Frontpage

Department of Physics

Examination paper for TFY4190 Instrumentation

Examination date: June 6 , 2024

Examination time (from-to): 9:00 to 13:00

Permitted examination support material:
C: Specified printed support material is allowed. A specific basic calculator is allowed.
Allowed: Mathematical formulas (Rottmann or equivalent). English dictionary.

Academic contact during examination: Steinar Raaen
Phone: 482 96 758

Academic contact present at the exam location: No

OTHER INFORMATION

Get an overview of the question set before you start answering the questions.

Read the questions carefully and make your own assumptions. If a question is unclear/vague, make your own assumptions and specify them in your answer. Only contact academic contact in case of errors or insufficiencies in the question set. Address an invigilator if you wish to contact the academic contact. Write down the question in advance.

No hand drawings: This exam does not include hand drawings. If you receive hand drawing sheets, this is by mistake. **You will not be able to submit the sheets, and they will not be graded.**

Weighting: *The maximum number of points is indicated in each problem.*

Notifications: If there is a need to send a message to the candidates during the exam (e.g. if there is an error in the question set), this will be done by sending a notification in Inspera. A dialogue box will appear. You can re-read the notification by clicking the bell icon in the top right-hand corner of the screen.

Withdrawing from the exam: If you become ill or wish to submit a blank test/withdraw from the exam for another reason, go to the menu in the top right-hand corner and click “Submit blank”. This cannot be undone, even if the test is still open.

Access to your answers: After the exam, you can find your answers in the archive in Inspera. Be aware that it may take a working day until any hand-written material is available in the archive.

1 P1-TFY4190v2024

Convert the decimal number 54.285 to binary format.

Enter the answer here: .

Maximum marks: 2

2 P2-TFY4190v2024

A single precision binary number consists of 32 bits. The MSB gives the sign, the next 8 bits the exponent, and the 23 remaining bits give the fraction. A bias of 127 is used for the exponent.
What is the decimal value of the double precision number given in hexadecimal form by ABEA8000 ?

Enter **$\log_{10}$ (|decimal value|)** here:

Maximum marks: 2

3 P3-TFY4190v2024

A 12bit AD converter operates in a voltage range from -5 to 5 V.
What is the resolution of the ADC?

