Sample: Engineering - Instrument Control Principles

Question 2.

Determine if the value of the ballast resistor is satisfactory if a 5 volt, 0.5-watt Zener diode is used in the circuit of FIGURE 1.

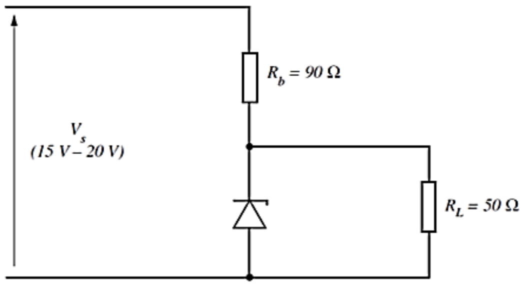

FIGURE 1

Solution

Voltage on ballast resistor is

$$V_R = V_s - V_z.$$

Thus

$$V_{Rb_{min}} = 15 - 5 = 10\ V;$$

$$V_{Rb_{max}} = 20 - 5 = 15\ V.$$

Maximum current through ballast resistor

$$I_{max} = I_{z_{max}} + \frac{V_z}{R_L} = 0.1 + \frac{5}{50} = 0.2\ A.$$

Therefore

$$R_{b_{max}} = \frac{V_{Rb_{max}}}{I_{max}} = \frac{15}{0.2} = 75\ \Omega;\ R_{b_{min}} = \frac{V_{Rb_{min}}}{I_{max}} = \frac{10}{0.2} = 50\ \Omega.$$

Answer

With $R_b = 90\ \Omega$ zener is not overloaded, but it supposed to be lowered down to 75 Ω for 20V and 50 Ω for 15V (or we may select value between 50 Ω and 75 Ω).

Question 3.

A wirewound potentiometer having 300 turns is to be used in the following system (FIGURE 2).

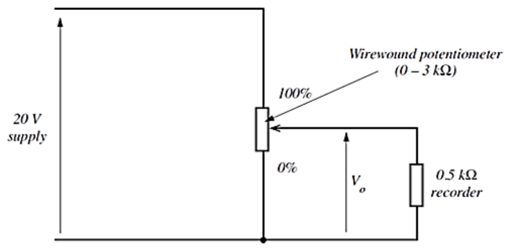

FIGURE 2

As the slider is positioned in 10% increments from the 0% point to the 100% point, the following voltage levels were recorded.

Table 1

Tapper position	*0%*	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*100%*
Output voltage	*0 V*	*1.298 V*	*2.04 V*	*2.654 V*	*3.278 V*		*4.918 V*	*6.194 V*	*8.163 V*	*11.688 V*	*20 V*

(a) Calculate the value of the output voltage at 50%.

Solution

$$V_o = I \cdot R_o = \frac{V_s}{\frac{R_{max}}{2} + \frac{0.5 \cdot R_{max} \cdot R_r}{0.5 \cdot R_{max} + R_r}} \cdot \frac{0.5 \cdot R_{max} \cdot R_r}{0.5 \cdot R_{max} + R_r} = \frac{20}{\frac{3}{2} + \frac{0.5 \cdot 3 \cdot 0.5}{0.5 \cdot 3 + 0.5}} \cdot \frac{0.5 \cdot 3 \cdot 0.5}{0.5 \cdot 3 + 0.5} = 4V.$$

(recorder is wired parallel to lower part of potentiometer)

Answer $V_o = 4\ V$.

(b) Draw a graph of 'tapper' position against input voltage. V_0.

Solution

According to a Table 1, graph of 'tapper' position against input voltage is shown on FIGURE 3

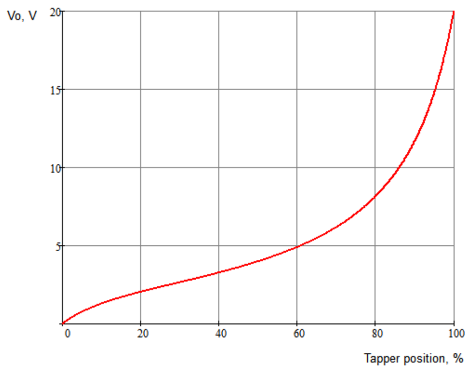

FIGURE 3

(c) Indicate on the graph the ideal characteristics of such a system.

Solution

Ideal characteristic of such a system is linear (if $R_r = \infty$ and $V_s = const$) – FIGURE 4. It has 300 “steps” (300 turns) see the FIGURE 5.

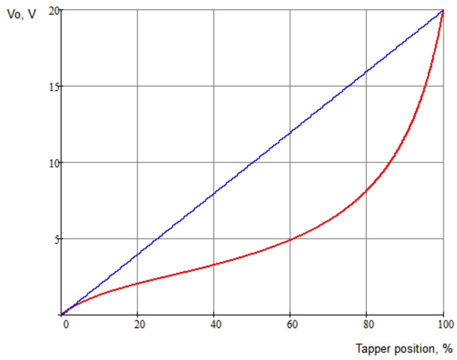

FIGURE 4

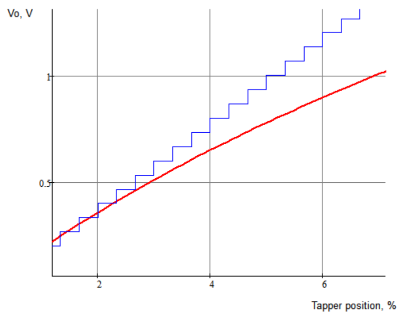

FIGURE 5

(d) Calculate the maximum error as a percentage of the true value.

