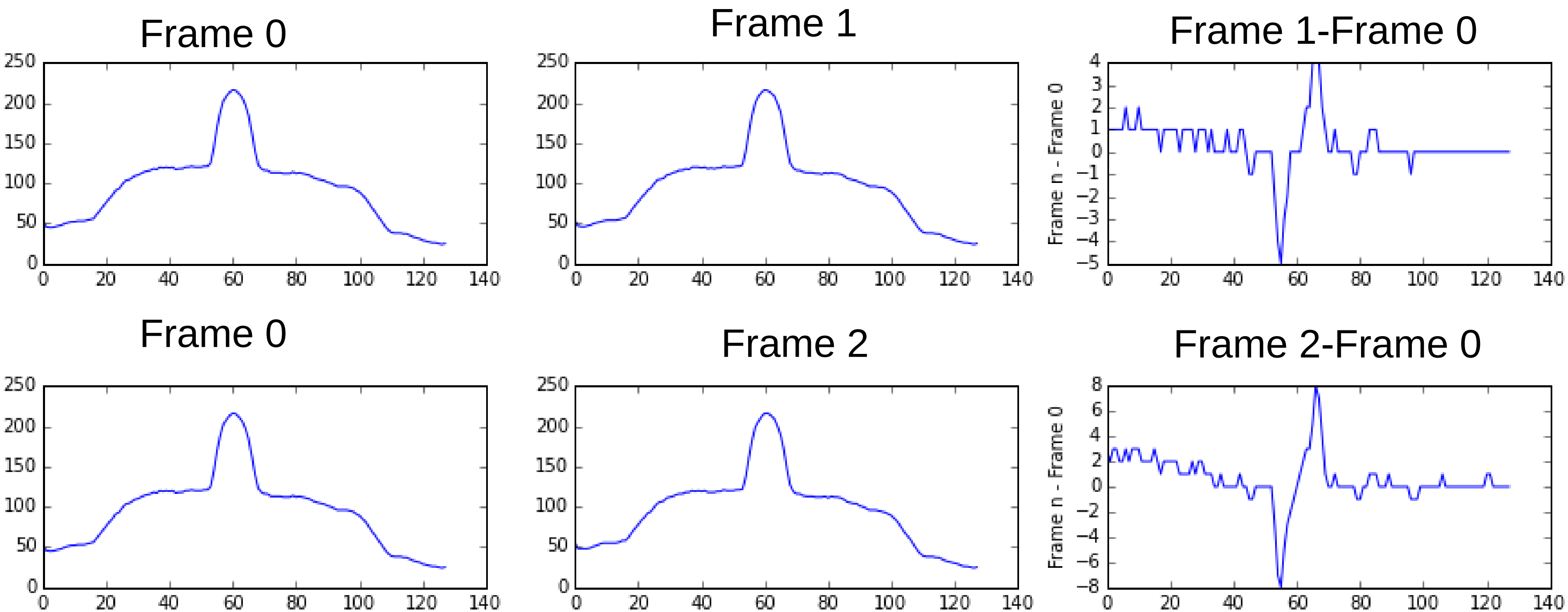
Line sensor

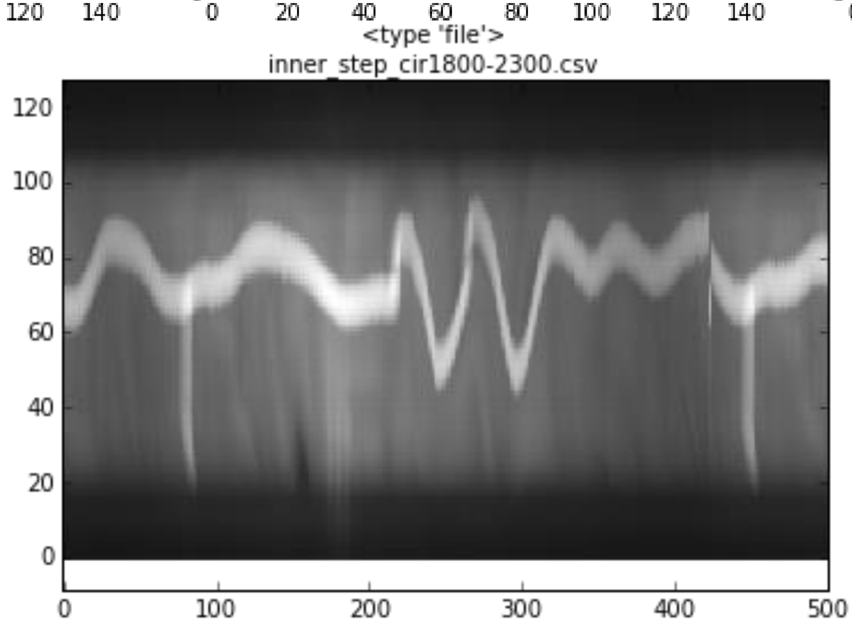
Possible algorithms for line detection

e.g. scipy.signal.filter

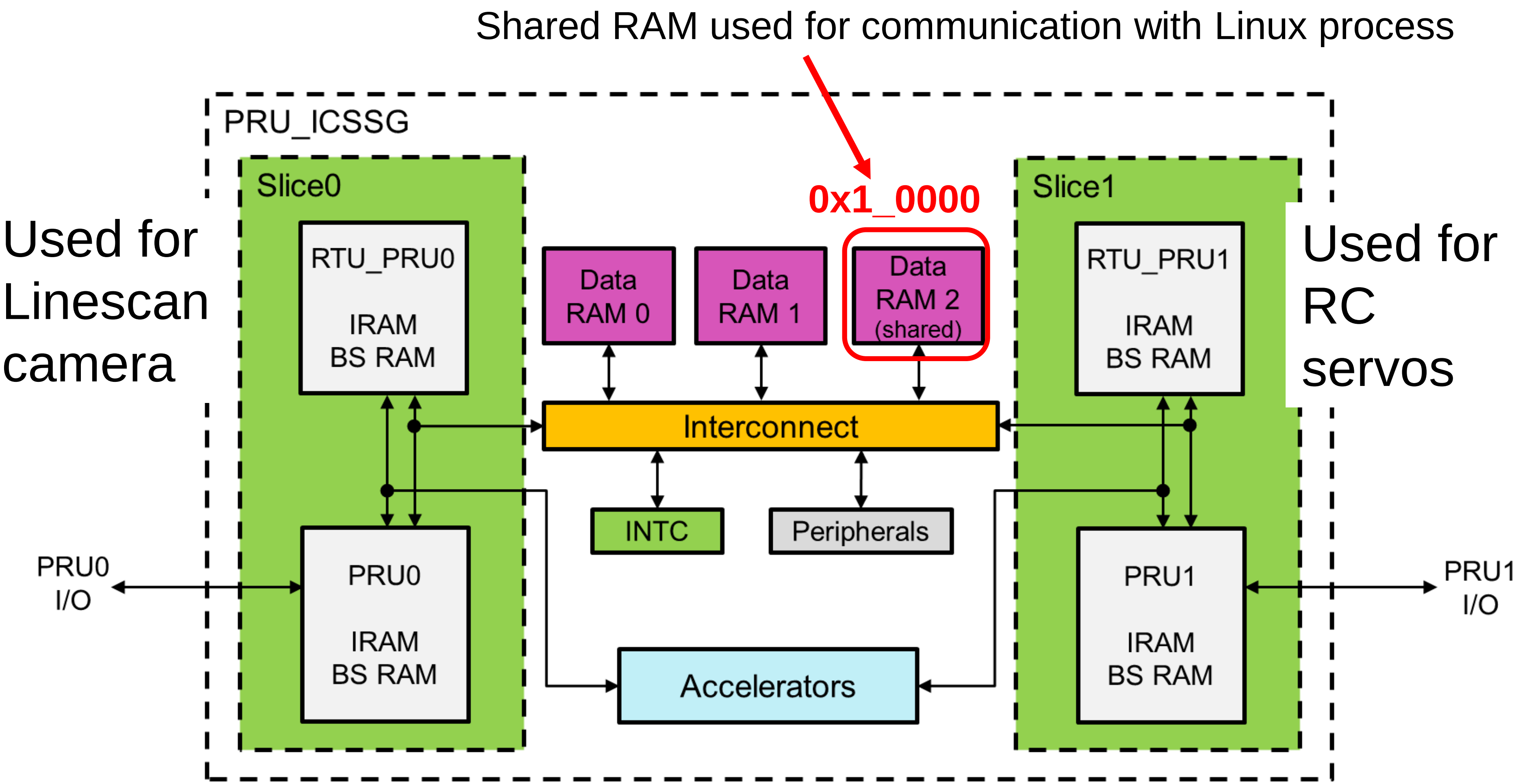
- Subtraction- to find left and right edge of line (ok if not noisy, somewhat lighting invariant)
- Difference of gaussians (idea is to smooth then differentiate)
- Correlation (best match position for known features)
  - scipy.signal.correlate

TSL 1401 line sensor NATCAR 8 bit





Programmable Real-time Unit (PRU)



Used on BeagleBone Blue
PRU1: RC servo
PRU0: real-time A/D for line camera (was originally used for quad encoder Ch4)