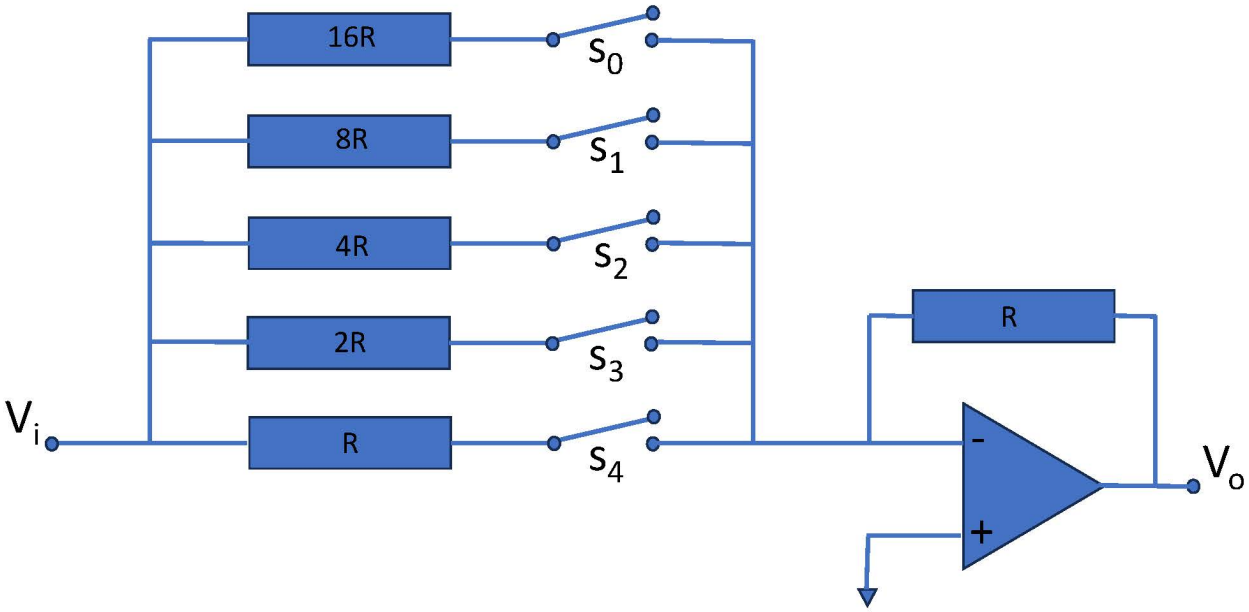
Enter the number here: V

The output voltage is given in binary 2-complement form. What is the analogue input voltage when the output is given by the binary number 1111 1101 0000?

Enter the number here: V

Maximum marks: 2

4 P4-TFY4190v2024



The DAC shown in the figure above consists of an ideal operational amplifier, resistors and switches. The reference voltage V_i = +4V, and R = 100 Ω.

Find the output voltage corresponding to the digital input of 27.

Write the answer here: .

