## Library 1666: Electrical Engineering

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## 1. Disclaimer \& Copyright

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This software is not sold, only the right for using it is granted. Using this software is only allowed on the calculator the software has been licensed for.
This program has been tested but may contain errors. I'm making no warranty of any kind with regard to this software, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. I shall not be liable for any errors or for incidental or consequential damages in connection with the furnishing, performance, or use of this software. Suggestions, criticism and/or improvement suggestions can be send to the author at Software49g@gmx.de. All rights reserved. © Andreas Möller 2013

## 2. Credits

Thanks to ACO for the HP 49G, Wolfgang Rautenberg for OT49, Eduardo M. Kalinowski for "Programming in System RPL", Mika Heiskanen for BZ and various post from different authors in comp.sys.hp48. Without them this program couldn't been written.

## 3. System Requirements \& Installation

### 3.1. System Requirements

Library 1666: Electrical Engineering has been coded and compiled with Debug4x and is written in System RPL. It is designed for the HP 49G+ and HP 50G.
Electrical Engineering requires TreeBrowser and GUISLV/GUIMES is recommended as the default solver for it.
If you are not familiar about TreeBrowser and GUISLV/GUIMES then please read the documentations that comes with it.

### 3.2. Installation \& Deinstallation

Use the installation program EEI on the SD card to install / update / modify / delete the Electrical Engineering library.

Insert the SD card into the turned off calculator and then power up the calculator. Now start the installation program EEI from the SD card.
$->$ in RPN mode key in :3:EEI [ENTER] [EVAL]
$->$ in ALG mode key in EVAL(:3:EEI) [ENTER]
The installation program will guide you through the installation process.

## 4．Using the library

## 4．1．Starting Electrical Engineering

Electrical Engineering can be started in different ways．
Through the APPS key

or through the library menu via $\quad \stackrel{\Gamma}{L I B}$ ．


## ELECTR <br> EEヨாヨlusis <br> EEセquヨチi ロாョ <br> EECommands EEversion

### 4.2. Choosing a set of equations of a subtopic

Move the cursor to a subtopic and then press TOOL to open a choose box to select the equations which will be passed to the Multiple Equation Solver.


``` Resistive Gircuits
```



``` -0hH's LITH ITN FOHET
Tehpridture EfFECt
Haximuh Foher Transper
In and I sodrce Equivilence
Edpucitance and Electric Fields
Inductance and Hagnetish
Electron Hotion
Heters ond Eridse Gircuits
FL and FLC Circuits
```



Butistive Gircuits

Inductance and Hagnetish
Electron Hotion
Heters ond Eridse Gircuits
FL and Fil Girclits
+EMFH WHES日FICTG SI HALT HEOLT







Ares
EDIT WHES UIEN HLL HEOLT

### 4.3. Choosing all equations of a subtopic

Move the cursor to a subtopic and then press (APPS to start the Multiple Equation Solver with all equations of that subtopic.


### 4.4. Choosing a single equation of a subtopic

Move the cursor to the equation of a subtopic and then press APPS
*)
*)
Empucitance dnd Eldetric Fislds
Empucitance dnd Eldetric Fislds
Foint churge
Foint churge
Lony Charged Line
Lony Charged Line
Chorued bisk
Chorued bisk


FITGMESHINS
FITGMESHINS
Codxid! Edble
Codxid! Edble
sphere
sphere
Inductunce and Hagnetish
Inductunce and Hagnetish
Elsctron Hotion
Elsctron Hotion



Resistive Gircuits
Edpucitunce and Eldetric Figlds
Foint Charge
Ghat. ヨrti i

Conxia! Eable
sphere
Inductance and Hognetish
Electron Hotion


## 5. Using Analysis

### 5.5. AC Circuits

\&ELECTRICAL EMIIIEEFIMG ACIALYSIS:



```
Ooltage [ivider
Curient divider
Girguit FerForHance
Folyphose Gircuits
LadNer fistHor*
Filter dasisn
gorin and Frequsnoy
Fovrist Transforns
THo-Fort listHor-K=
-EXFH WHES FICT SI a HHLT HELF
```


### 5.5.1. Impedance Calculations

## Example:

Compute the impedance of a series RLC circuit consisting of a 10_Ohm resistor, a 1.5_Henry inductor and a 4.7_Farad capacitor at a frequency of 100_Hertz.