Shared 12 kb Address Space

PRU0		**LINUX**
0x1_0000	For encoder	`rc_pru_shared_mem_ptr();`
	Flag = 1 to start conversion	`shared_mem_32bit_ptr[16+1]`
	Pixel 0	`shared_mem_32bit_ptr[16+2]`
	…	
	Pixel 127	`shared_mem_32bit_ptr[16+2+127]`

Linux LineCamera.c line 116:

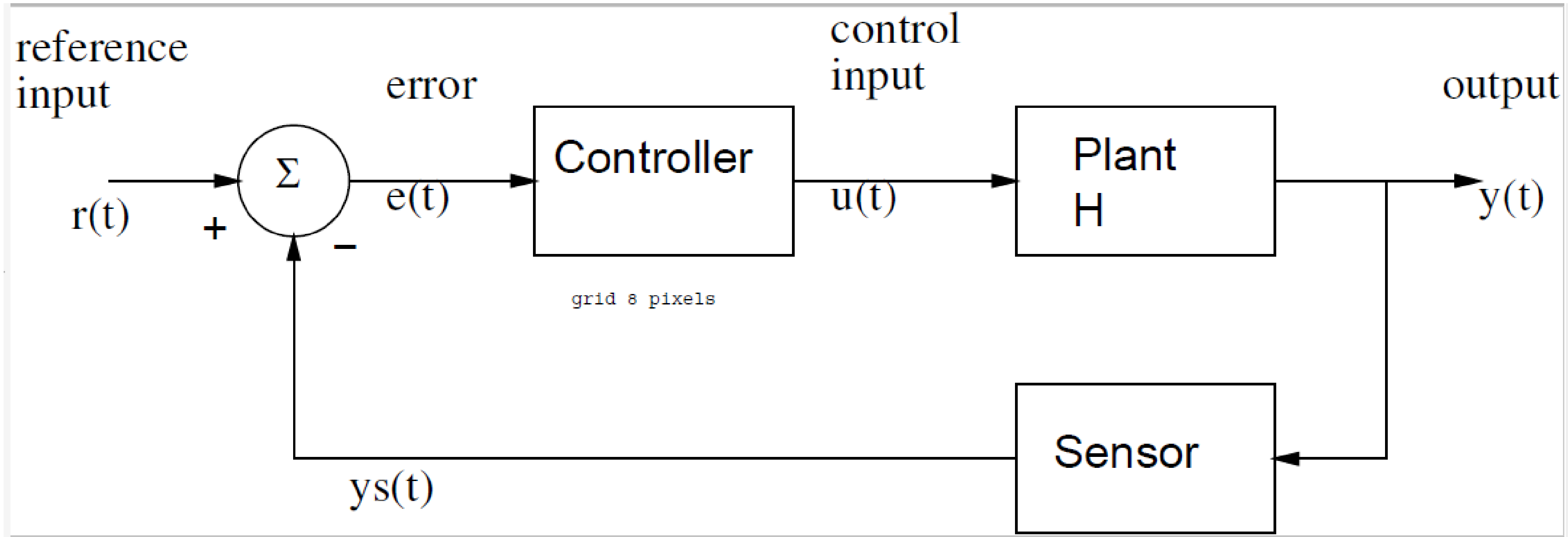
```
shared_mem_32bit_ptr[ENCODER_MEM_OFFSET+1] = 1;
// set flag to start conversion by PRU
while(shared_mem_32bit_ptr[ENCODER_MEM_OFFSET+1] == 1);
```

PRU main_pru0.c line 117:

```
while(shared_mem_32bit_ptr[ENCODER_MEM_OFFSET+1] == 0);
// loop until command
//… read 128 pixels …
shared_mem_32bit_ptr[ENCODER_MEM_OFFSET+1] = 0;
// reset to zero
```

Extra Slides

Velocity control overview



On board…

Proportional control:

