

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 $d > \frac{1}{4}$ of the horizontal distance in 0.5 seconds. The speed is then $s > d/0.5s = (2.5 \times 10^{-2} \text{ m})/(0.5 \text{ s}) = 5 \times 10^{-2} \text{ m/s}$.

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

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 $n.n \times 10^y$)

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 $n.n \times 10^y$)

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

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

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

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

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