Week -3 Tutorial MTRN3026 Mechatronics Systems

Q1 A separately excited DC motor operating at 1000 rpm has a load current of 100 A and a terminal armature voltage of 240 V. If the armature winding resistance is 0.1Ω, determine the following:

(i) The developed torque **Ans: 219.75 N-m**

(ii) The motor speed and the load current if the torque is doubled at the same field excitation **Ans: 956.5 rpm; 200A**

Q2 Starting with the differential equations governing a DC motor, obtain the state-space equations with armature voltage and load torque as inputs and the speed of the motor and armature current as outputs.

Ans: Refer to lecture materials of Week#3.

Q3 Obtain the transfer function of the system with a system block diagram as shown in Figure 1.

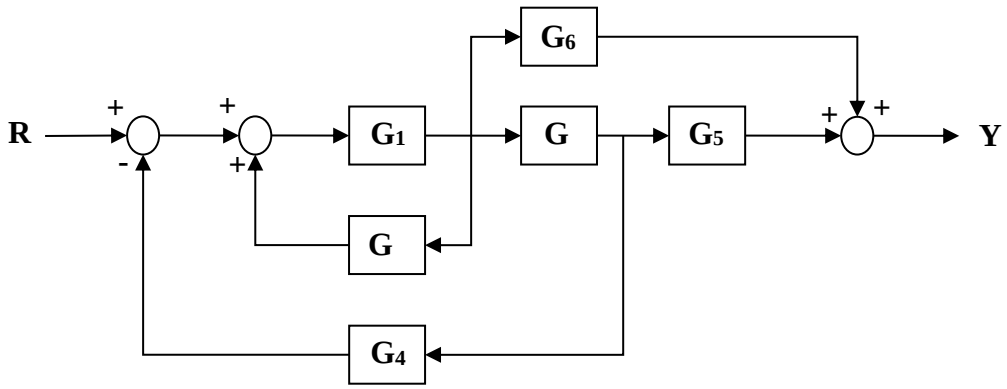


Figure 1

Ans: $Y/R = (G_6+GG_5)*G_1/(1-GG_1+GG_1G_4)$

Q4 Find the parameters of a DC motor from the following experimental data.

A 20 V, 2 A DC motor draws 0.25 A current with 1 V terminal voltage while the motor is not allowed to run. The armature current takes 1 mS to settle to steady state value. At no load with a 10 V terminal voltage the motor draws a current of 0.1 A and runs at 1000 rpm. The motor settles to steady state speed in 2 s and while the power is switched off the motor takes 10 s to come to rest.

Ans: Ra = 4 Ω; La = 0.8 mH; $K_b\phi$ = 0.0917 V/rad/s; B = 1.2479 N-m/rad/s' J = 2.4978 kg-m2.

With the parameters obtained above, find the open-loop transfer function between the speed and input voltage of the DC motor.

Ans: Please refer to the lecture materials.

Q5 The relationship between the generated force, exciting current and airgap of an electromagnet is given by $$F = k\left(\frac{i}{g}\right)^2$$

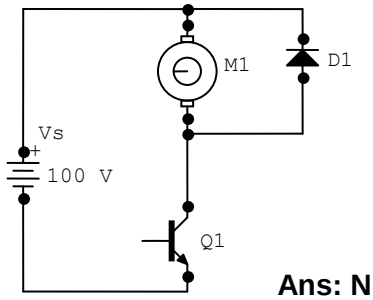
where F is the force generated, i is the current and g is the gap distance and k is a constant. Derive a linearised relationship between the force, current and distance around a nominal operating point io and go.

Ans: $\Delta F = 2Fo\ (\Delta i/i_o - \Delta g/g_0)$

Q6 (i) The speed of a PM DC motor is controlled by a chopper as shows in in Figure 2. The DC supply voltage is 100 V, the armature resistance is Ra = 0.5 Ohm, the armature inductance is La = 20 mH and the back EMF constant is 0.05 V/rpm. The motor drives a constant load torque requiring an average current of 20 A. Assume that the motor current is continuous.

Determine the (a) range of speed control and (b) range of duty ratio to achieve that.

Figure 2



Ans: N = 0 to 2000 rpm; D = 0 to 1;

(ii) With respect to Figure 2, explain the practical problems of the circuit if it is used to control the speed of your electric vehicle.
Ans: Running in one direction only.

(iii) How do you modify the above scheme (Figure 2) to achieve a Four-quadrant operation. Please explain the Four-quadrant operation with the help of a torque-speed diagram.

(iv) Please write down the disadvantages of a PM motor drives.
Ans: Low rating; performance will vary with time due to demagnetization

Q7 In Figure 3 the motor has to drive a load of 100 N-m at a speed of 1000 rpm. The armature resistance is 0.05 Ω and the torque constant is 4 N-m/A. Find the duty ratio of the switch.

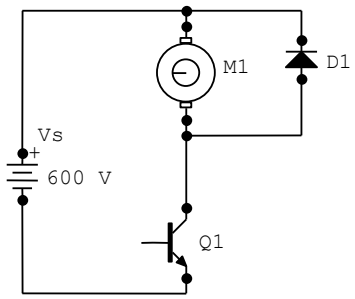


Figure 3

Ans: D = 70%.

