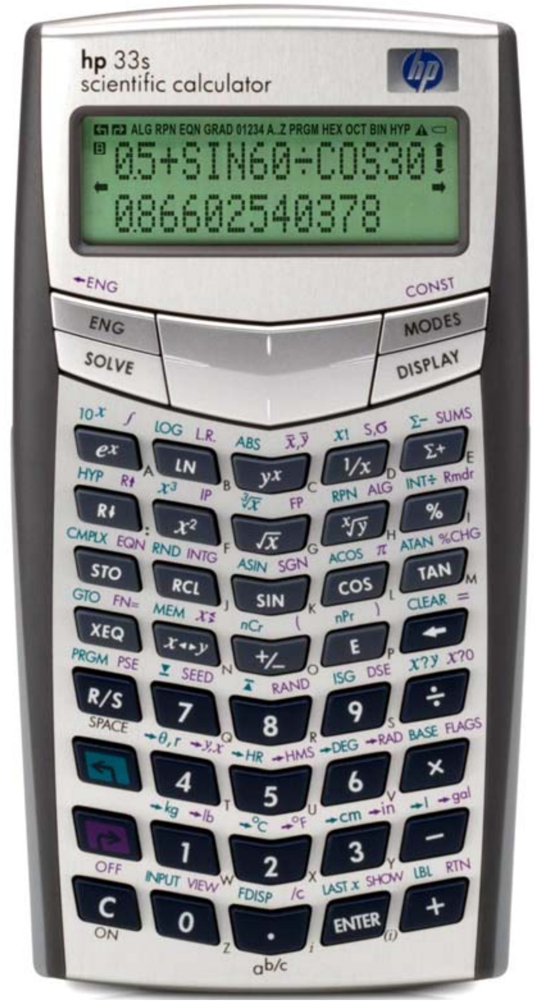
hp calculators



HP 33S Applications in electrical engineering

Applications in electrical engineering

Practice solving problems in electrical engineering

- Application 1: Transmission line impedance
- Application 2: Resistive attenuator design

Applications in electrical engineering

This training aid will illustrate the application of the HP 33S calculator to several problems arising in electrical engineering. These examples are far from exhaustive, but do indicate the incredible flexibility of the HP 33S calculator.

Practice solving problems in electrical engineering

Application 1: Transmission line impedance

The formulas below allow for the computation of the high frequency characteristic impedance for three types of transmission lines, where D is the input wire spacing, d is the wire diameter, ε is the relative permittivity, and h is the wire height.

Open two wire line $$Z_0 = \frac{120}{\sqrt{\varepsilon}} \mathrm{LN}\left(\frac{2D}{d}\right)$$ Figure 1

Single wire near ground $$Z_0 = \frac{138}{\sqrt{\varepsilon}} \mathrm{LOG}\left(\frac{4h}{d}\right)$$ Figure 2

Coaxial line $$Z_0 = \frac{60}{\sqrt{\varepsilon}} \mathrm{LN}\left(\frac{D}{d}\right)$$ Figure 3

In the examples that follow, the HP 33S will be used to solve problems involving these equations. If repetitive calculations with these equations is foreseen, they could be entered into the HP 33S as equations and solved in that manner.

<u>Example 1:</u> Compute Z_0 for RG-218/U coaxial cable with D = 0.68 inches, d = 0.195 inches, and ε = 2.3 (polyethylene).

<u>Solution:</u> In RPN mode: [6] [0] [ENTER] [2] [·] [3] [√x] [÷] [0] [·] [6] [8] [ENTER] [0] [·] [1] [9] [5] [÷] [LN] [×]

In algebraic mode: [6] [0] [÷] [2] [·] [3] [√x] [×] [↱] [(] [0] [·] [6] [8] [÷] [0] [·] [1] [9] [5] [↱] [)] [LN] [ENTER]

Figure 4

<u>Answer:</u> 49.42 ohms.

<u>Example 2:</u> Compute Z_0 for an open 2-wire line with D = 6 inches, d = 0.0808 inches, and ε = 1 (air).

<u>Solution:</u> Note that the division by the square root of 1 in the solutions below is unnecessary, but included for clarity.

In RPN mode: [1] [2] [0] [ENTER] [1] [√x] [÷] [6] [ENTER] [2] [×] [0] [·] [0] [8] [0] [8] [÷] [LN] [×]

In algebraic mode: [1] [2] [0] [÷] [1] [√x] [×] [↱] [(] [6] [×] [2] [÷] [0] [·] [0] [8] [0] [8] [↱] [)] [LN] [ENTER]

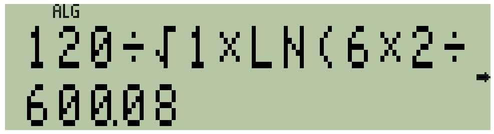


Figure 5

Answer: 600.08 ohms.