## Solution:





```
        ConFig:Seriss
    Elehents: FLE
Frequenisy: 100_Hz
        F: 10_\
        L:1.5_H
        6:4.7.F
        z: [id. Dididid, 542.4rr45.
        Y:0.000011,-0.001051)
Fissult: Impedances dis
+ETR WHFE WIEN \ SOLNE
```



### 5.5.2. Voltage Divider

## Example:

Calculate the voltage drop across a series of loads connected to a voltage source of $\left(110+15^{*} \mathrm{i}\right)$ volts. The load consists of a 50 ohm resistor, and impedances of $\left(75+22^{*} \mathrm{i}\right)$, and (125-40*i) ohms.

## Solution:





### 5.5.3. Current Divider

## Example:

Calculate the voltage drop across impedances connected in parallel to a current source of $\left(50+25^{* i}\right)$. The load consists of a 50 ohm resistor, and impedances of ( $75+22^{* i}$ ), and (125-40*i) ohms.

## Solution:




## 5．5．4．Circuit Performance

## Example：

Calculate the performance parameters of a circuit consisting of a current source （10－5＊i）with a source admittance of（ $0.0025-0.0012^{*} i$ ）and a load of（ $0.0012+0.0034 * i$ ）．

## Solution：



```
Lond Typu: bidHittance
Is: (10.,-5.)
Ys: (.0035,-.0012)
YL: (.0012, .0034)
Chouse Imprdonce or HdHittumes
```





```
VL: [140E.130053E5,-21$5.544E00..
```

VL: [140E.130053E5,-21\$5.544E00..
IL:9.11494873179,2.1472623215..
IL:9.11494873179,2.1472623215..
F: 2094.92111165
F: 2094.92111165
4: -23935.7792165
4: -23935.7792165
NI : З43コ2. 3512262
NI : З43コ2. 3512262
@: -1. 231501371234
@: -1. 231501371234
FF:.332S20117736
FF:.332S20117736
FHOX:12500
FHOX:12500
Lond woltage (Wy
Lond woltage (Wy
+ETR WIEN प \ W W

```
+ETR WIEN प \ W W
```


IL: 5.11454273173, 2.1472623216..
F: 2094.92111169
\&: - 23935.7792165
UI : 24322. 3912362
由: -1.231501371324
FF: . $332 \mathrm{ESJ0117735}$
FHIX: 13500

Lodd gdHittonce For hox. poher ta

+ ETR WIED


### 5.5.5. AC Circuits Command Line Programs



VZDIV: Voltage Divider Load Type Impedance VYDIV: Voltage Divider Load Type Admittance CZDIV: Current Divider Load Type Impedance CYDIV: Current Divider Load Type Admittance ZCPERF: Circuit Performance Load Type Impedance YCPERF: Circuit Performance Load Type Admittance

### 5.6. Polyphase Circuits

```
&ELECTFIGAL E|GIMEERI|G ANIALYSIS%
ALEGrEDits
```



```
Wye + & EonNSTSion
Ed|miced Hys Lond
EGlanied i Lond
LIdder [lethor'h
Filter Design
gininmu Frequency
Fo|risi Tronsforis
THo-Fort liethorks
Tronsformer Ferformonice
-EXFH WHES FICT SI G HBLT HELF
```


### 5.6.1. $\quad$ Wye $\leftrightarrow \Delta$ Conversion

## Example:

Compute the Wye impedance equivalent of a $\Delta$ network with impedances ( $75+12^{*} \mathrm{i}$ ), (75-12*i), and 125 ohms.

## Solution:

SOLTE

```
Inputt Typu: & + Y
Inputt Typu: & + Y
ZA: (75.,12.)
ZA: (75.,12.)
2E: (75.,-12.)
2E: (75.,-12.)
20:135
20:135
21:
21:
23:
23:
23:
23:
Fesult: Y Impugances (ox)
Fesult: Y Impugances (ox)
+ETR WHES WIEN
+ETR WHES WIEN


\section*{5．6．2．Balanced Wye Load}

\section*{Example：}

A Wye network consists of three impedances of（50＋25＊i）with a line voltage of 110 volts across line 1 and 2．Find the line current and power measured in a two－wattmeter measurement system．

\section*{Solution：}




\section*{5．6．3．Balanced \(\Delta\) Load}

\section*{Example：}

A Delta network consists of three impedances of（50－25＊i）with a line voltage of 110 volts across line \(A\) and \(B\) ．Find the line current and power measured in a two－wattmeter measurement system．

\section*{Solution：}

\begin{tabular}{|c|c|c|c|}
\hline \multicolumn{4}{|l|}{} \\
\hline \multicolumn{4}{|l|}{V6\％： 055.95 .2627944162\()\)} \\
\hline \multicolumn{4}{|l|}{IA ： \(3.40210235533,-.2042047106 .\).} \\
\hline \multicolumn{4}{|l|}{} \\
\hline \multicolumn{4}{|l|}{} \\
\hline \multicolumn{4}{|l|}{F ： 193.5} \\
\hline \multicolumn{4}{|l|}{ННЕ：306． 568740914} \\
\hline \multicolumn{4}{|l|}{Н⿵冂： 374.231259085} \\
\hline Wolto & OSt E0 & & \\
\hline ＋ 8 TH & WIEW & & 明 \\
\hline
\end{tabular}

\subsection*{5.6.4. Polyphase Circuits Command Line Programs}
```