Q8 The circuit shown in Figure 4 is a two op-amp instrumentation amplifier.

(a) Derive the expression for the output voltage, V_{OUT}, as a function of inputs V_{in1} and V_{in2}. Assume ideal op-amps.
(b) If R1=R4 and R2=R3, simplify the expression for V_{OUT}.

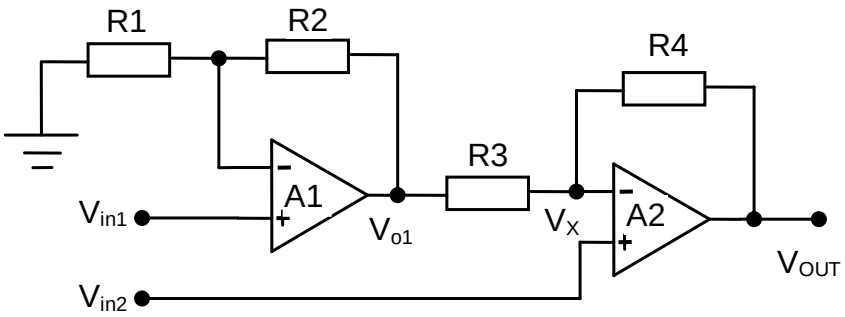


Figure 4 Two Op-Amp Instrumentation Amplifier

Ans: $V_{out} = Vin_2 – Vin_1 * (R_4/R_1) *(R_1 + R_2)/(R_3 + R_4)$
$Vout = V_{in2} – V_{in1}$

Q9 For the clipping circuit shown in Figure 5 below, draw the voltage waveform across the load resistance R_L. Show appropriate voltage values on the waveform. All the diodes in the circuit are made of silicon.

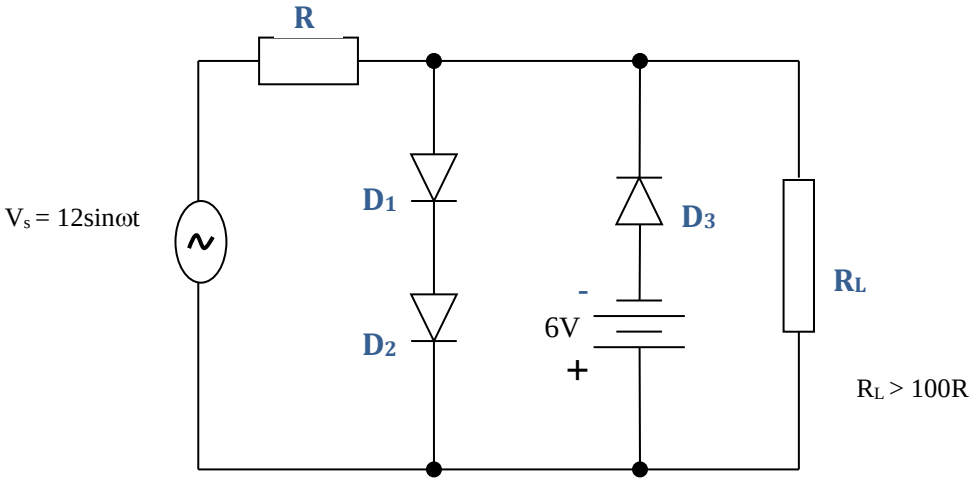


Figure 5: Clipping Circuit

Ans: Positive 1.4 V and Negative -6.7 V.

Q10 Given the circuit shown in Figure 6.

a. Starting from basic principles, derive an expression for the output voltage v_0 in terms of the other circuit parameters of the circuit shown in Figure 6. State any assumptions made.

b. What is the function of this circuit?

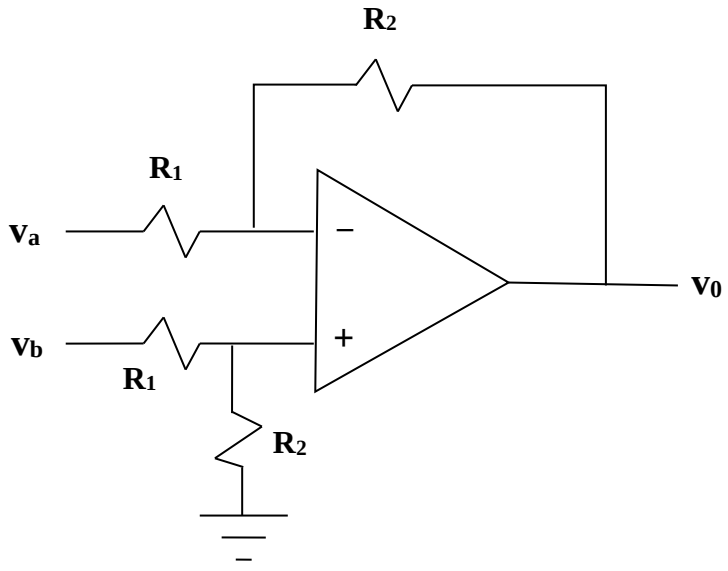


Figure 6

Ans: Vo = (R_2 /R_1) *(V_b – V_a)
Differential Amplifier.