RIS - LAB 2

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LAB 2 – (TASK 1.10 – 1.16)

TASK 1.10

We started off by creating a Simulink model as shown in Lab-Manual Fig 1.10 as follows:

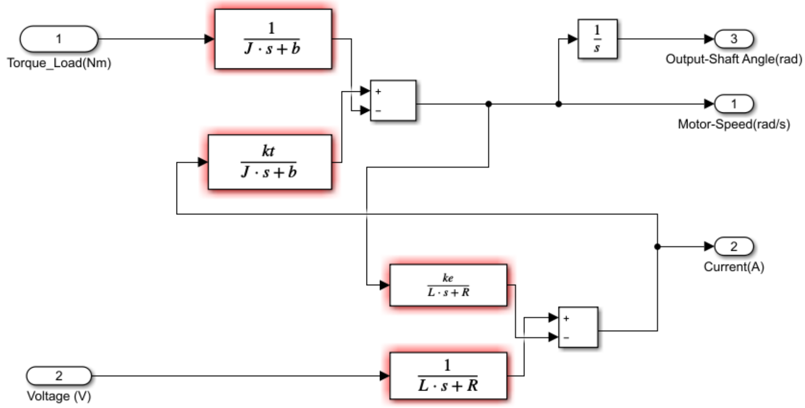


Figure 1.1: Simulink Model

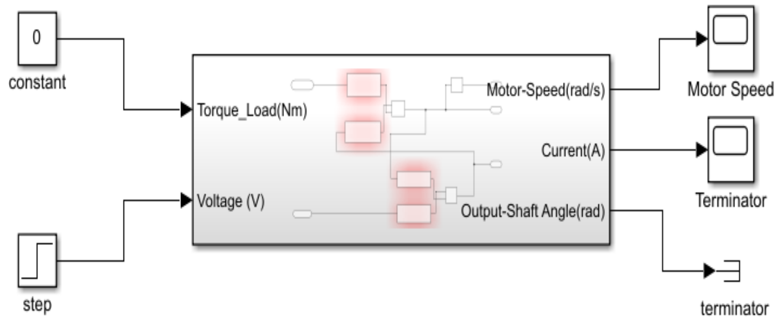


Figure 2.2: Subsystem

Here, we also made sure that the equations from Lab-Manual are implemented and are as follows:

$$\Omega(s) = \frac{k_t}{Js+b} I(s) - \frac{1}{Js+b} T_L(s)$$
$$I(s) = \frac{1}{L_a s + R_a} V_a(s) - \frac{k_e}{L_a s + R_a} \Omega(s)$$

Equation 1.24a and 1.24b

Moving on, we used values from Previous Tasks and saved them into a file called “motor_params.mat”.

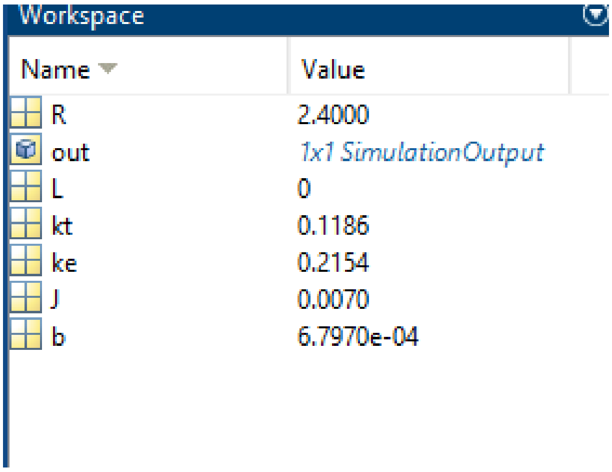


Figure 1.3: Variables saved

For the next step, we set the Step Value to 12V at t=1, keeping the load-torque value 0. We simulated the system for the range 0-10 seconds with ode45 and got the results as follows:

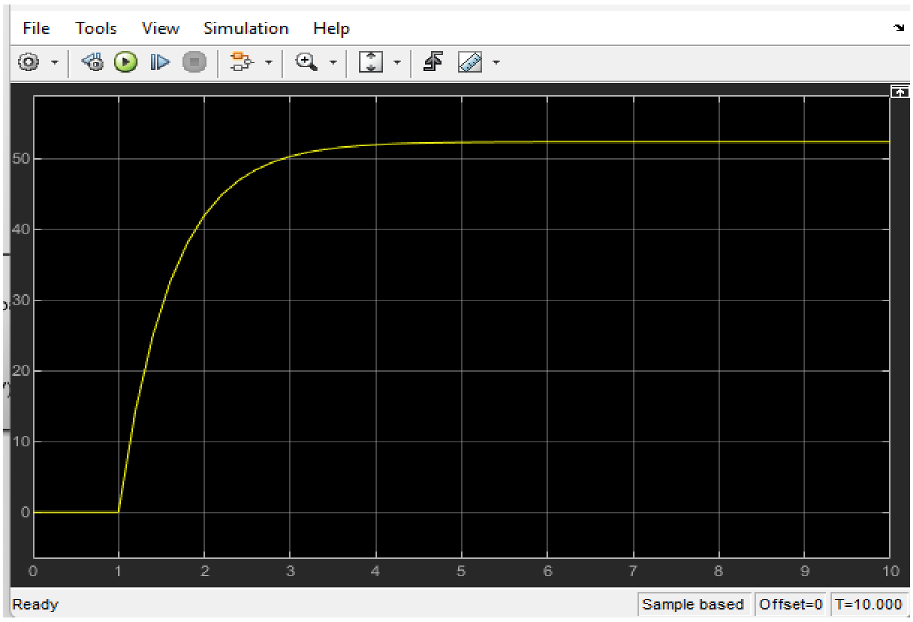


Figure 1.4: Scope of Motor Speed

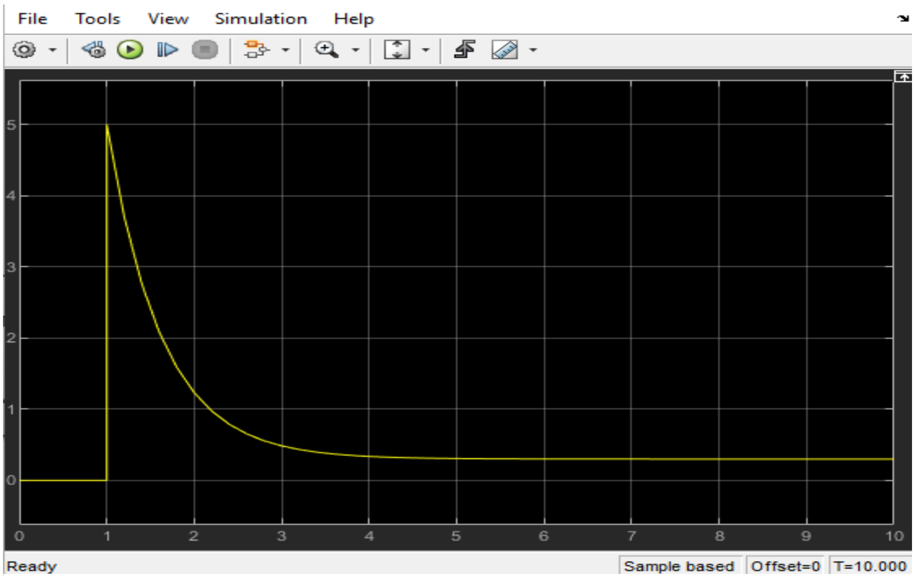


Figure 1.5: Scope of Current

For the next sub-part, from Equation 1.18 we have:

$$v_a - iR_a - L_a\frac{di}{dt} = e \overset{(1.6)}{=} k_e\dot{\theta}_g$$

When the voltage steps to 12V at t=1s, speed of motor w=0, resulting in i = 5A and as t increases voltage generated by motor increases resulting in current decrease. We can see that after the peek, current and motor speed decrease drastically to no load values.

Moving on, we add a step load-torque of 0.25Nm at t=6s. We also moved the stop time to 15 seconds.