Y'*
\triangleHOAD
YLOFD

```

\section*{T+ \(4+{ }^{\circ}\)}
\(Y \rightarrow \Delta: \quad\) Wye \(\leftrightarrow \Delta\) Conversion Input Type \(Y \rightarrow \Delta\)
\(\Delta \rightarrow Y: \quad\) Wye \(\leftrightarrow \Delta\) Conversion Input Type \(\Delta \rightarrow Y\)
\(\Delta\) LOAD: Balanced \(\Delta\) Load
YLOAD: Balanced Wye Load

\subsection*{5.7. Ladder Network}
\&ELECTRIGAL EMIIIEERIIIG ANALYSIS
AL Gircuits.
Folyphose Eircuits

Fit ter desizin
Gin ond Frequency
Fonrist Tronsforts
THO-FOTt liethorks
Tronsforter Fsifortance
Transhission Lines
Error Functions
```

WhES FICT SI 日 HHLT SOLNE

```

\section*{Example:}

A transistor amplifier is characterized by a base resistance of 2500_ \(\Omega\), a current gain of 100_A and is operating at a frequency of 10000_Hertz.


This schematic can be reduced to a ladder network consisting of a parallel capacitor of \(318 \_\)pF and a controlled current of \(2500 \_\Omega\) for rb and 100_A for \(\beta\), a parallel resistor of \(1 \_M \Omega\) and a series capacitor of \(0.638 \_\mu \mathrm{F}\).


Solution:









\subsection*{5.8. Filter Design}
```

\&ELECTFICHL E|IGIIEEFIIIG ARIALYSIS%
AL Gircuits
Folyphose Gircuits
Lodder listubork
*174% uretym
Thabyshme Filter
EuttarHorth Filter
HCtive Filter
gininnd Frequency
Fo|rier Tronsforis
THo-Fort lictHor-k
Tromsformer FerFormonice
-EXFH WHES FICT SI G HBLT HELF

```

\subsection*{5.8.1. Chebyshev Filter}

\section*{Example:}

Design a low-pass Chebyshev filter with a cutoff at 500 _Hz, a termination resistance of \(50 \_\Omega, 3 \mathrm{~dB}\) pass band ripple and a 30 dB attenuation at 600 Hz .

\section*{Solution:}

```

    Char:LON PEES
        6:50]
        F0:5010_Hz
        F1:6010}-H
        \Deltadb: 301dB
    Fipple:3_dB
    Chobse bundpuss churdeteristic
CHODS \ CEOLTE

```


\section*{5．8．2．Butterworth Filter}

\section*{Example：}

Design a 100 ＿Hz wide Butterworth band pass filter centered at 800 ＿Hz with a 30＿dB attenuation at \(900 \_\mathrm{Hz}\) ．The termination and source resistance is \(50 \_\)．


```

        F: SG_I
        f0: 8010_Hz
        F1:9610_Hz
        \Deltadb: 301dB
    EandHidth: 106]Hz
Chouse bondpugs churucteristic
CHODS
|SOLTE

```

響 Result：EuttsrHorth Filter 多響 L3：0． 001064363016
ᄂ4： 0.15373186991
c4： 0.0001001025745
c5：0． 0.010104501582
L5：0． 000107921515
L6：0． 04119233039

＋STR WIED

\subsection*{5.8.3. Active Filter}

\section*{Example:}

Design a High Pass active filter with a cutoff at \(10 \_\mathrm{Hz}\), a midband gain of \(10 \_\mathrm{dB}\), a quality factor of 1 and a capacitor of \(1 \_\mu \mathrm{F}\).

