Chapter 2 – Sensors and Actuators

1. A scientific calculator has 5 rows and 9 columns. How many bits required for addressing assuming separate row and column addresses?

   ANS: 5 Rows → 3 bits, 9 columns → 4 bits: 7-bit address required.

2. Your smartphone touch screen implements a 100 x 100 switch array. What is the minimum number of bits that defines the address of each switch assuming separate row and column addresses?

   ANS: 100 Rows → 7 bits, 100 columns → 7 bits: 14-bit address required.

3. Finger swipe speed. Your smartphone square touch screen measures 10 cm x 10 cm and implements a 100 x 100 switch array. A horizontal finger swipe must activate at least 25 columns in any particular row within 0.5 seconds. What is the minimum speed (m/s) that your finger must travel to form a valid finger swipe?

   ANS: The finger must travel distance d > a quarter of the horizontal distance in 0.5 seconds. The speed is then $s > d/0.5s = (2.5 \times 10^{-2}\ m)/(0.5\ s) = 5 \times 10^{-2}$ m/s.

4. Your audio system uses 24 bits to encode audio waveform samples. How many different levels can be encoded using the approximation $2^{10} = 10^3$?

   ANS: $2^{24} = (2^4)(2^{10})(2^{10}) = 16(10^3)(10^3) = 16$ million

5. Your smartphone has an 8 Megapixel camera (2^{23} pixels) with each pixel containing red, green, and blue sensors. If each sensor produces 256 levels of intensity, how many bits are required to encode an image? (Express answer as n.n x 10^y)

   ANS: 256 levels are encoded with 8 bits, yielding 24 bits/pixel. $24 \times 2^{23} = 2.4 \times 2^{24} = (2.4)(2^4)(2^{10})(2^{10}) = (2.4)(16)(10^3)(10^3) = 3.8 \times 10^7$.

6. A consumer TV with 4K resolution has a screen that contains 3840 by 2160 array of pixels. Each RGB LED can shine at 256 intensity levels. The number of bits required to display a complete image equals _____. ? (Express answer as n.n x 10^y)

   ANS: $(3)(8)(3{,}840)(2{,}160) = 199 \times 10^6 = 2.0 \times 10^8$

7. An IR autofocus system has emitter and detector apertures separated by 1cm and modeled as pin holes. The light reflected from an object at range r casts a spot that is detected at a displacement of 0.1mm from the detector axis. The detector lies 0.5cm behind the pin hole. The value of r equals _____ (x.x m)

   ANS: $f = 5x10^{-3}$ m, $s = 10^{-2}$ m, $x=10^{-4}$ m. $r/s = f/x \rightarrow r = sf/x = (10^{-2}m)(5 \times 10^{-3}m)/ (10^{-4}m) = 5 \times 10^{-1}m = 0.5$ m.

8. An air sonar detects the echo TOF from an object to be 10 milliseconds. The object range equals ___(x.xx) m.

   ANS: $r = (c)(TOF)/2$. In air c=350 m/s. $r = (350 \text{ m/s}) (10^{-2} \text{ s})/ 2 = 1.75$ m

9. An underwater sonar detects the echo from an object at 100m range. The TOF equals ___ (x.xx s).

   ANS: $TOF = 2r/c$. In water c=1500 m/s. $TOF = (2 \times 100m)/ (1500 \text{ m/s}) = 0.133 \text{ s} = 1.33$ s