Solution

Maximum error is given when x=0.5 (page 10, ICP Lesson 1).

True value is $20 \cdot 0.5 = 10\ V$.

Measured value is 4V.

Maximum error is $\frac{10-4}{10} \cdot 100 = 60\%$.

Answer: 60%

(c) Suggest how the system could he improved to give a characteristic closer to the ideal.

Answer

1. It is necessary to use receiver with much greater internal resistance.

2. Voltage source could be stabilized.

3. Number of turns could be increased.

Question 4.

(a) Describe the principal features and behaviour of monomode, multimode stepped-index and multimode graded-index optical fibre.

Illustrate your answer with appropriate sketches.

Answer

Stepped-index multimode optical fibre will support many modes (FIGURE 6,a); its refractive index changes, ideally, as a step between the core and the cladding. FIGURE 6(b) gives the refractive index profile of a stepped-index multimode fibre.

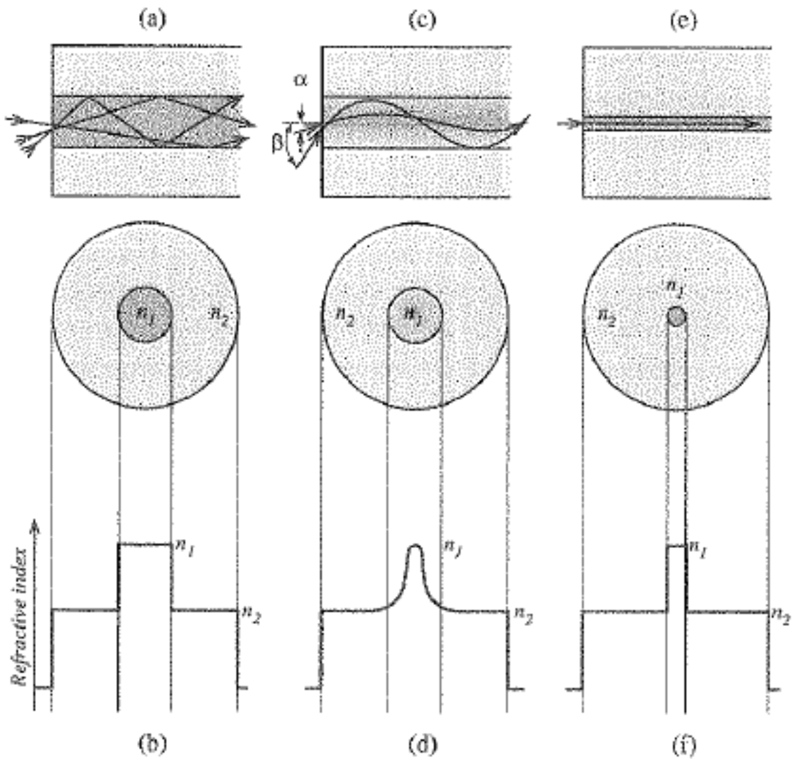

FIGURE 6

Graded-index multimode fibre. The refractive index profile of the graded-index multimode fibre, FIGURE 6(d), shows that here the refractive index of the core material is not uniform, but increases from the cladding value at the interface towards a maximum value at the centre of the core. The shape of the profile is parabolic and is designed to minimize modal dispersion in multimode fibre.

It works as follows:

The profile of the fibre causes the light rays to follow wave like paths (FIGURE 6(c)). The smaller the entry angle α of the ray, the more closely it will stay to the center of the core and the shorter will be its path length down the fibre. Rays with a larger entry angle β will make larger excursions into the outer core material and will therefore have a longer path length down the fibre.

Such rays, however, will spend more of their time travelling in material of a lower refractive index and, as the speed of light in a medium is given by c/n, will have a higher average speed than those travelling nearer to the core. The refractive index profile of the fibre is designed to get all modes to the end of the fibre at the same time.

Stepped-index monomode fibre

The maximum number of modes in a (two dimensional) fibre is given by equation:

$$m_{max} = \frac{2d}{\lambda}\left(1 - \left(\frac{n_2}{n_1}\right)^2\right)^{1/2}$$

For given values of n_1 and n_1, it is possible to make m_{max} less than two by making the fibre diameter d sufficiently small. Such a fibre would only support one mode, see FIGURES 6(e) and 6(d), a ray that travels axially down the fibre and modal dispersion should not be present.

Monomode fibres give the highest performance in terms of bandwidth and bitrate and also can give the widest repeater spacing. But they are more difficult to handle and joint because of the small core diameter.

(b) Inscribe some of the advantages of optical fibre as a transmission medium compared to electrical transmission.

Answer

1. Increase in bandwith/bitrate – in present, nearly 8000 telephone conversations can be carried by a monomode fibre (microwave – 1000, coaxial - 2000)
2. Reduced size and weight
3. Optical fibre is virtually immune from electromagnetic interference
4. Security – no energy is radiate outside of the cladding