```

Type:High Fges
F0:10_Hz
A: 10_dB
\&:1
C:1_\muF
Choose Filter Type
CHODS
150LTE

```


\subsection*{5.8.4. Filter Design Command Line Programs}


CHLP: Chebyshev Filter Low Pass
CHHP: Chebyshev Filter High Pass
CHBP: Chebyshev Filter Band Pass
CHBE: Chebyshev Filter Band Elimination


BWLP: Butterworth Filter Low Pass
BWHP: Butterworth Filter High Pass
BWBP: Butterworth Filter Band Pass
BWBE: Butterworth Filter Band Elimination


ACLP: Active Filter Low Pass
ACHP: Active Filter High Pass
ACBP: Active Filter Band Pass

\subsection*{5.9. Gain and Frequency}
\&ELEGTFIGAL EMGIDEERIDG ANALYSIS
Folyphose Gircuits Lodder listhork
Filter [issian ain FTronsper Function
Eode Flots
Folitier Tronsforms
THo-Fort liethorks
Tronsformer Frirornonce
Transtission Lines
Error Functions
-EXFH WHEE FICT SI \(\square\) HHLT HELF

\subsection*{5.9.1. Transfer Function}

\section*{Example:}

Find the transfer function and its partial fraction expansion for a circuit with a zero located at \(-10 \_r / s\) and three poles located at \(-100 \_r / s,-1000 \_r / s\) and \(-5000 \_r / s\). Assume that the multiplier constant is 100000.

\section*{Solution:}

\(H(5):\)
\(.002 \cdot \frac{1 .-\frac{5}{-10}}{\left.\left.\left(1 .-\frac{s}{-100}\right)\right]\left(1 .-\frac{5}{-1000}\right)\right]\left(1 .-\frac{5}{-5000}\right)}\)


The function is stored automatically as 'Hs' in the current directory.

Bode Plots will automatically use this function, if it is present.
```

FFE:
-2.04021633

```

\section*{5．9．2．Bode Plots}

\section*{Example：}

Graph the gain and phase plots for the transfer function just computed in the previous example．

\section*{Solution：}

```

Indep: 's'
Flot Type:G⿱㇒日:
u-Hin: . }
u-Hax: 100060
Hutoscole:Y'YS
Labe! Flot:YEs
CH0WS

```


```

MFer: ' 0102*(<1.-5/-10,.,
Indep: 's'
Flot Type:Phase
*-Hin: . }
w-Hax: 1060106
nutoscole:Y'es
Label fot:Y'䍃
CH00S
EFise D|aid

```


\subsection*{5.9.3. Gain and Frequency Command Line Programs}


XFERPZ: Transfer Function Roots
XFERND: Transfer Function Coefficients
PFER: Partial Fraction Expansion Roots
PFEC: Partial Fraction Expansion Coefficients

\subsection*{5.10. Fourier Transforms}
\&ELECTFIGAL EMGIMEERIIG ANIALYSIS
AL Gircuits
Folyphose Gircuits
LIdAE Clethork
Filter desizn
ginin ond Frequency
 FF F
Inuerse FFT
THO-Firt hethorks
Transforter Fsifortance
Transhission Lines
-EXFH WHEE FICT SI \(\square\) HHLT HELF

\subsection*{5.10.1. FFT}

\section*{Example:}

Find spectral coefficients for the periodic time signal [11 2 2 3 4].

\section*{Solution:}


\subsection*{5.10.2. Inverse FFT}

\section*{Example:}

Find spectral coefficients for the periodic time signal [llllll 123121\(].\)

\section*{Solution:}


\subsection*{5.10.3. Fourier Transforms Command Line Programs}

\section*{\(\stackrel{+}{\mathrm{F} F F T}\)}
+FFT \(\operatorname{FFT}+\square\) CHES
\(\rightarrow\) FFT: Fast Fourier Transformation
FFT \(\rightarrow\) : Inverse Fast Fourier Transformation

\section*{5．11．Two－Port Networks}
\＆ELECTFIGAL EMGIMEERIIG ANIALYSIS
AE Gircuits
Fobyphase Eircuits
Lodder listhork
Filter desizn
Gin and Frequency
Fourist Transforts

Froroheter donversion
Gircdit Ferformones
Interconnected THo－Forts
Transformer ferfortance
EEXFH WHEE FICT SI GHLT HELF

\section*{5．11．1．Parameter Conversion}

\section*{Example：}

Convert a resistive two－port network with z11＝ \(10 \_\Omega\), z12＝7．5＿\(\Omega\) ，z21＝7．5＿\(\Omega\) ， \(z 22=9.375 \Omega\) into its equivalent \(h\) values．

Solution：