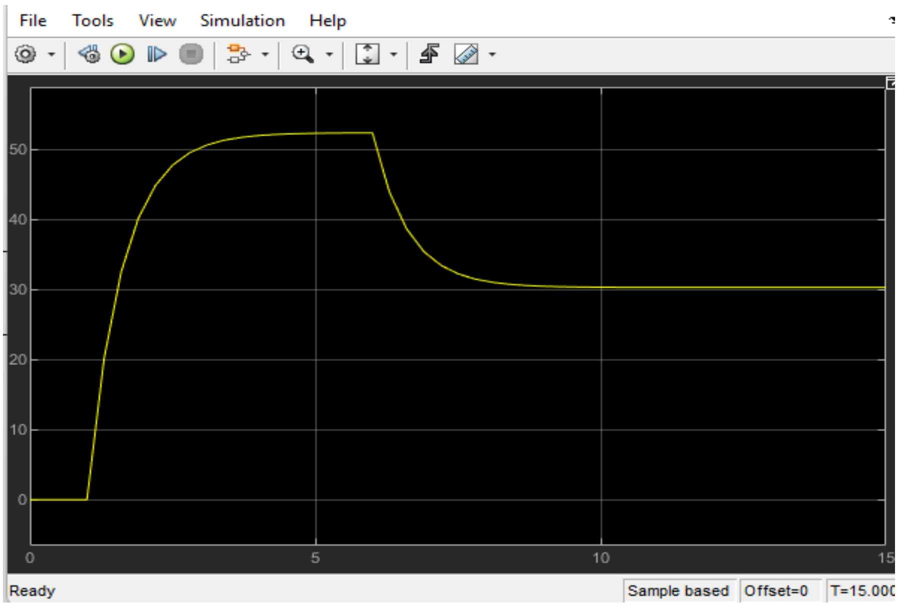


Figure 1.6: Motor Speed Scope with 0.25Nm load-torque at t=6s

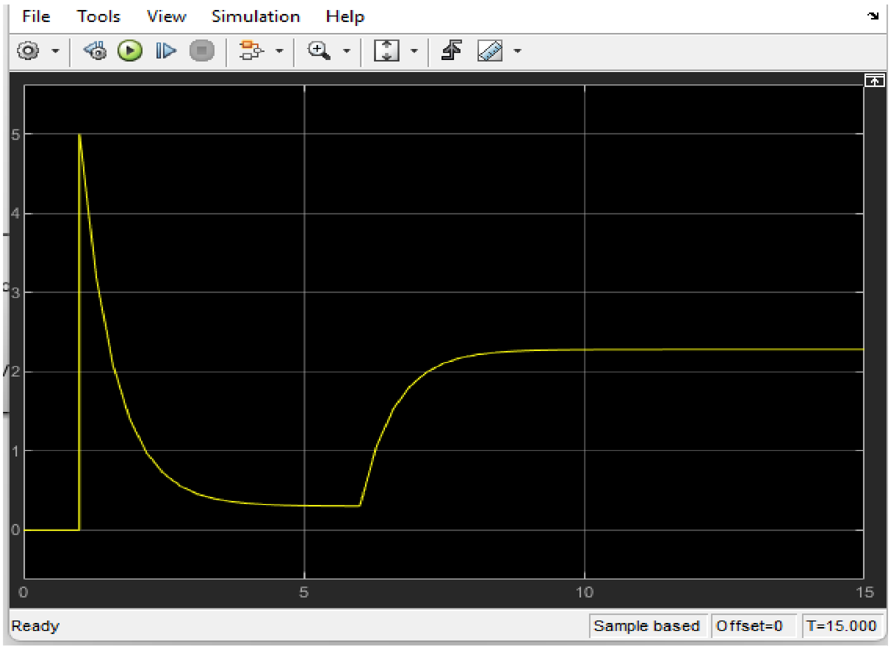


Figure 1.7: Current Scope with 0.25Nm load-torque at t=6s

Here, we can clearly infer that there is a difference in scopes with external load torque at t=6s as compared to t=1s. Here, changes made by changing the load-torque are evident in scopes above.

Finally, changing the load-torque to the initial one i.e. 0, we apply two steps to Voltage such that it changes from 0-12V at t=1s and then decreases to 0V at t=6s. The model change and results are as follows:

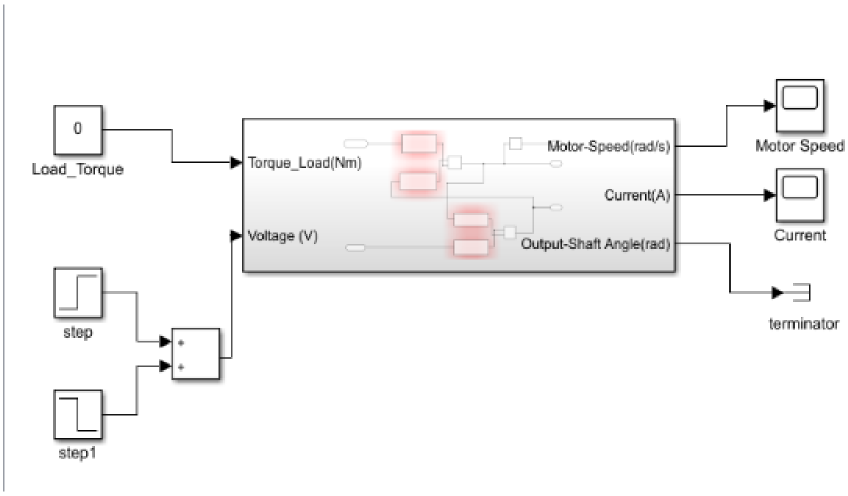


Figure 1.8: Model for step 7

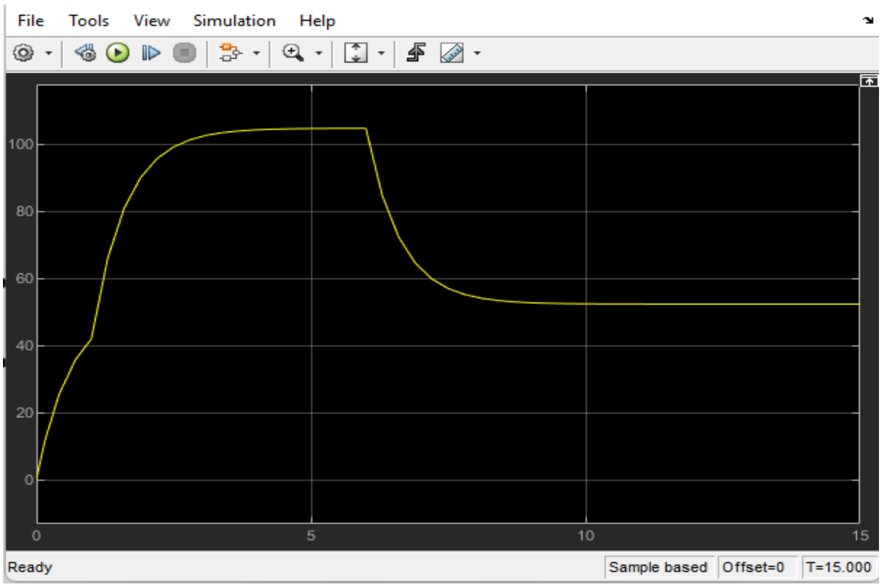


Figure 1.9: Motor Speed Scope

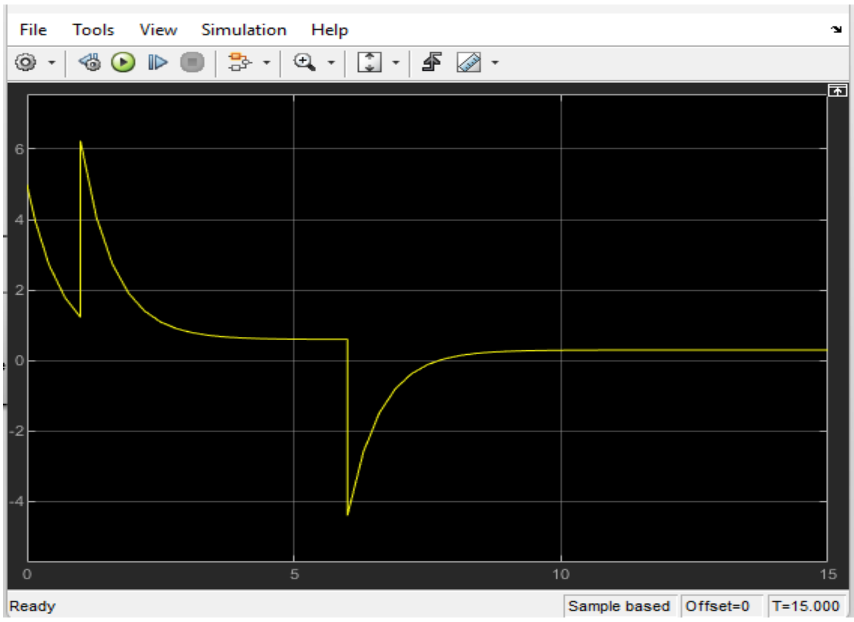


Figure 1.10: Current Scope

Considering equation from 1.18, we realize that as the voltage goes from 12-0, motor speed is at max, 52.36rad/s making the RHS greater than LHS. For reaching an equilibrium, current decreases to negative, increasing LHS value. This negative current spike rebalances the equation.

TASK 1.11

For this part, we add a sine wave function with amplitude 6V and frequency of 1 rad/s to the voltage of our sub-system, simulating it for 30s. We get the results as follows:

