EE 16B fall 2016
Final Project

SIXT33N Project: Written Report

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Circuit:

Final Design: (Refer to figure 1 for more details)

1. V+ into mic board at 2.2-2.4V.
2. We pass the signal from the mic board (V_{mic}) through a second order low pass filter consisting of 2 RC circuits separated by a buffer to prevent decoupling. Frequency response stage needed to prevent aliasing since Launchpad samples every 0.35 ms.
3. Output from filter (V_{filter}) goes through gain stage (noninverting op amp). We offset output from mic with a bias from a potential divider consisting of two 51k ohm resistors and a potentiometer to center signal around 1.6V since Launchpad only takes 0-3.3 (see diagram). Potential divider stage connected to negative terminal of op amp. Buffer connected to output from potential divider stage to prevent feedback current (see figure 1).
4. Final buffer stage connected to output of gain stage to prevent damage to MSP pins.

Gain and Frequency Response:

1. Cutoff frequency of filter at 1.59 kHz (approximated to 1.5 kHz), with R = 1 kΩ, C = 0.1µF. See figure 1 for transfer function.
2. Gain stage has gain of 1.5, with R_1 = 2 kΩ, R_2 = 1kΩ. See figure 1 for gain function.

PCA Classification:

Commands:

1. Words:
   a. Orange: Forward (fast)
   b. Port: Forward (slow)
   c. Expert: Left
   d. Taco: Right

2. Figures:

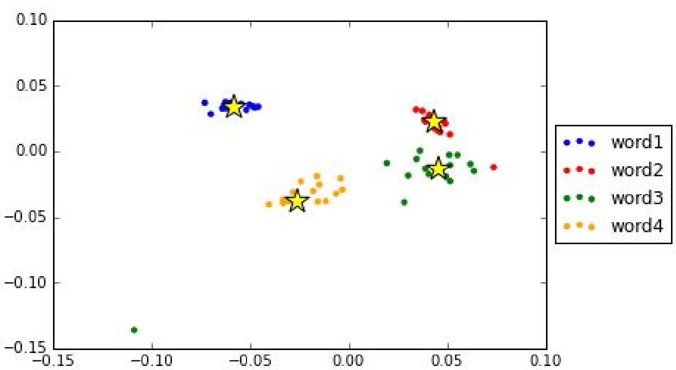

Fig. 6: The scatter plot of the measured waveforms' projection with respect to the two highest SVD values (see Fig. 2).

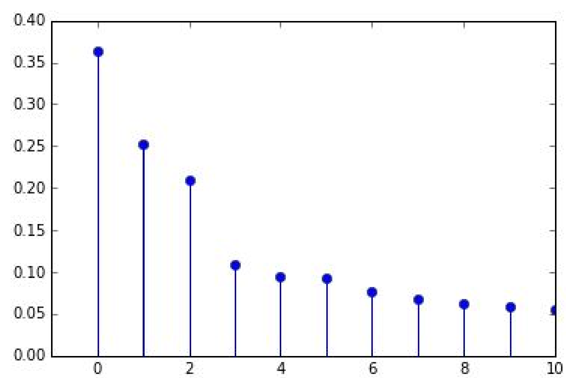

Fig. 7: SVD values for the recorded words.

Processing:

1. Variables:
    a. Snippet Size = 60
    b. Pre Length = 5
    c. Threshold = 0.5
2. From the pre-length, it is clear that the most variance in the words were found in the first syllable of each word (see Fig. 3, which makes this contrast more apparent).
3. The recordings were poor due to the 60 Hz interference and the surrounding noise in the lab. The former was reduced by recording the words farther away from the walls (upon the recommendation of a lab assistant).
4. Words which classified poorly were words with many syllables (for example fast-forward, deliberate etc.), which resulted in subsequent recordings to vary. Recordings improved with increased stress of certain syllables and lengthening the pronunciation of some vowels (for example, taco was recorded as T-A-A-C-O, whereas port was recorded as PO-RT).
5. Appending recordings of the same word from a couple of sessions allowed us to more rigorously test the correct classification of the words.