Maximum marks: 2

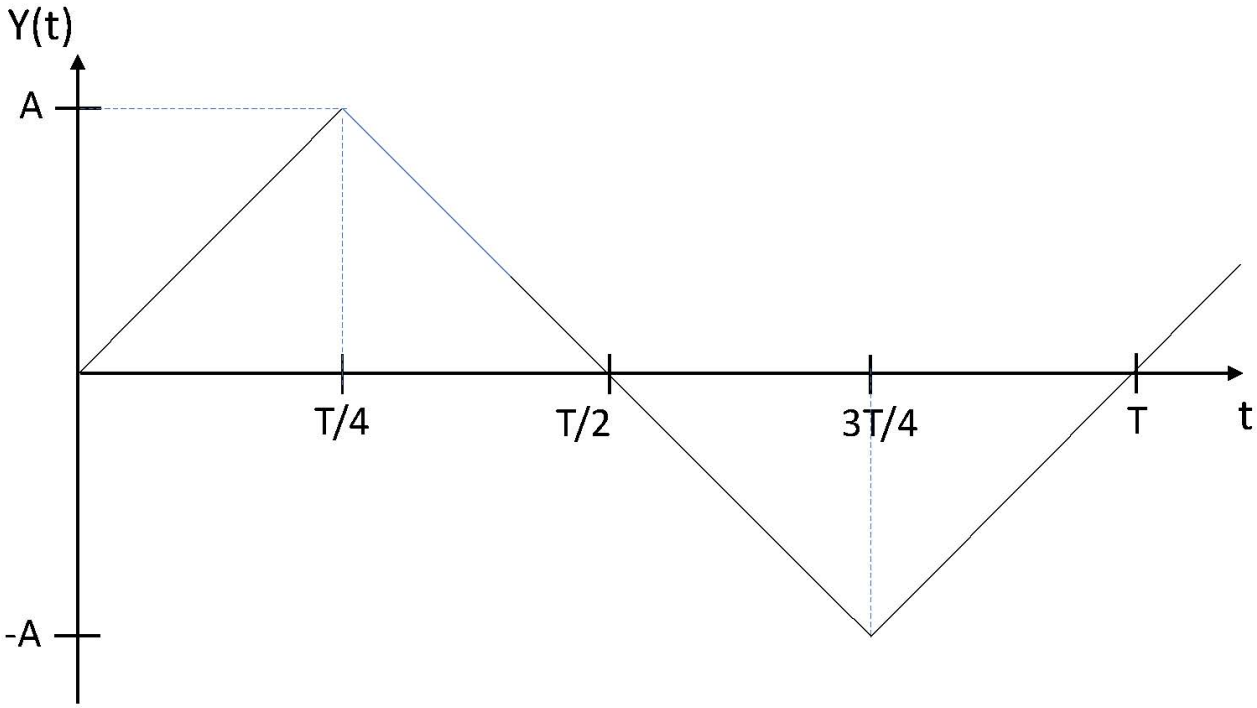
5 P5-TFY4190v2024

The pressure in a vacuum chamber is measured 15 times. The results are:
1.1, 1.2, 1.0, 1.2, 0.9, 1.1, 1.2, 1.0, 0.8, 1.0, 1.3, 1.0, 1.0, 0.9, 1.1 (in units 10^{-7} Pa).
What is the precision in % for the third measurement (value $1.0 \cdot 10^{-7}$ Pa) ?
Select one alternative:

- 96 %
- 90 %
- 95 %
- 98 %
- 92 %

Maximum marks: 2

6 P6-TFY4190v2024



One period of a periodic signal is shown in the figure above. The maximum value of the signal is A=6V, and the period is T.

What is the RMS value of the signal?

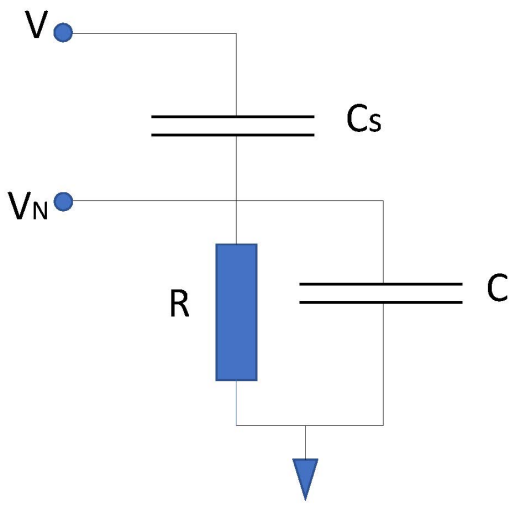
Enter the answer here: V.

What is the rectified average of the signal?

Enter the answer here: V.

Maximum marks: 2

7 P7-TFY4190v2024



The input circuit of an amplifier can be considered to consist of a $R = 10M\Omega$ resistor in parallel with a $C = 100pF$ capacitor as shown in the figure above. A power line of frequency $f = 50Hz$ and peak to peak voltage $V = 320V$ results in a noise voltage of $V_N = 1V$ at the input of the amplifier due to capacitive coupling.

Find the capacitance C_S between the power line and the input circuit.

Select one alternative:

- 0.52 pF
- 0.62 pF
- 1.24 pF
- 0.89 pF
- 1.04 pF

Maximum marks: 2

8 P8-TFY4190v2024

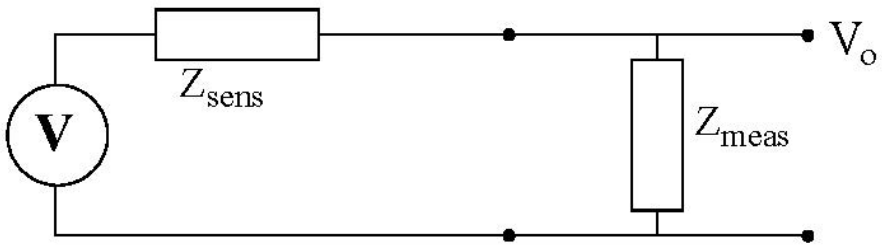
A disturbance in form of a sharp voltage pulse (delta pulse) is impinging on a system of transfer function F(s) as shown above. The transfer function of the measurement system is given by: $F(s) = \frac{s}{(s+1)(s+2)}$.

How large is the effect of the disturbance on the output signal y(t) after t = 0.5s ?

Enter the answer in % of the maximum disturbance: [ ] %.

