Sensing, Computing, Actuating
Lecture 1 - Resistive displacement

Exercise 1: Throttle position sensor

A throttle position sensor (TPS) is a system that determines the ignition timing of an engine by comparing the position of the throttle valves with the rotational speed of the engine. The system is used in almost all modern gasoline engines. The throttle position sensor is normally located on the butterfly valve. The sensor is typically build using a potentiometer that provides a variable electrical resistance which is dependent on the position of the throttle valve. Figure 1 provides a schematic view of the throttle position sensor. The sensor consists of a variable resistor R_T of which its resistance varies between 0 Ω (at $\Theta = 0°$) and R_T Ω (at $\Theta = 270°$). The sensor is connected to a circuit that processes the repsonse from the sensor. This circuit has a purely resistive input-impedance $R_m = R_T/a$.
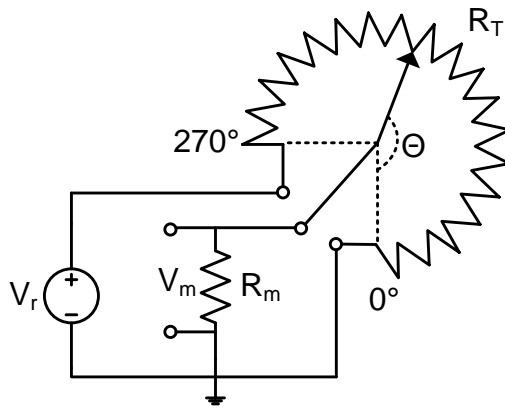

Figure 1: Throttle position sensor with processing circuit.

(a) Show that the voltage V_m across the resistor R_m in terms of the supply voltage V_r, the angle Θ, the resistance R_T and the constant a is equal to:

$$V_m = \frac{270°\Theta}{(270°)^2 + a\Theta(270° - \Theta)} V_r$$

(b) Show that the relative error ϵ in the output voltage V_m of the sensor due to the loading resistance R_m is equal to:

$$\epsilon = \frac{a\Theta(270° - \Theta)}{(270°)^2 + a\Theta(270° - \Theta)}$$

(c) What ratio R_T/R_m should the resistors R_T and R_m have such that the relative error ϵ in term of the output voltage V_m due to the loading resistance R_m is always smaller then 5%?

(d) Assume that the potentiometer has a resistance of 250 kΩ. The potentiometer has been build by turning a wire with a length of 1 m around a tube that has an average diameter of 2 cm. The wire has a specific resistance of 20000 $\mu\Omega$cm. What is the resolution of the sensor in degrees?