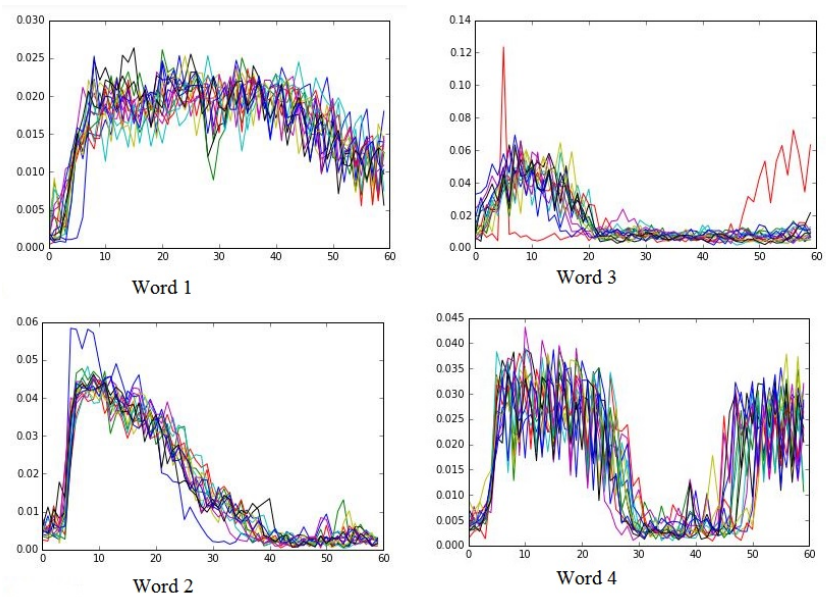

Fig. 8: The snippets of recorded waveforms of words.

Controls:

Open Loop Model:

1. See figure 2.

Closed Loop Model:

1. See figure 3, 4 and 5. We need the closed loop model for our system to correct itself and to converge to stability via adjusting the PWM input signals to the motors if the encoders receive noise in their readings or experience sudden changes in their readings due to e.g. a sudden change in terrain.

2. We manipulated our closed loop model to implement turning by artificially increasing the input to one of the motors in order to make the system recognize the sudden increase in input and thereby reduce the turning of motor receiving a sudden increase

in input and increase the turning of the other motor, thereby ‘tricking’ the closed loop model.

Choosing Controller Values:

We chose k_l = -0.6 and k_r = 0.3 because it worked well for our system by preventing either motor from overcorrecting or overcompensating and by making both wheels converge to stability.

General:

1. What we learned :
    a. Designing and building circuits that meet specification.
    b. Analyzing and debugging issues at different points in the project.
    c. How to compartmentalize a large project, to ease designing and executing the project.
    d. Understanding that the real world is full of uncertainties, challenges and imperfection by stepping out of a theoretical construct. And to correct for these differences by trying various techniques that involved hardware and mathematical hacks that deviated from theoretical models.
    e. And lastly, how to build a (toy) car!

2. Shortcomings:
   After successfully completing controls part 2, and collecting very good data both in air and on the ground, it came as a surprise while working on advanced controls that the encoder values collected by the LaunchPad while on the ground were erratic (with chunks of readings being uncharacteristically larger than the rest in the same recording) whereas the readings collected with the car in air were as expected. Even after replacing almost all the parts (the encoder, the LaunchPad, the jumper cables and BJT), our Lab GSI (Juan Duarte) and we were unable to solve the problem. Upon the suggestion from our GSI, we decided to hardcode the PWM values and were successful in driving the car straight again. We were able to implement the control scheme as described earlier in this report, but because we encountered this strange problem during the integration week, we had to hard code the PWM values to complete the project.