Maximum marks: 2

9 P9-TFY4190v2024



The figure above show an equivalent circuit for a voltage source and a measurement circuit. The impedance for the source $Z_{sens} = 50 + j20\,\Omega$.
What should the impedance Z_{meas} be for transfer of maximum power from the source to the measurement circuit?

Enter the real part of the answer here: Ω

Enter the imaginary part of the answer here: $j\Omega$

What should the impedance Z_{meas} be for maximum accuracy of the output signal V_o?
Select one alternative

- $Z_{meas} = Z_{sens}$
- $Z_{meas} >> Z_{sens}$
- $Z_{meas} << Z_{sens}$

Maximum marks: 3

10 P10-TFY4190v2024

Convert decimal 4038.356 to hexadecimal format.
The answer is given by:
Select one alternative:

- FC6.4FF3...
- FC6.6011...
- FC6.5C1E...
- FC6.5B30...
- FC6.5B22...

Maximum marks: 2

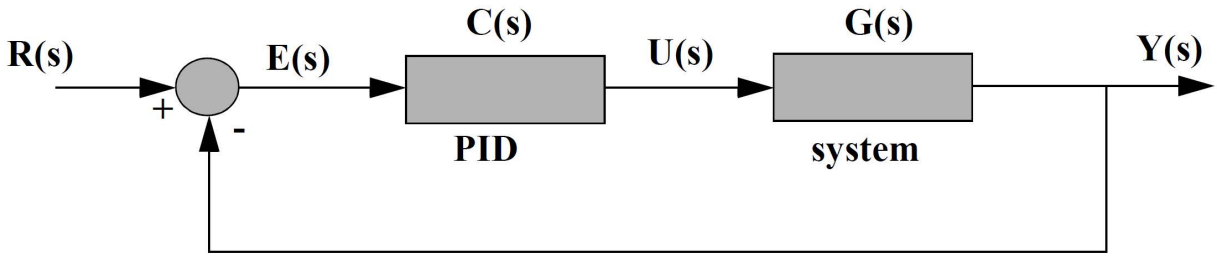
11 P11-TFY4190v2024

A harmonic signal $u(t) = 5cos\omega t\ [V]$ is to be sampled by using a 14 bit ADC. The frequency of the signal is given by $f = 1kHz$. The signal should not increase by more than 25% of the resolution between samplings. Find the maximum sampling time that may be used for digitizing the signal.

Enter the maximum sampling time here: ns.

Maximum marks: 2

12 P12-TFY4190v2024



A PID regulated system is shown in the figure above.
The transfer function of the system is given by $G(s) = \frac{1}{0.01s^3+s+1}$
Assume proportional control and harmonic signal and find the angular frequency where the regulated system starts to oscillate.

Enter the answer here: [ ] rad/s.

Find the period of the oscillations at this point.

Enter the oscillation period here: [ ] s.

Maximum marks: 2

13 P13-TFY4190v2024

A signal has bandwidth from 5 to 25000Hz. Only frequencies up to 18000Hz are of interest for a particular application. Assume that a digital sampling is to be done of the signal.
What should the minimum sampling frequency be to avoid aliasing?

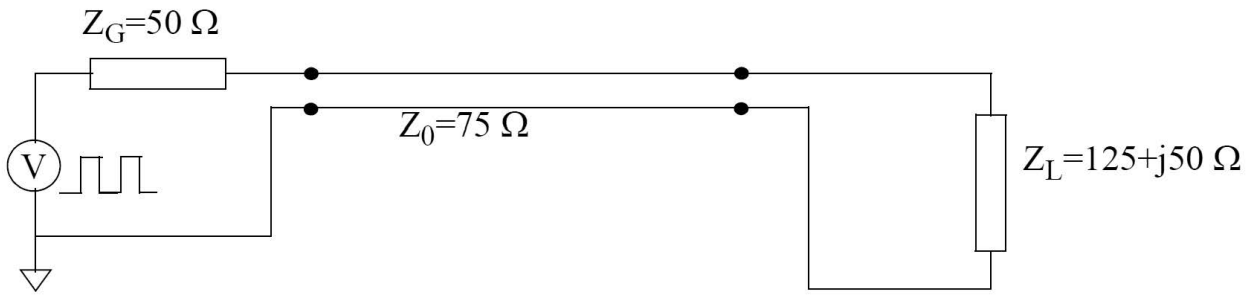
Enter the answer here: [ ] Hz

What should the cut-off frequency be for the low-pass filter?