Example 3: Compute Z_0 for an air line consisting of a single 0.1285 inch wire six inches from a ground plane.

Solution: Note that $\varepsilon = 1$, since this is an air line.

In RPN mode: [1] [3] [8] [ENTER] [1] [√x] [÷] [4] [ENTER] [6] [×] [0] [.] [1] [2] [8] [5] [÷] [left-shift] [LOG] [×]

In algebraic mode: [1] [3] [8] [÷] [1] [√x] [×] [right-shift] [(] [4] [×] [6] [÷] [0] [.] [1] [2] [8] [5] [right-shift] [)] [left-shift] [LOG] [ENTER]

Figure 6

Answer: 313.44 ohms.

Application 2: Resistive attenuator design

The T attenuator can be used to match between two resistive impedances, R_{in} and R_{out}, as shown in the diagram in Figure 7.

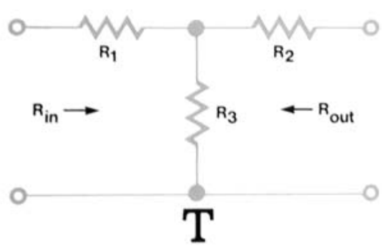


Figure 7

For the T attenuator, the formulas below will compute the minimum loss of the attenuator and values for the resistors R1, R2, and R3, which will yield an attenuator having any desired loss.

Minimum loss
$$M = 10 \times LOG\left(\sqrt{\frac{R_{in}}{R_{out}}} + \sqrt{\frac{R_{in}}{R_{out}} - 1}\right)^2$$
Figure 8

Resistor R3
$$R3 = \frac{2 \times \sqrt{N \times R_{in} \times R_{out}}}{N - 1}$$
Figure 9

Resistor R1 $$R1 = R_{in} \times \left(\frac{N+1}{N-1}\right) - R3$$ Figure 10

Resistor R2 $$R2 = R_{out} \times \left(\frac{N+1}{N-1}\right) - R3$$ Figure 11

where N is defined as $$N = 10^{\left(\frac{DbLoss}{10}\right)}$$ Figure 12

<u>Example 1:</u> Determine the element values for a T attenuator matching 75 Ω to 50 Ω with a 6 dB loss.

<u>Solution:</u> Solve for the value of N and store it in variable N.

In RPN mode: [1] [0] [ENTER] [6] [ENTER] [1] [0] [÷] [y^x] [STO] [N]

In algebraic mode: [1] [0] [y^x] [↱] [(] [6] [÷] [1] [0] [↱] [)] [ENTER] [STO] [N]

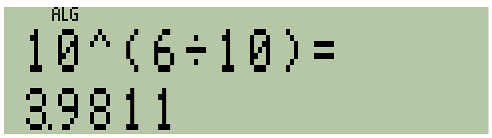


Figure 13

Solve for minimum loss.

In RPN mode: [7] [5] [ENTER] [5] [0] [÷] [1] [x↔y] [−] [↰] [LAST x] [√x] [x↔y] [+/−] [√x] [+] [x^2] [↰] [LOG] [1] [0] [×]

In algebraic mode: [1] [0] [×] [↱] [(] [↱] [(] [7] [5] [÷] [5] [0] [↱] [)] [√x] [+] [↱] [(] [7] [5] [÷] [5] [0] [−] [1] [↱] [)] [√x] [↱] [)] [x^2] [↰] [LOG] [ENTER]

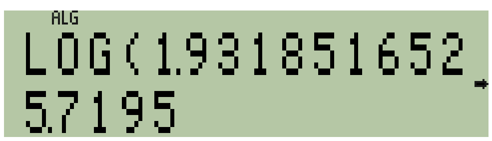


Figure 14

Solve for the resistor R3 and store its value in variable R.

In RPN mode: [RCL] [N] [ENTER] [7] [5] [×] [5] [0] [×] [√x] [2] [×] [RCL] [N] [1] [−] [÷] [STO] [R]

In algebraic mode: [2] [×] [↱] [(] [RCL] [N] [×] [7] [5] [×] [5] [0] [↱] [)] [√x] [÷] [↱] [(] [RCL] [N] [−] [1] [↱] [)] [ENTER] [STO] [R]

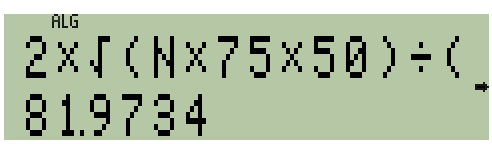


Figure 15

Solve for the resistor R1.