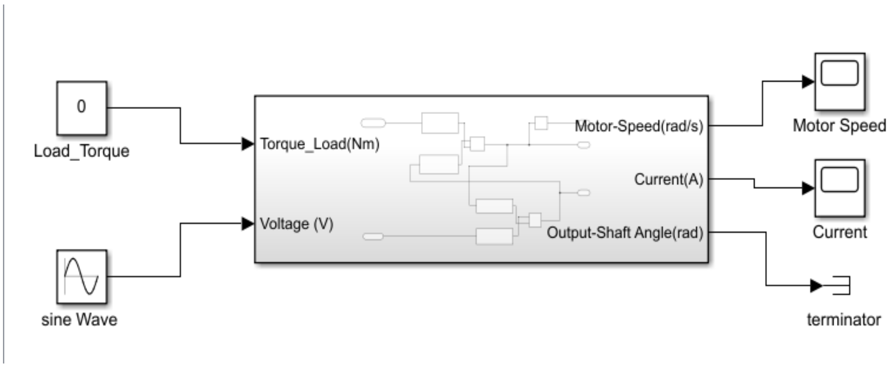


Figure 2.1: Subsystem with Sine Wave Function

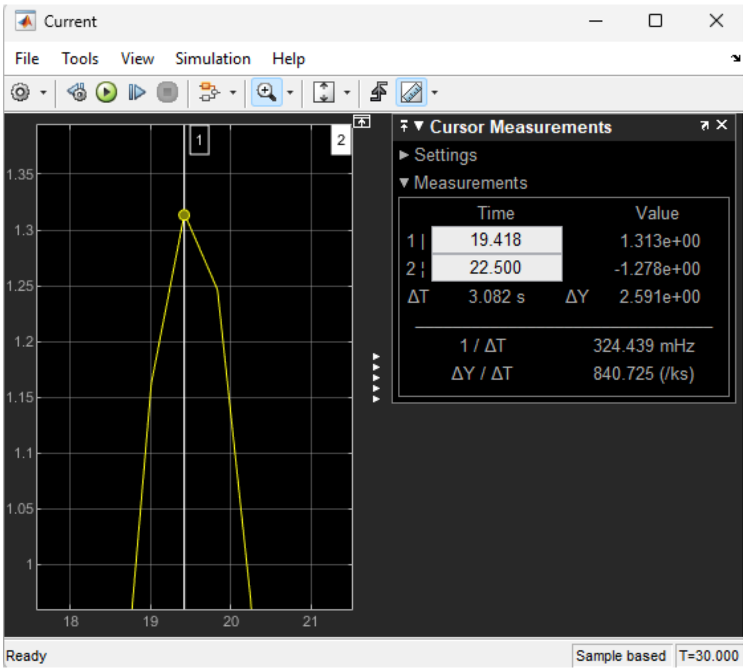


Figure 2.1: Current Scope for value of I

As we can clearly observe from the current scope, I = 1.313 here. Plucking this in the formula we get:

$$h(w = 1) = \frac{I}{6} = \frac{1.313}{6} = 0.218\ A/V$$

TASK 1.12

For this part, we are using a pulse generator and connect it to the input Voltage. We set the time period of pulse-generator to correspond to that of an Arduino PWM signal, at 2milli-seconds and set the amplitude to be 12V. The results we got are as follows:

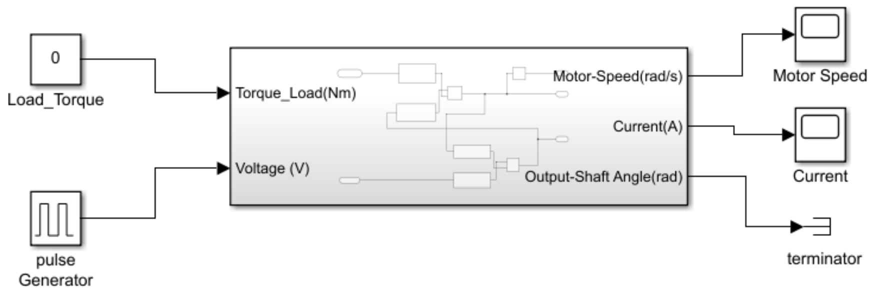


Figure 3.1: Subsystem with Pulse Generator as its input Voltage

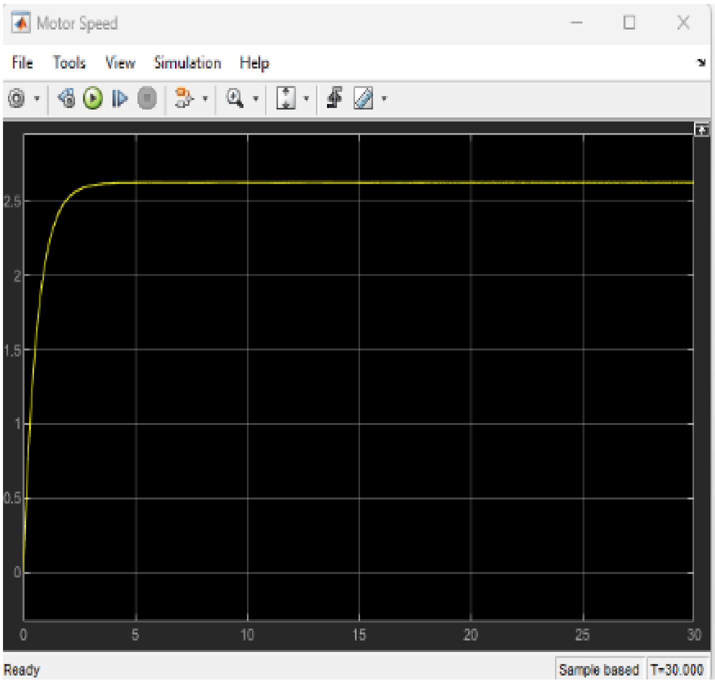


Figure 3.2: Motor Speed Scope at 5% Pulse Width

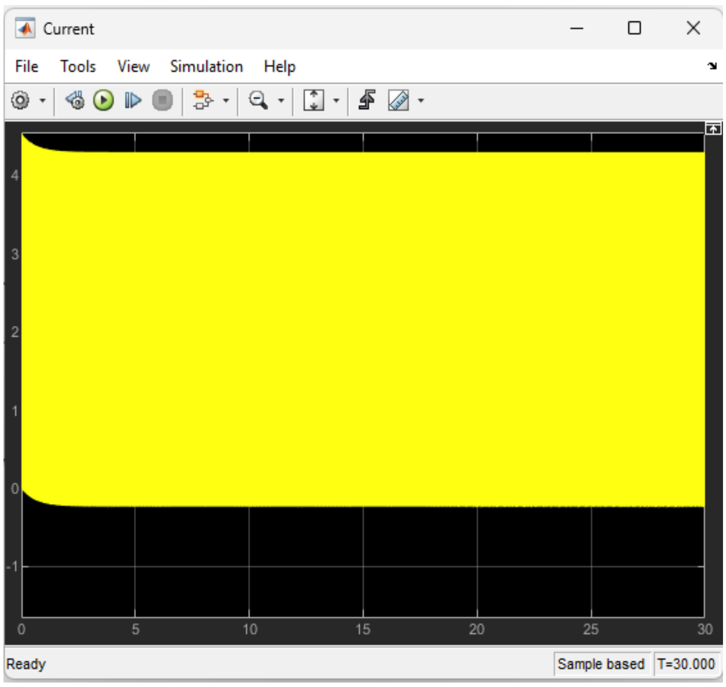


Figure 3.3: Current Scope at 5% Pulse Width

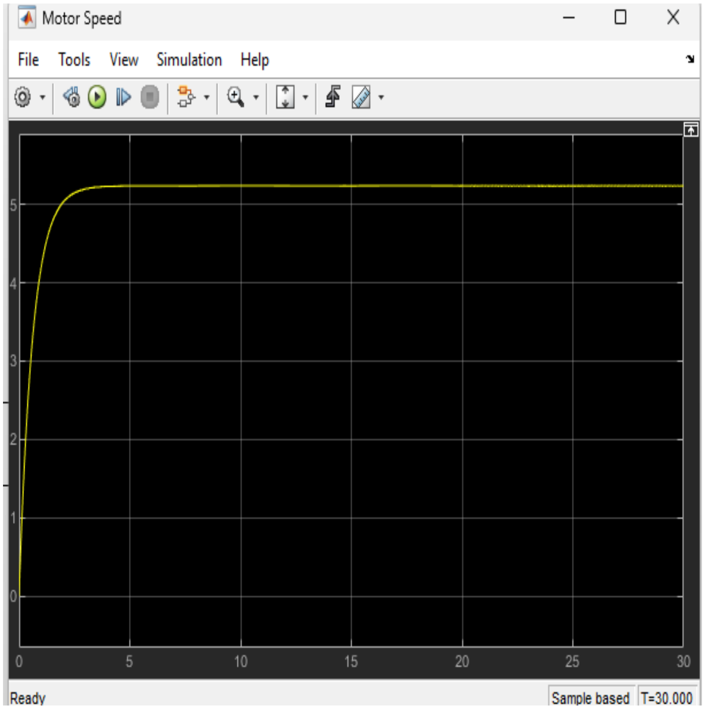


Figure 3.4: Motor Speed Scope at 10% Pulse Width

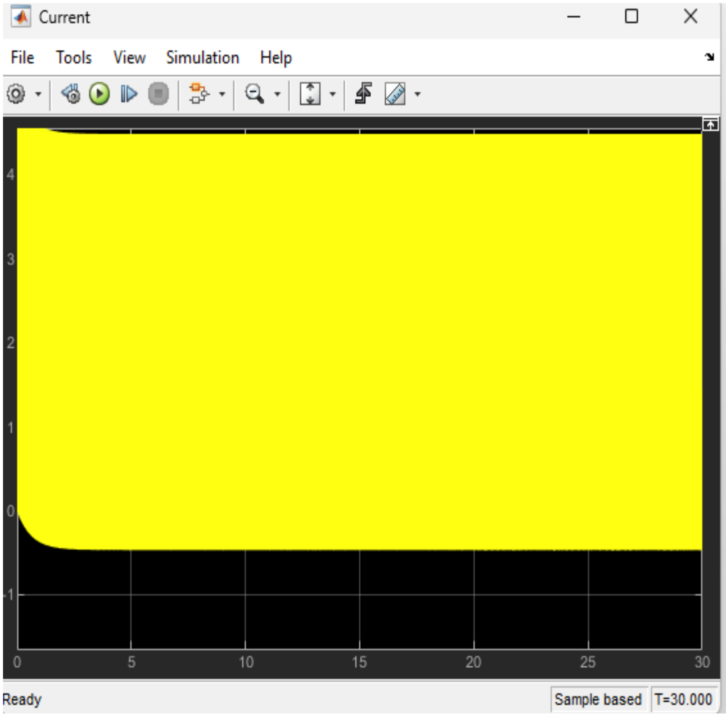


Figure 3.5: Current Scope at 10% Pulse Width

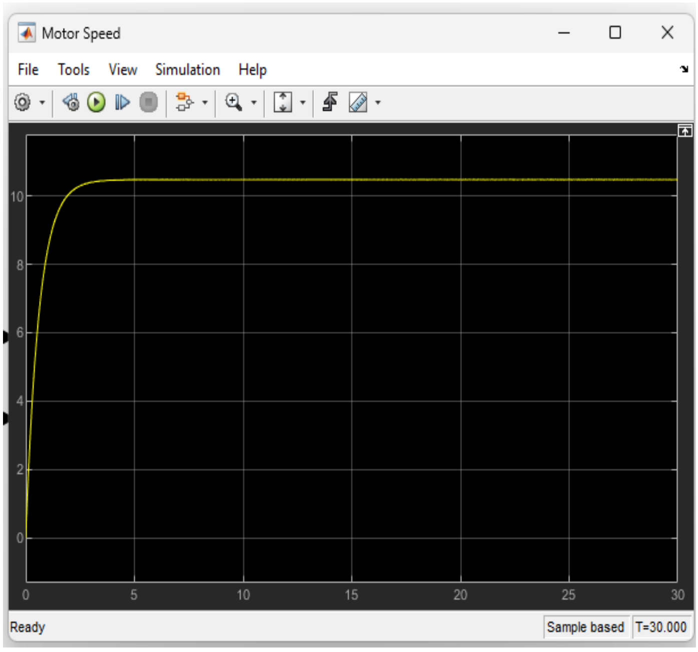