Enter the answer here: [ ] Hz

Maximum marks: 2

14 P14-TFY4190v2024



A high frequency pulse train enters a transmission line as shown in the figure. At the end of the transmission line is a complex load that consists of a serial coupling of a resistor and a solenoid. Find the reflection coefficients at the load. Give the answer in amplitude and phase angle. Assume loss-less transmission line.

The amplitude of the reflection coefficient is: [ ] .

The phase of the reflection coefficient is: [ ] ^{o} (degrees).

Maximum marks: 2

15 P15-TFY4190v2024

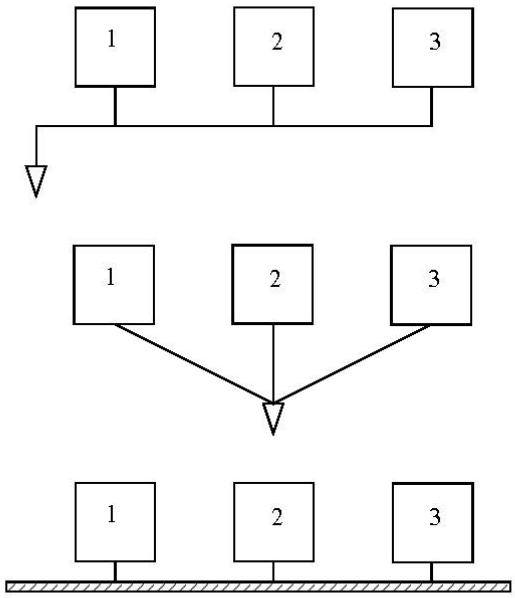
In the figure to the right below are shown three grounding schemes.
Which statement belongs to each figure?

Place the statements on top of the correct figure (drag and drop):