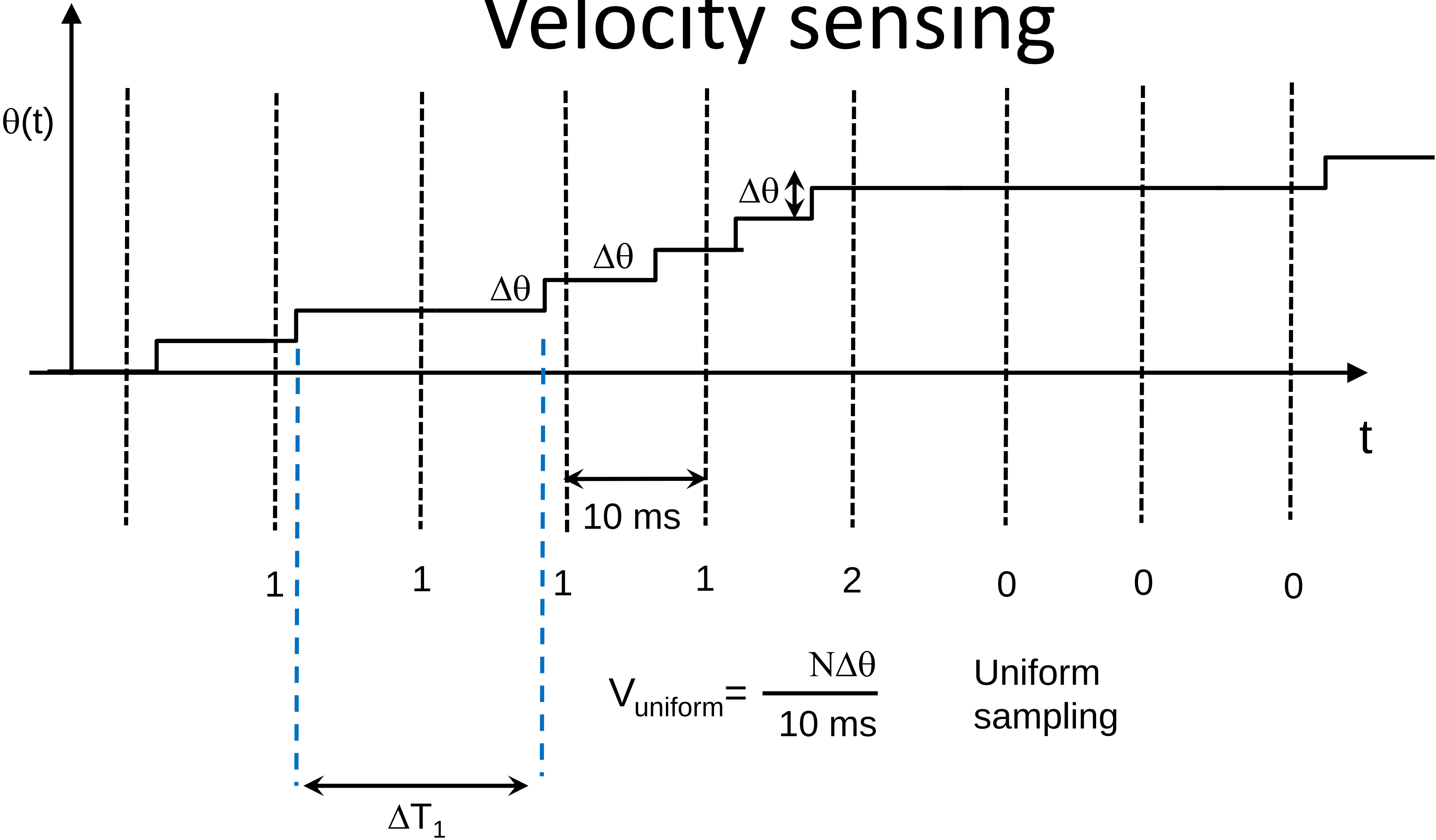
U = kp*e = kp* (r-y);

Here: r is desired velocity, U is PWM %

Proportional + integral control

```
U = kp*e + ki * e_sum;
e_sum = e_sum + e;
```