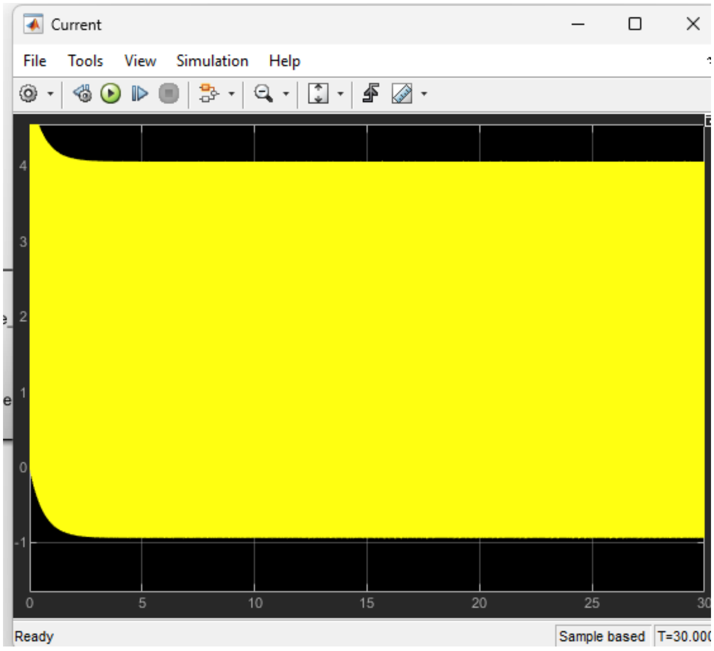


Figure 3.6: Motor Speed Scope at 20% Pulse Width



F Figure 3.7: Current Scope at 20% Pulse Width

We can conclude that pulse width determines the motor speed. We notice that pulse width is directly proportional to the signal. The range between the two values i.e. 5% and 20% pulse width is in correlation with the output speed.

TASK 1.13

For this task, we set load-torque input to 0 and apply a step voltage input of 12V at t=0. We then measured Tc from Motor Speed scope to calculate J.