Low ground currents

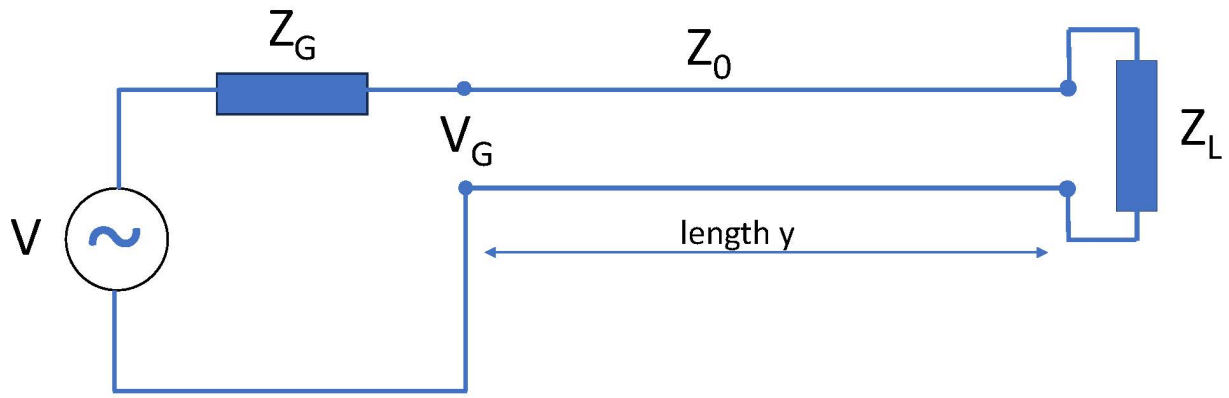
High frequency signal

High ground currents and low frequency



Maximum marks: 3

16 P16-TFY4190v2024



A high frequency voltage signal of angular frequency $\omega = 1 \cdot 10^9 s^{-1}$ is transmitted from a source to a transmission line of length y, as shown in the figure above.
The inductance and capacitance per length of the transmission line are $L = 250nH/m$ and $C = 100pF/m$, respectively.
The characteristic impedance of the transmission line is $Z_0 = \sqrt{L/C}$.The transmission line may be assumed to be loss-less. The load impedance is 150Ω.

Voltage and current as measured from the load impedance is written:
$V(d) = Be^{\gamma d}[1 + \Gamma_R e^{-2\gamma d}]$ and $I(d) = \frac{Be^{\gamma d}}{Z_0}[1 - \Gamma_R e^{-2\gamma d}]$
Assume loss-less transmission line so that $\gamma = \alpha + j\beta \approx j\beta = j\omega\sqrt{LC}$

The line impedance at distance d from the load may be found by $Z(d) = \frac{V(d)}{I(d)}$.
Find the magnitude of the ratio $\left|\frac{Z(d)}{Z_0}\right|$ at distance $d = 20cm$ from the load.

Enter the answer here: Ω.

Maximum marks: 3

Solution Exam June 6, 2024

Problem 1

Convert 54.285 to binary format. 54 => 110110, 0.285 => 0. 0100100011.. (0.01001 is sufficient)

Problem 2

SPFP number ABEA8000 => 1|010 1011 1|110 1010 1000 0000 0000 0000

sign is negative, exponent is $2^6 + 2^4 + 2^2 + 2^1 + 2^0 = 64+16+4+2+1 = 87$ – bias 127 => -40

1 + fraction = 1 + ½ + ¼ +1/16 +1/64+1/256 = 1.8320 => Number = $-2^{-40} * 1.8320 = -1.67\ 10^{-12}$

$\text{Log}_{10}(|-1.67\ 10^{-12}|) = -11.78$

Problem 3

resolution=LSB=$\frac{5-(-5)}{2^{12}-1}$= 0.0024 V

Binary number is: 1111 1101 0000
sign is negative, 2komp = 000 0011 0000 = 2^5+2^4= 48
input voltage= -48*0.0024V= -0.117 V

Problem 4

DAC (5 bits), $S_4S_3S_2S_1S_0$ = 11011 => 27 and $I_x = (V_i/R)*(1+1/2+1/8+1/16) = (V_i/R)*(27/16) = -V_o/R$,

=> Vo=-4V*27/16 = -6.75V

Problem 5

p_n = 1-|x_5-<x>|/|<x>| = = 1-|1.0-1.053|/1.053 = 0.95 = 95%

Problem 6

Y(t)=4At/T, $Y_{RMS} = \sqrt{\frac{4}{T}\int_0^{\frac{T}{4}}(\frac{4A}{T}t)^2 dt}$ = $\frac{A}{\sqrt{3}} = 0.577A = 3.46$, $Y_{rectified} = \frac{4}{T}\int_0^{\frac{T}{4}}\frac{4A}{T}tdt = \frac{A}{2} = 0.50A = 3.0$

Problem 7

$$I = \frac{V - V_N}{\frac{1}{j\omega C_S}} = \frac{V_N(1 + j\omega RC)}{R} => \frac{V_N}{V} \approx \frac{j\omega RC_S}{1 + j\omega RC} => \left|\frac{V_N}{V}\right|^2 = \frac{(\omega RC_S)^2}{1 + \omega^2 R^2 C^2}$$

$$C_s = \left|\frac{V_N}{V}\right|\frac{1}{R}\sqrt{\frac{1}{\omega^2} + R^2C^2} = 1.04pF$$

Problem 8

$$R(s) = 1\ and\ F(s) = \frac{s}{(s+1)(s+2)}$$

From Laplace table $y(t) = f(t) = 2e^{-2t} - e^{-t} => y(0.5s) = 0.13 = 13\%$

Problem 9

Maximum power transfer => $Z_{meas} = Z_{sens}^* = 50 - j20\ \Omega$

Maximum accuracy of output signal if $Z_{meas} >> Z_{sens}$

Problem 10

Convert 4038.356 to hexadecimal.