Velocity sensing



$$V_{uniform} = \frac{N\Delta\theta}{10\text{ ms}}$$

Uniform sampling

$$V_{edge} = \frac{\Delta\theta}{\Delta T_1}$$

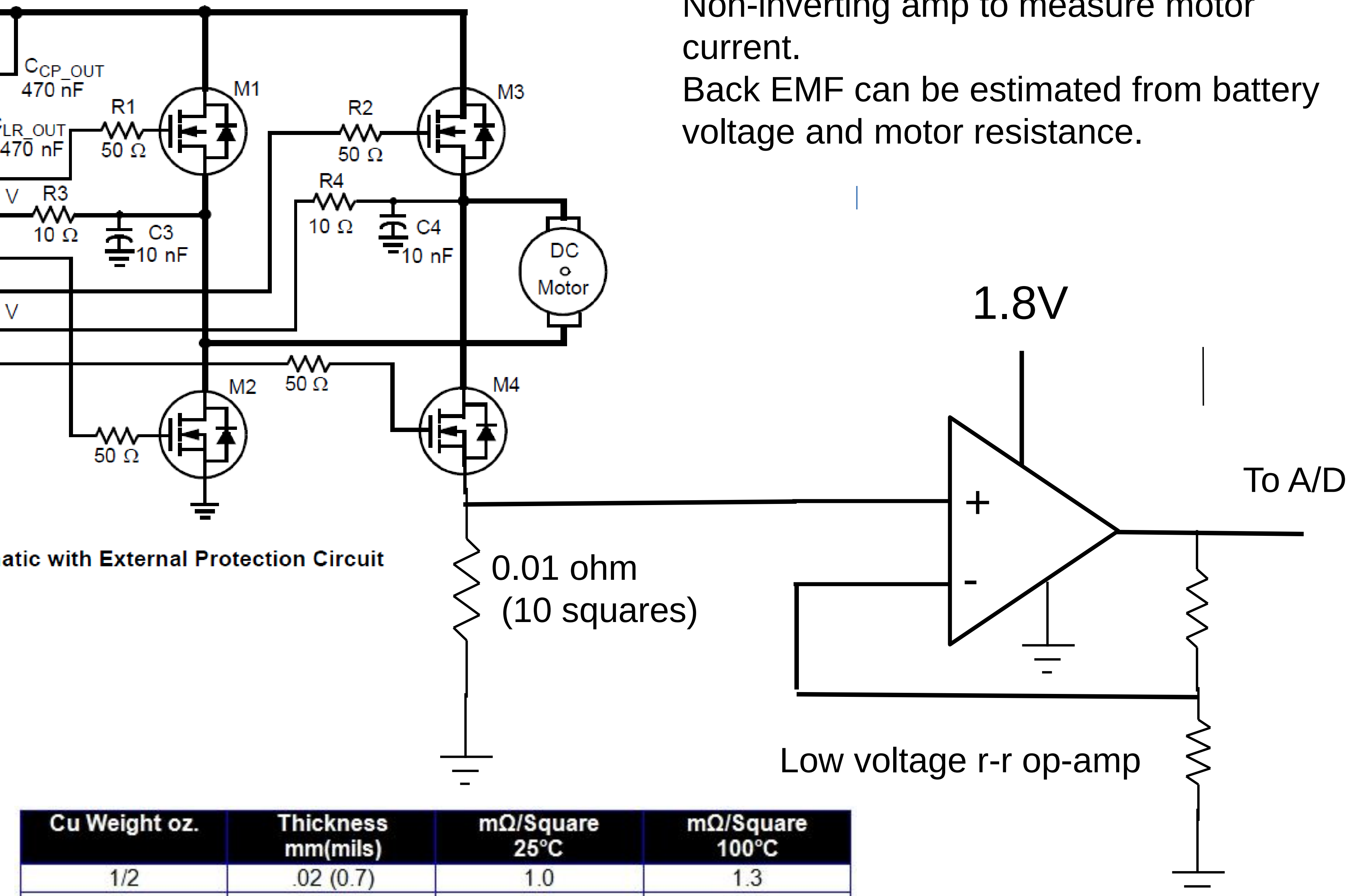
Edge timing

Velocity sensing (recap)

V~ (change in angle)/(change in time)

On board…

Non-inverting amp to measure motor current.
Back EMF can be estimated from battery voltage and motor resistance.