Tc here is the time it takes to reach 63% of 52.36 rad/s speed which equals to 32.99rad/s. Using motor speed scope, we measured Tc = 0.659 from the graph:

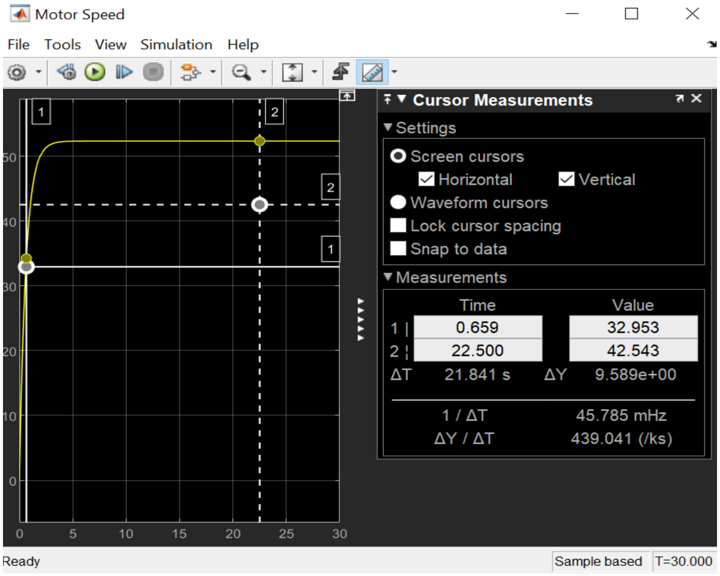


Figure 4.1: Value of Tc from Motor Speed Scope

Plucking this value for J, we get:

$$J = \frac{T_c(R_a b + k_e k_t)}{R_a}$$

Plucking in all the values, we get:

$$\text{J} = \quad 6.91 * 10 - 4$$

We can clearly see that our J approximation is close to its theoretical value $7*10^{-4}$

TASK 1.14

From Equation 1.24a and 1.24b, we have:

$$\Omega(s) = \frac{k_t}{Js+b} I(s) - \frac{1}{Js+b} T_L(s)$$

$$I(s) = \frac{1}{L_a s + R_a} V_a(s) - \frac{k_e}{L_a s + R_a} \Omega(s)$$

As we are given in the question statement, load torque $T_L(s) = 0$, we can simplify equation 1.24a to as follows:

$$\Omega(s) \ = k_t * \frac{I(s)}{Js + b}$$

Now, we substitute equation 1.24a into 1.24b to get:

$$I(s) = \frac{V_a(s)}{L_a s + R_a} - \frac{k_e k_t}{(L_a s + R_a) * (Js + b)}$$

$$I(s) + \frac{k_e k_t}{(L_a s + R_a) * (Js + b)} \ I(s) = \ \frac{V_a(s)}{L_a s + R_a}$$

$$I(s) * \left(\frac{k_e k_t + (L_a s + R_a) * (Js + b)}{(L_a s + R_a) * (Js + b)}\right) = \ \frac{V_a(s)}{L_a s + R_a}$$

We can further simplify this to get the transfer function as follows:

$$H_1(s) = \ \frac{I(s)}{V_a(s)} = \frac{(Js + b)}{(L_a s + \ R_a) * (Js + b) + (k_e k_t)}$$

TASK 1.15

Given w=1 and plucking this into s = jw, we get s=j. With this information, we have:

$$|H_1(j)| = \frac{(0.007j + 6.818 * 10 - 4)}{((10 - 4j + 2.4) * (0.007j + 6.818 * 10 - 4) + (0.2154 * 0.1187)}$$

$$= \ 0.13309 \ + \ 0.1750j$$

$$= |0.13309^2 + \ 0.1750^2| = 0.2198$$

The value calculated is very close to the value obtained in Task 1.11 i.e., 0.218A/V

TASK 1.16

For this part, we use result from above to derive L_a which is here the only unknown parameter.

We find this here as follows:

$$|H_1(jw)| = \frac{(Js + b)}{(L_a s + \ R_a) * (Js + b) + (k_e k_t)}$$

$$|H_1(jw)| * \ [(L_a s + \ R_a) * (Js + b) + (k_e k_t)] \ = (Js + b)$$

Simplifying this, we get:

$$HL_a s^2 \ + \ \ HL_a bs \ = \ Js + b - Hk_e k_t - HR_a Js - \ HR_{ab}$$

Factoring out and solving for L_a, we get the equation as follows:

$$L_a = \frac{= \ Js + b - Hk_e k_t - HR_a Js - \ HR_{ab}}{HJs^2 + Hbs}$$

Plucking in all the values and calculations made so far, we get $L_a = 10^{-4}$