4038/16 = 252 + 6/16
252/16 = 15 + 12/16
15/16 = 0 + 15/15

=> FC6

0.356*16 = 0.696 + 5
0.696*16 = 0.136 +11
0.136*16 = 0.176 + 2
0.176*16 = 0.816 + 2
0.816*16 = 0.056 + 13

=> 5,11,2,2,13, = 5B22D…

Problem 11

$u(t) = 5\ cos\omega t \Rightarrow \frac{du}{dt} = -5\omega\ sin\omega t \Rightarrow \left|\frac{du}{dt}\right|_{max} = 5\omega = 10\pi f$, which is maximum rate of change

Resolution $q = \frac{5-(-5)}{2^{14}-1}V = 0.61mV$, and we have that $\frac{0.25q}{\tau} = 10\pi f \Rightarrow \tau = \frac{q}{40\pi f} = 4.86ns$

Problem 12

$$G(s) = \frac{1}{0.01s^3 + s + 1} \overset{s=j\omega}{\Longrightarrow} G(\omega) = \frac{1}{1 + j(\omega - 0.01\omega^3)} = \frac{1 + j(0.01\omega^3 - \omega)}{1 + (\omega - 0.01\omega^3)^2}$$

$\angle G(\omega) = \tan^{-1}(0.01\omega^3 - \omega)$ since tan(180°) = 0, we get ω(180°) = 10 rad/s

$$\omega T_0 = 2\pi \Rightarrow T_0 = \frac{2\pi}{\omega} = 0.628\ s$$

Problem 13

Nyquist f_s = 50kHz, $f_{cut\text{-}off}$ = 18kHz

Problem 14

$$\Gamma_R = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{1 + j}{4 + j} = \frac{(1 + j)(4 - j)}{(4 + j)(4 - j)} = \frac{5}{17} + j\frac{3}{17}$$

$$|\Gamma_R| = \frac{\sqrt{25 + 9}}{17} = 0.343\ \ and\ \ \angle\Gamma_R = \tan^{-1}\frac{3}{5} = 30.96°$$

Problem 15

Low ground currents => use serial coupling

High frequency signal => use ground plane

High ground currents, low frequency => use star coupling (parallel coupling)

Problem 16

HiFreqSignalTrans.

$$\gamma = \alpha + j\beta \xrightarrow{loss-less,\alpha=0} j\beta = j\omega\sqrt{LC} = j1 \cdot 10^{9}\sqrt{250 \cdot 10^{-9}\ 100 \cdot 10^{-12}}m^{-1} = j5\ m^{-1}$$

$$\frac{Z(d)}{Z_0} = \frac{1 + \Gamma_R e^{-2\gamma d}}{1 - \Gamma_R e^{-2\gamma d}} = \frac{1 + \Gamma_R cos(2\beta d) - j\Gamma_R sin(2\beta d)}{1\ -\ \Gamma_R cos(2\beta d) + j\Gamma_R sin(2\beta d)}$$

$$A = \left|\frac{Z(d)}{Z_0}\right| = \sqrt{\frac{\left(1 + \Gamma_R cos(2\beta d)\right)^2 + \left(\Gamma_R sin(2\beta d)\right)^2}{\left(1\ -\ \Gamma_R cos(2\beta d)\right)^2 + \left(\Gamma_R sin(2\beta d)\right)^2}}, \qquad \Gamma_R = \frac{Z_L - Z_0}{Z_L + Z_0} = 0.5$$

d=0.2m => 2βd=2.0 => A=0.707