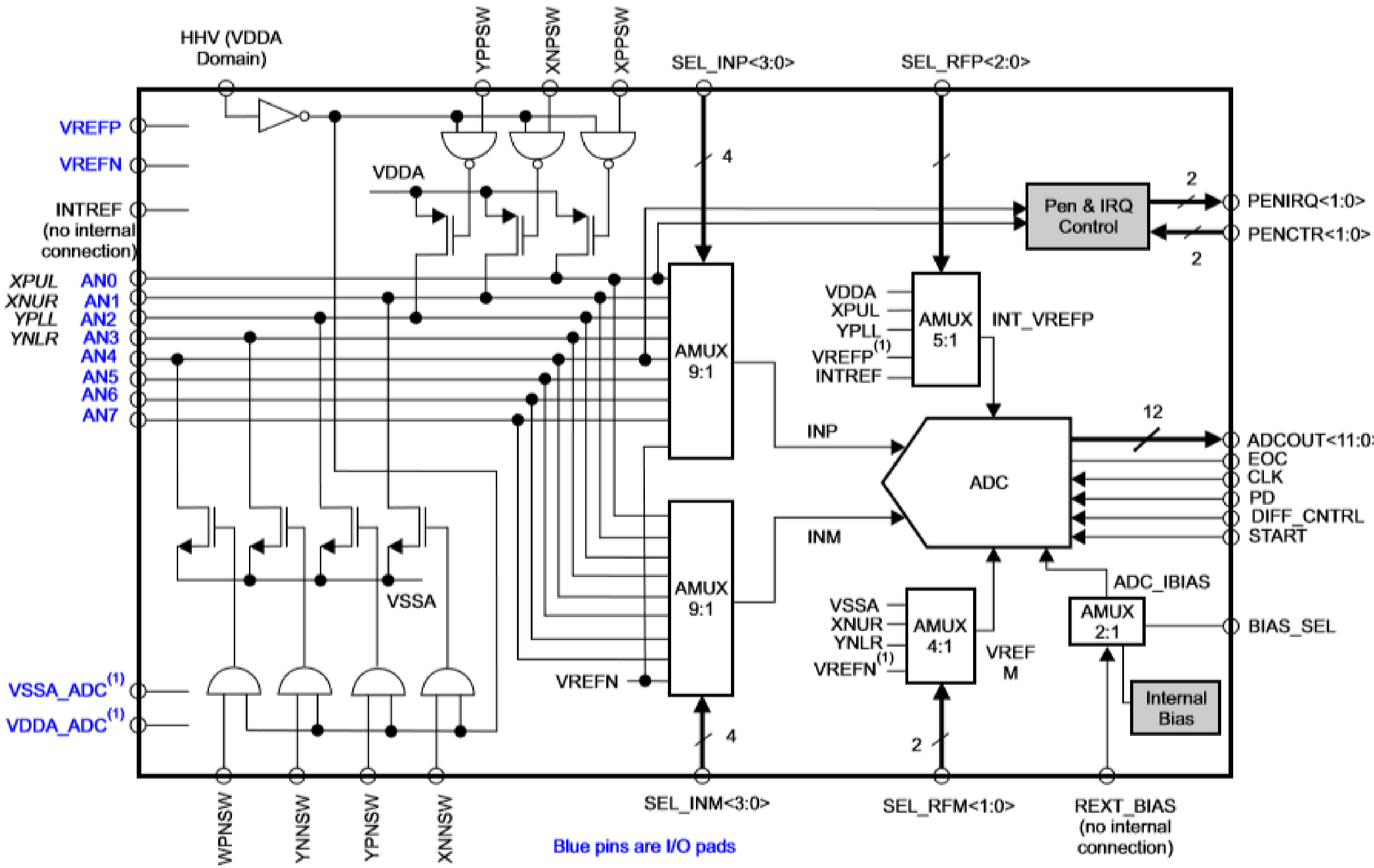


Cu Weight oz.	Thickness mm(mils)	mΩ/Square 25°C	mΩ/Square 100°C
1/2	.02 (0.7)	1.0	1.3
1	.04 (1.4)	0.5	0.65

Back EMF velocity sensing

Analog/Digital Overview

Figure 12-2. Functional Block Diagram



(1) In the device-specific datasheet:

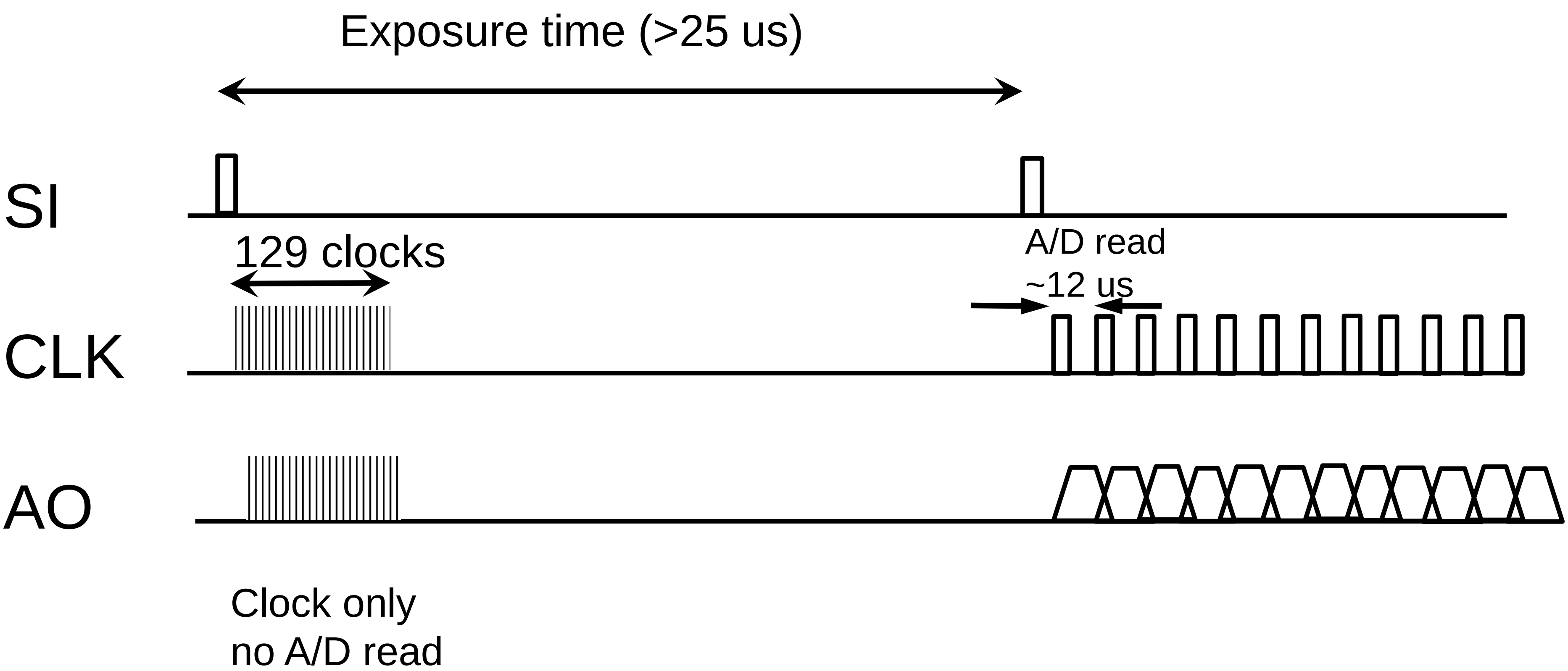
- VDDA_ADC and VSSA_ADC are referred to as "Internal References"
- VREFP and VREFN are referred to as "External References"