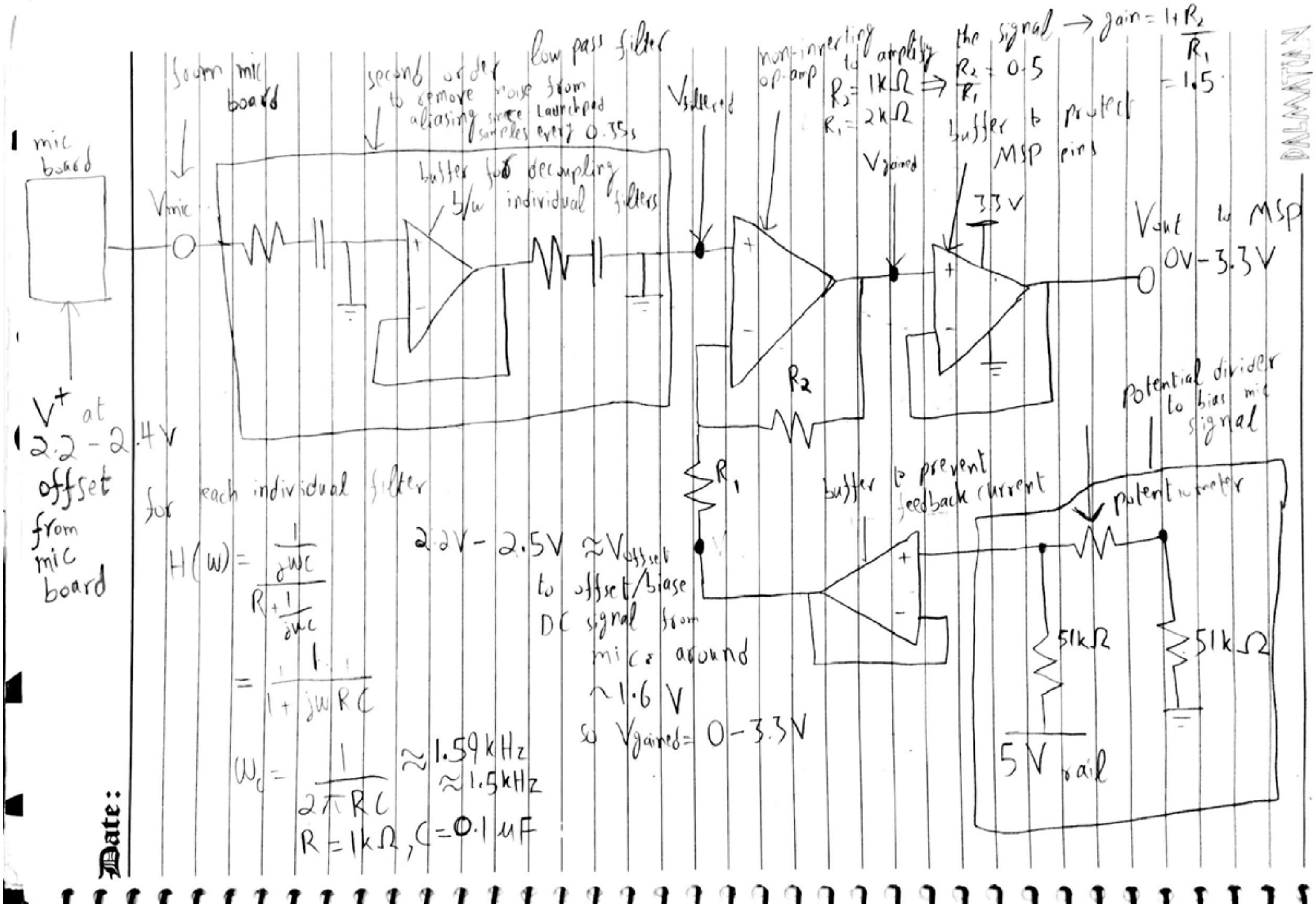

Figure 1: Final Front End Circuit Diagram

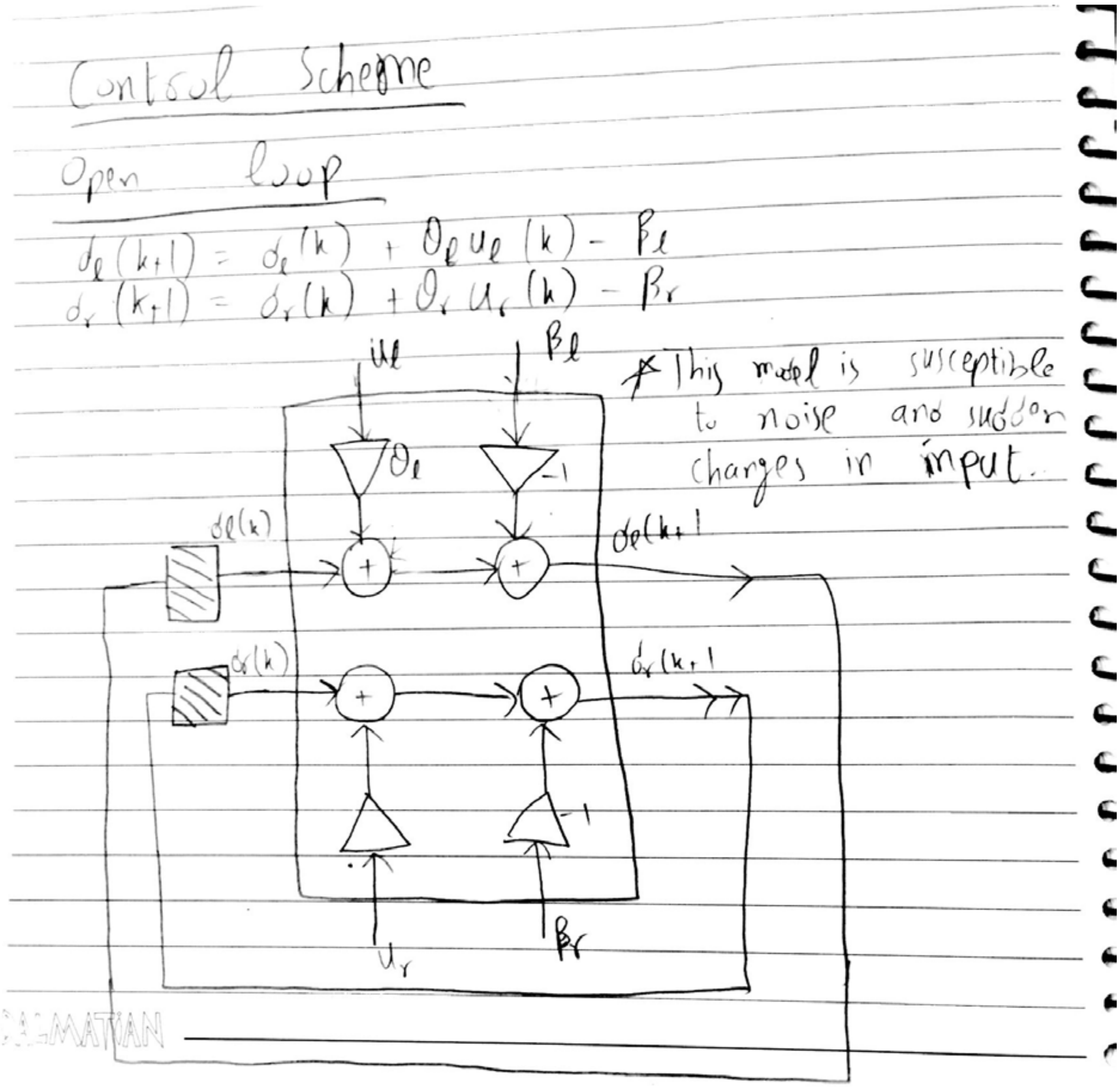

Figure 2: Open Loop Control Scheme Block Diagram

Date: Control Scheme Derivation

$$d_\ell(t+1) - d_\ell(t) = \vartheta_\ell u_\ell(t) - \beta_\ell \qquad (1)$$

$$d_r(t+1) - d_r(t) = \vartheta_r u_r(t) - \beta_r \qquad (2)$$

$$u_\ell = \frac{v^* + \hat{\beta}}{\hat{\vartheta}_\ell} + \frac{k}{\hat{\vartheta}_\ell}\left(d_\ell(t) - d_r(t)\right) \qquad (3)$$

$$u_r = \frac{v^* + \hat{\beta}}{\hat{\vartheta}} + \frac{k}{\hat{\vartheta}_r}\left(d_\ell(t) - d_r(t)\right) \qquad (4)$$

def $\delta(t) = \delta_\ell(t) - \delta_r(t)$

(5) = (1) − (2), subst. (3),(4) in (5)

$$\delta(t+1) - \delta(t) = \vartheta_\ell\left[\frac{v^* + \hat{\beta}_\ell}{\hat{\vartheta}_\ell} + \frac{k_\ell}{\hat{\vartheta}_\ell}\delta(t)\right] - \vartheta_r\left[\frac{v^* + \hat{\beta}_r}{\hat{\vartheta}_r} + \frac{k_r}{\hat{\vartheta}_r}\delta(t)\right] - (\beta_\ell - \beta_r)$$

$$\delta(t+1) = \frac{\vartheta_\ell}{\hat{\vartheta}_\ell}(v^* + \hat{\beta}_\ell) - \frac{\vartheta_r}{\hat{\vartheta}_r}(v^* + \hat{\beta}_r) + \frac{\vartheta_\ell k_\ell}{\hat{\vartheta}_\ell}\delta(t) - \frac{\vartheta_r k_r}{\hat{\vartheta}_r}\delta(t) + \delta(t) - (\beta_\ell - \beta_r)$$