In RPN mode: [RCL] [N] [1] [+] [RCL] [N] [1] [−] [÷] [7] [5] [×] [RCL] [R] [−]

In algebraic mode: [↱] … [7] [5] [×] [↱] [(] [↱] [(] [RCL] [N] [+] [1] [↱] [)] [÷] [↱] [(] [RCL] [N] [−] [1] [↱] [)] [↱] [)] [−] [RCL] [R] [ENTER]

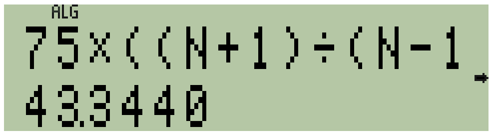


Figure 16

Solve for the resistor R2.

In RPN mode: [RCL] [N] [1] [+] [RCL] [N] [1] [−] [÷] [5] [0] [×] [RCL] [R] [−]

In algebraic mode: [5] [0] [×] [↱] [(] [↱] [(] [RCL] [N] [+] [1] [↱] [)] [÷] [↱] [(] [RCL] [N] [−] [1] [↱] [)] [↱] [)] [−] [RCL] [R] [ENTER]

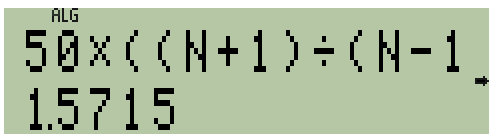


Figure 17

Answer: The minimum loss is 5.7195 dB. The value of R1 is 43.3440 ohms, R2 is 1.5715 ohms, and R3 is 81.9734 ohms.

Example 2: Determine the element values for a T attenuator matching 50 Ω to 50 Ω with a 10 dB loss.

Solution: Solve for the value of N and store it in variable N.

In RPN mode: [1] [0] [ENTER] [1] [0] [ENTER] [1] [0] [÷] [y^x] [STO] [N]

In algebraic mode: [1] [0] [y^x] [↱] [(] [1] [0] [÷] [1] [0] [↱] [)] [ENTER] [STO] [N]

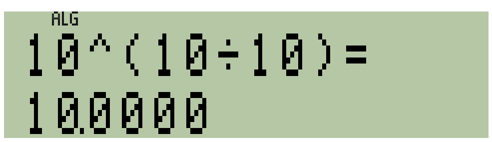


Figure 18

Solve for minimum loss.

In RPN mode: [5] [0] [ENTER] [5] [0] [÷] [1] [x↔y] [−] [↰] [LASTx] [√x] [x↔y] [+/−] [√x] [+] [x^2] [↰] [LOG] [1] [0] [×]

In algebraic mode: [1] [0] [×] [↱] [(] [↱] [(] [5] [0] [÷] [5] [0] [↱] [)] [√x] [+] [↱] [(] [5] [0] [÷] [5] [0] [−] [1] [↱] [)] [√x] [↱] [)] [x^2] [↰] [LOG] [ENTER]

Figure 19

Solve for the resistor R3 and store its value in variable R.

In RPN mode: RCL N ENTER 5 0 × 5 0 × √x 2 × RCL N 1 − ÷ STO R

In algebraic mode: 2 × ↱ (RCL N × 5 0 × 5 0 ↱) √x
÷ ↱ (RCL N − 1 ↱) ENTER STO R

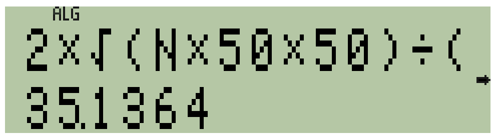


Figure 20

Solve for the resistor R1.

In RPN mode: RCL N 1 + RCL N 1 − ÷ 5 0 × RCL R −

In algebraic mode: 5 0 × ↱ (↱ (RCL N + 1 ↱) ÷ ↱ (RCL N − 1
↱) ↱) − RCL R ENTER

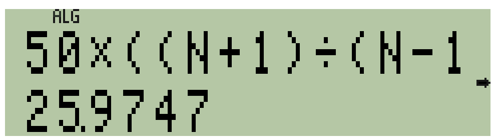


Figure 21

Solve for the resistor R2.

In RPN mode: RCL N 1 + RCL N 1 − ÷ 5 0 × RCL R −

In algebraic mode: 5 0 × ↱ (↱ (RCL N + 1 ↱) ÷ ↱ (RCL N − 1
↱) ↱) − RCL R ENTER

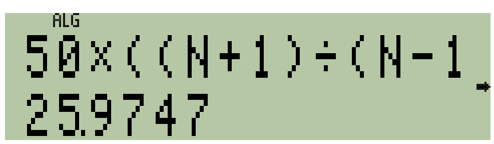


Figure 22

Answer: The minimum loss is 0.0 dB. The value of R1 is 25.9747 ohms, R2 is 25.9747 ohms, and R3 is 35.1364 ohms.