Caution: 1.8V MAXIMUM

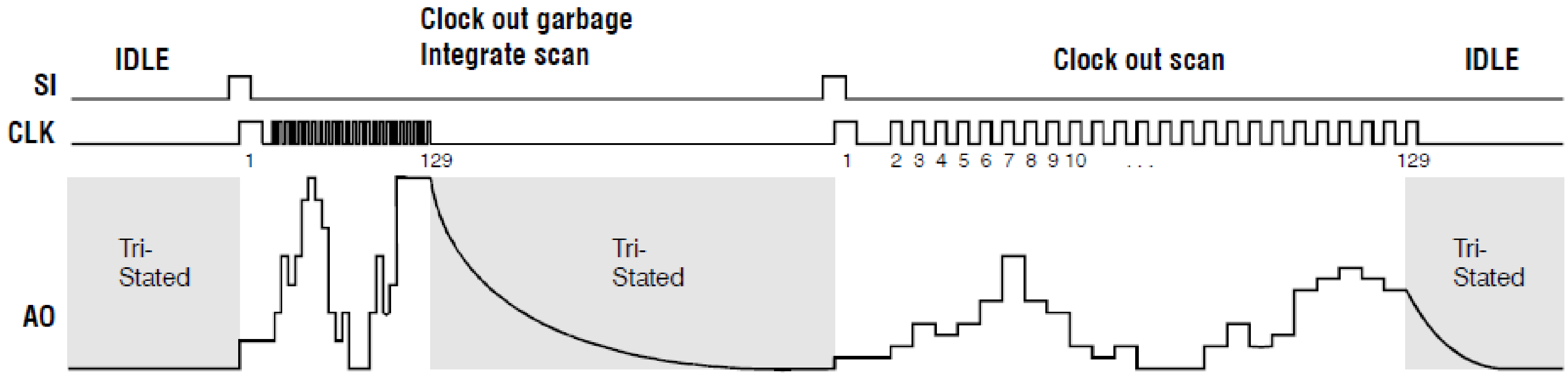
Note: lots of sequencing/delays.

Set up in PRU0 to read 128 elements at ~8 us/sample.

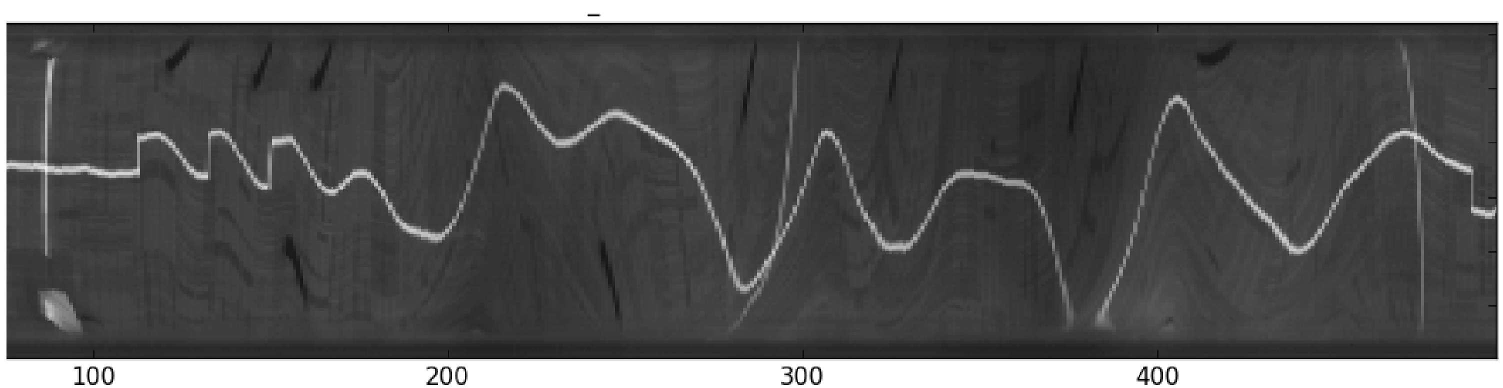
TSL 1401 line sensor- option exposure control
(would need to modify PRU code)