$$\delta(t+1) = \frac{\vartheta_\ell}{\hat{\vartheta}_\ell}(v^* + \hat{\beta}_\ell) - \frac{\vartheta_r}{\hat{\vartheta}_r}(v^* + \hat{\beta}_r) - (\beta_\ell - \beta_r) + \delta(t)\left[\frac{\vartheta_\ell}{\hat{\vartheta}_\ell}k_\ell - \frac{\vartheta_r}{\hat{\vartheta}_r}k_r + 1\right] \qquad (6)$$

for $\hat{\vartheta}_\ell = \vartheta_\ell$, $\hat{\vartheta}_r = \vartheta_r$, $\hat{\beta}_\ell = \beta_\ell$, $\hat{\beta}_r = \beta_r$ (6) reduces to

$$\delta(t+1) = (1 + k_\ell - k_r)\,\delta(t) \qquad (7)$$

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Figure 3: Closed Loop Derivation

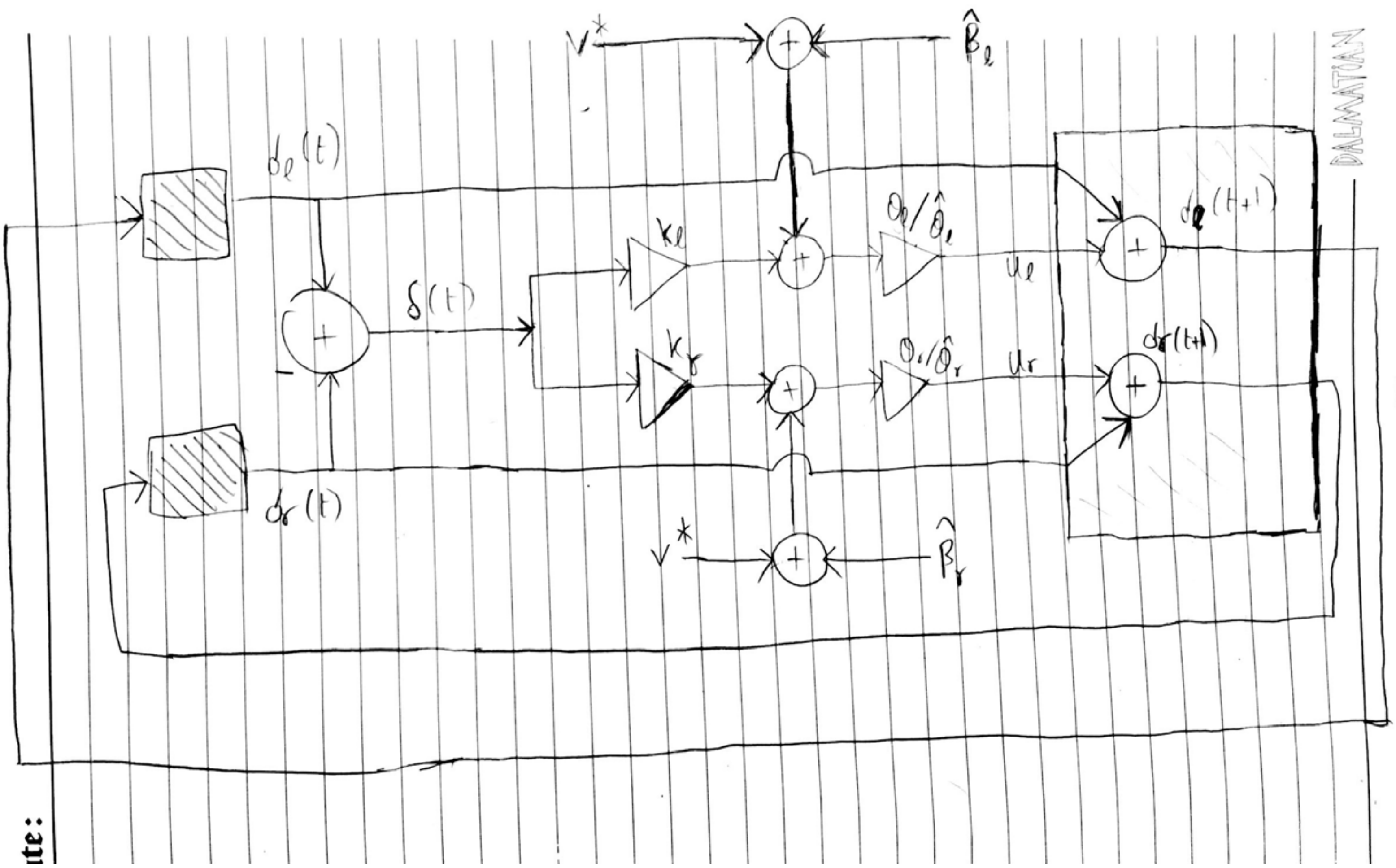

Figure 4: Full Closed Loop Block Diagram (using assumptions detailed in figure 3, this reduces to figure 5)

