Sensing, Computing, Actuating
Lecture 7 - AD/DA conversion

Exercise 1: Electronic control unit

Electronic control units (ECUs) are commonly used in modern vehicles. The are used to control one or more of the electrical systems or subsystems inside a vehicle. The are often used to control for example the airbags, engine, and powertrain of a car. Other applications of ECUs are shown in Figure 1. Some modern cars contain up-to 80 ECUs and it is expected that this number will increase even further in the future. A micro-processor is often used at the heart of an ECU. Figure 2 shows the block diagram of the Freescale MPC5634M ECU. This ECU uses contains several micro-processors that can be used to run the digital signal processing and control algorithms that are needed to control the operation of a vehicle. These micro-processors process data that has been read by sensors. Typically, the sensors deliver an analog signal while the processor operates on a digital data stream. To connect these two components, the analog sensor value should first be digitized. For this purpose, the ECU contains an analog-to-digital converter (ADC). The ECU shown in Figure 2 contains two ADCs that are both able to perform an analog-to-digital conversion with a 12-bit resolution within 1μs. Hence, these ADCs can both output 1 million samples per second. They are based on the idea of successive approximation.

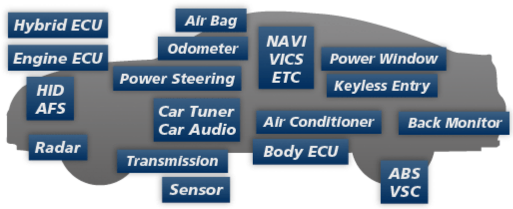

Figure 1: Applications of electronic control units (ECUs).

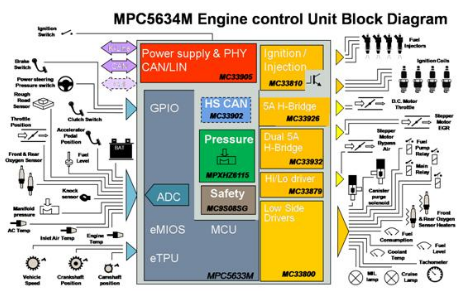

Figure 2: Electronic control unit (ECU) with ADC.

(a) A 5-bit DA converter has a voltage output. For a binary input of 10100, an output voltage of 12 mV is produced. What is the output voltage when the binary input is 11100?

(b) An 8-bit DA converter has a step size of 5 mV. What is the full-scale output voltage (i.e., maximal output voltage) of the DA converter?

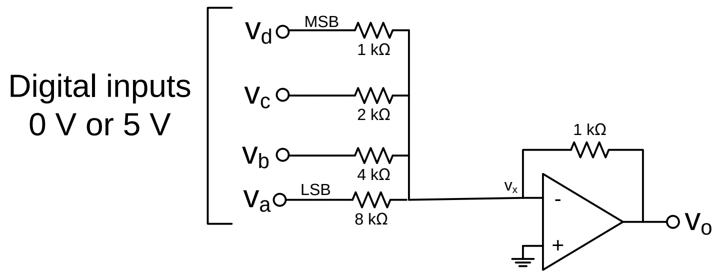

Figure 3: DA converter using summing op-amp.

(c) Show that the output voltage v_o of the DA converter shown in Figure 3 is equal to:

$$v_o = -(v_d + 0.5v_c + 0.25v_b + 0.125v_a)$$

(d) What is the resolution of the DA converter shown in Figure 3?

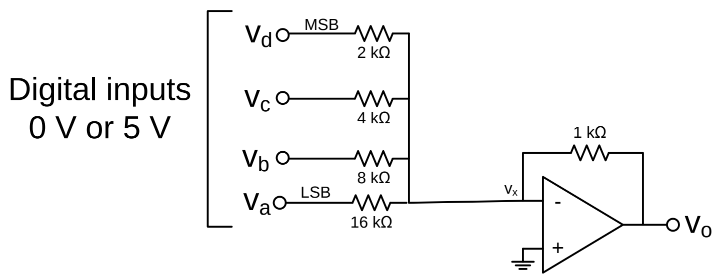

Figure 4: Alternative DA converter.

(e) What is the weight (contribution) of each input bit in the output voltage of the DA converter shown in Figure 4?

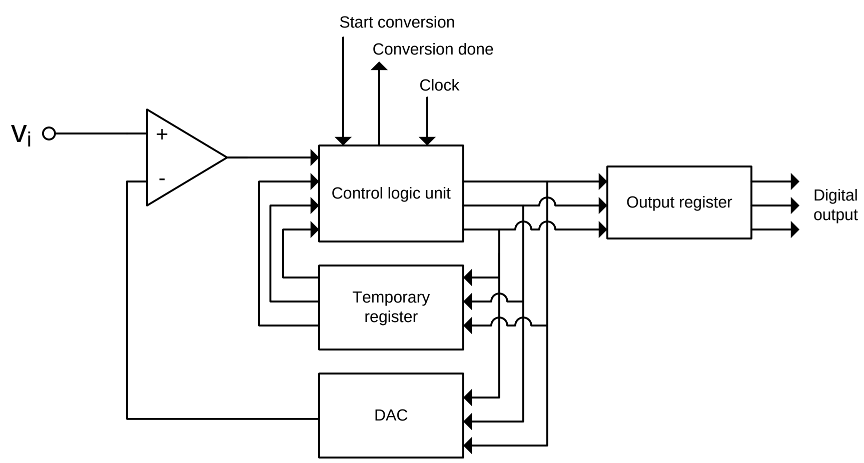

Figure 5: Successive approximation ADC.

(f) Figure 5 shows a successive approximation ADC that uses an 8-bit DAC which has a conversion range of 0 V to 5.12 V. Draw the ADC transfer curve (binary input versus v_i) showing all relevant values.

(g) Assume that $v_i = 1.64$ V. Draw the DAC output (labels and levels) and its binary input for the first five bits tested. (*Hint:* calculate the weight of each bit.)

(h) What is the main advantage of a successive approximation ADC over a dual-slope ADC?