

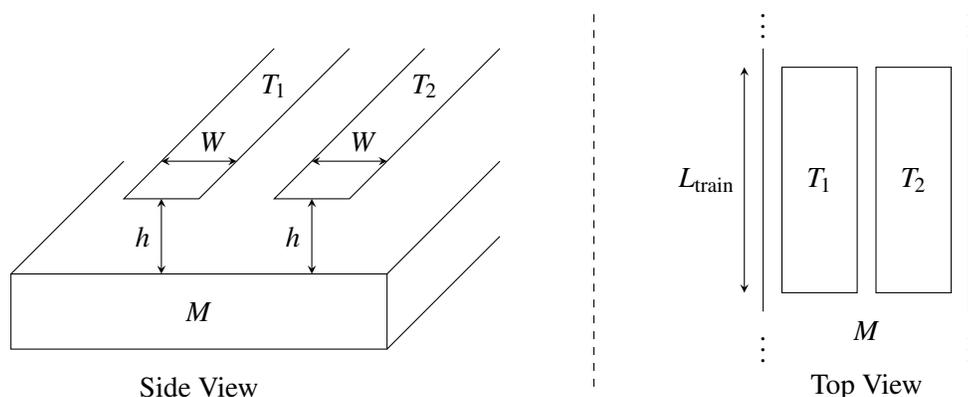
# EECS 16A    Designing Information Devices and Systems I

## Fall 2019    Discussion 9A

### 1. Maglev Train Height Control System

One of the fastest forms of land transportation are trains that actually travel slightly elevated from ground using magnetic levitation (or “maglev” for short). Ensuring that the train stays at a relatively constant height above its “tracks” (the tracks in this case are what provide the force to levitate the train and propel it forward) is critical to both the safety and fuel efficiency of the train. In this problem, we’ll explore how the maglev trains use capacitors to keep them elevated. (Note that real maglev trains may use completely different and much more sophisticated techniques to perform this function, so if you e.g. get a contract to build such a train, you’ll probably want to do more research on the subject.)

- (a) As shown below, let’s imagine that all along the bottom of the train, we put two parallel strips of metal ( $T_1$ ,  $T_2$ ), and that on the ground below the train (perhaps as part of the track), we have one solid piece of metal ( $M$ ).



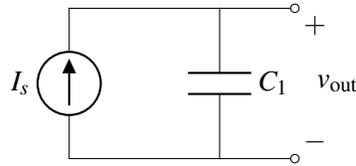
Assuming that the entire train is at a uniform height above the track and ignoring any fringing fields (i.e., all capacitors are purely parallel plate), as a function of  $L_{\text{train}}$  (the length of the train),  $W$  (the width of  $T_1/T_2$ ), and  $h$  (the height of the train off of the track), what is the capacitance between  $T_1$  and  $M$ ? How about the capacitance between  $T_2$  and  $M$ ?

- (b) Any circuit on the train can only make direct contact at  $T_1$  and  $T_2$ . To detect the height of the train, it would only be able to measure the effective capacitance between  $T_1$  and  $T_2$ . Draw a circuit model showing how the capacitors between  $T_1$  and  $M$  and between  $T_2$  and  $M$  are connected to each other.
- (c) Using the same parameters as in part (a), provide an expression for the capacitance between  $T_1$  and  $T_2$ .
- (d) So far we’ve assumed that the height of the train off of the track is uniform along its entire length, but in practice, this may not be the case. Suggest and sketch a modification to the basic sensor design (i.e., the two strips of metal  $T_1/T_2$  along the entire bottom of the train) that would allow you to measure the height at the train at 4 different locations.

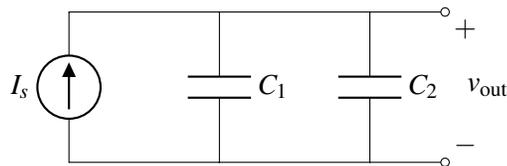
## 2. Current Sources And Capacitors

For the circuits given below, give an expression for  $v_{\text{out}}(t)$  in terms of  $I_s$ ,  $C_1$ ,  $C_2$ ,  $C_3$ , and  $t$ . Assume that all capacitors are initially uncharged, i.e. the initial voltage across each capacitor is 0V.

(a)

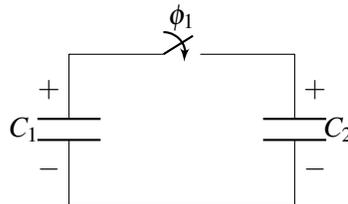


(b)



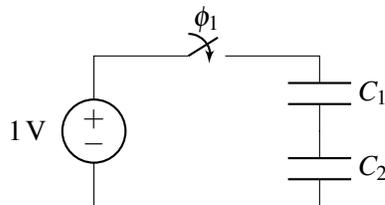
## 3. Capacitors and Charge Conservation

(a) Consider the circuit below with  $C_1 = C_2 = 1 \mu\text{F}$  and an open switch. Suppose that  $C_1$  is initially charged to +1V and that  $C_2$  is charged to +2V. How much charge is on  $C_1$  and  $C_2$ ?



(b) Now the switch is closed (i.e. the capacitors are connected together.) What are the voltages across and the charges on  $C_1$  and  $C_2$ ?

(c) Consider the following circuit with  $C_1 = 1 \mu\text{F}$  and  $C_2 = 3 \mu\text{F}$ . Suppose that both capacitors are initially uncharged (0V).



What are the voltages across each capacitor after the switch is closed? What are the charges on each capacitor?