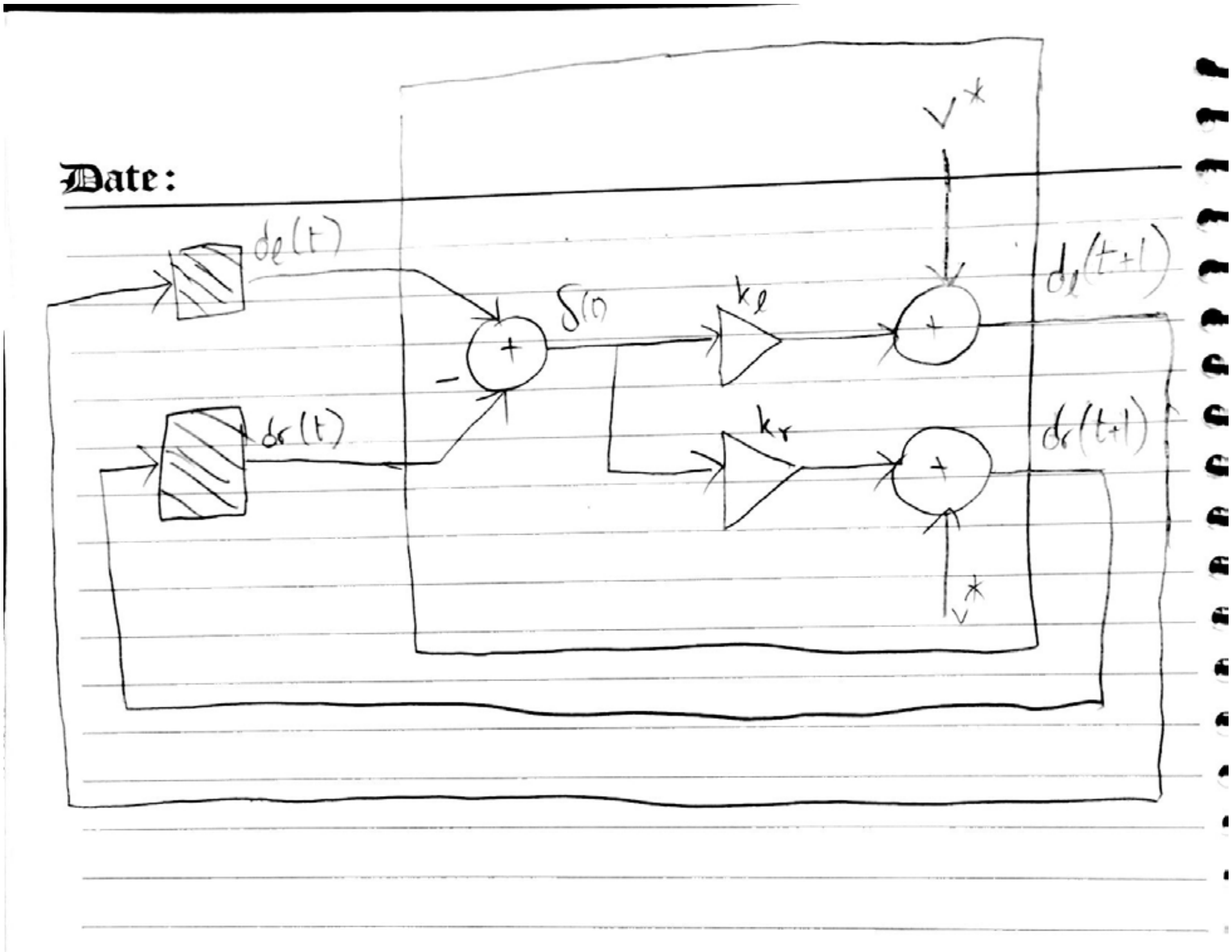

Figure 5: Reduced Closed Loop Block Diagram