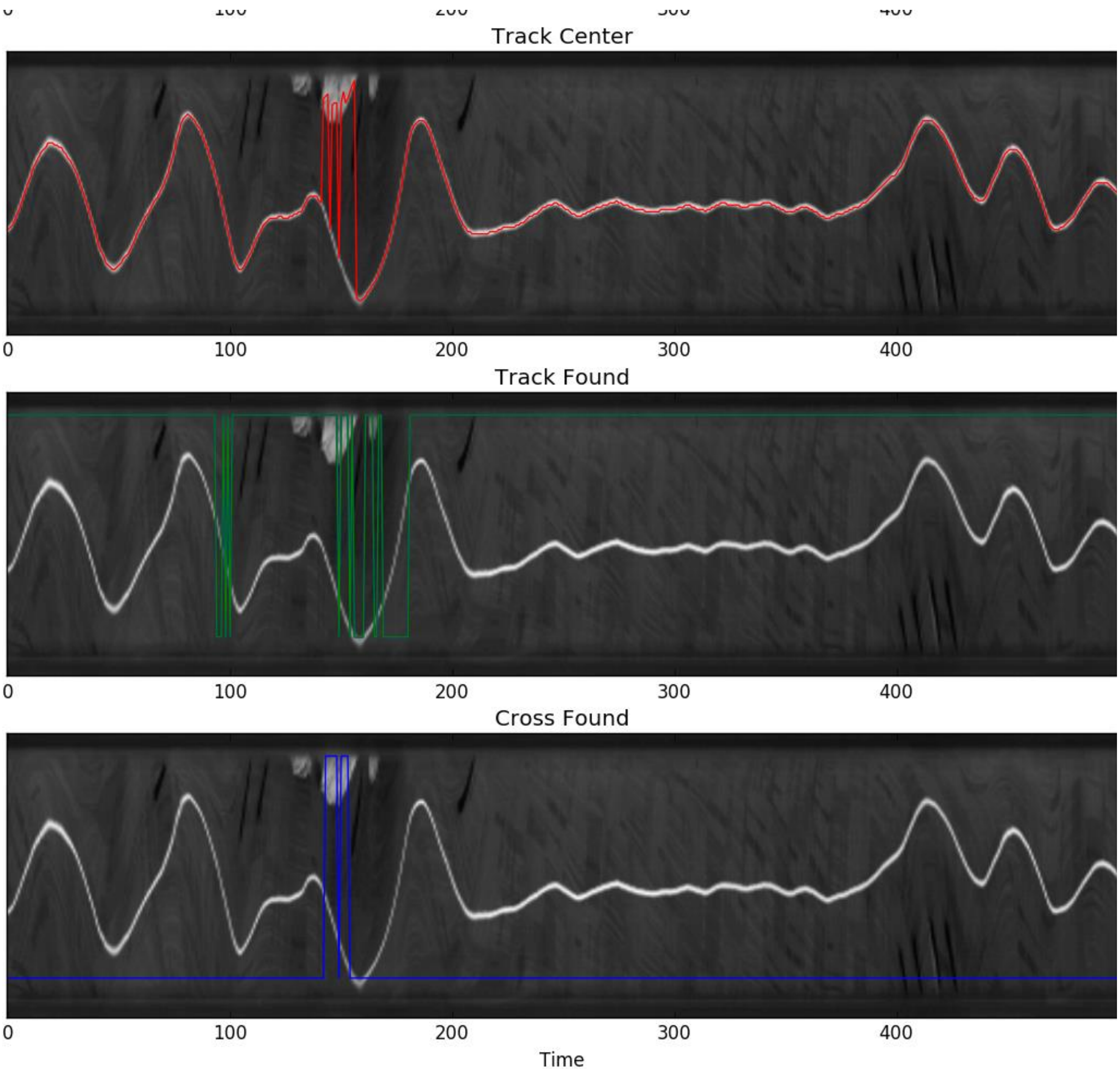


Automatic Gain Control



In all the discussion that follows, we will be using one-shot imaging.




0
100
200
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Track Center
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Track Found
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Cross Found
0
100
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400
Time