```

Input Type:z
211:10_0
212:7.5_\
221:7.5_0
232:9.375_0
output Type:马
Chobse 泣put purgheter type
CHOS \ COLNE

```
```

***esult: Forgheter Conuersion変
h11:4
h1z: 0. 801010100601010
h31: -0.8060601001000
h22: 0. 10666666667
F1 Impedanice V1/~I (NZ=0%

```


\subsection*{5.11.2. Circuit Performance}

\section*{Example:}

A transistor has the following h-parameters: h11 = 10_ \(\Omega\), h12 = 1.2_ \(\Omega\) h21= \(-200 \_\Omega\), \(\mathrm{h} 22=.000035 \_\Omega\). The source driving this transistor is a \(2 \_\mathrm{V}\) source with a source impedance of \(25 \_\Omega\). The output port is connected to a \(50 \_\Omega\) load. Find the performance characteristics of the circuit.

\section*{Solution:}

 Zin:11,989, DBEGFED Iout: -0, 03323622 vout: 1.66665816 zout: 0. 14583250
12 11 : -199.65061143
v2•ण1: 0.83263825
Input inpusdace tis
+ TR

 vコンU1: 0.83263825
v2vs: 0. 83090562
GF : -166.23673670
Fqu: 6. ©1777778
Fhox: 4.76188336
ZLopt: \(14.5 B 325\)
opt. lond inpedonce to


\subsection*{5.11.3. Interconnected Two-Ports}

\section*{Example:}

The 2 two-port networks are defined in terms of their \(z\) and \(h\) parameters. The \(z\) parameters are \(10,7.5,7.5,9.375\) respectively while the \(h\) parameters are \(25,0.001\), \(100,0.0025\). If the two-ports are connected in a cascade configuration, compute the y parameters for the resulting equivalent two-port.

\section*{Solution:}


```

First Input Typu:z
211:105

```

```

231:7.5WGGENGED
232: G

```

```

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Fesult: Interconincted Tho-Forts
y11: 国, 11565

y러 : 2. 686956


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\subsection*{5.11.4. Two-Port Networks Command Line Programs}

\section*{PCOHV \\ PDPERF}

PCONV: Two-Port Networks Parameter Conversion
"Input_Type" \%Real_11 \%Real_12 \%Real_21 \%Real_22 "Output_Type"
\(\rightarrow\)
OutTyp_\%Real_11 OutTyp_\%Real_12 OutTyp_\%Real_21 OutTyp_\%Real_22
PCPERF: Two-Port Networks Circuit Performance
"Input_Type" \%Real_11 \%Real_12 \%Real_21 \%Real_22 \%Real_Vs \%Real_Zs \%Real_ZL
\(\rightarrow\)
Zin lout Vout Zout I2/I1 V2/V1 V2/Vs GP Pav Pmax ZLopt

\section*{I 2 PCAS \\ }

I2PCAS: Two-Port Networks Cascade
I2PSS: Two-Port Networks Series Series
I2PPP: Two-Port Networks Parallel Parallel
I2PSP: Two-Port Networks Series Parallel
I2PPS: Two-Port Networks Parallel Series

\subsection*{5.12. Transformer Performance}


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    Short Gircujt Test
    Chulin FordHeters

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\subsection*{5.12.5. Open Circuit Test}

\section*{Example:}

Perform an open circuit test on the primary side of a transformer using the following data: The input to the primary coils with the secondary side open is \(110 \_\mathrm{V}\) and a current of \(1 \_\)A and a power of \(45 \_\mathrm{W}\). The secondary open circuit voltage is \(440 \_\mathrm{V}\). Find the circuit parameters of the transformer.

\section*{Solution:}

```

V1:110_V
va:440_V
II: 1_B
F1:45_N
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```


\subsection*{5.12.6. Short Circuit Test}

\section*{Example:}

Short circuit test data is taken on a transformer. A primary input voltage of 5_V forces \(18 \_A\) of current into the secondary winding under short circuit conditions. The power supplied for the test is 5 W. The transformer has a kVA rating of 30 and a primary voltage rating of 110_V. Find the parameters of the of the transformer.

\section*{Solution:}



```

41: $1,363,62719694$
Fis: 0. 01010361
kz : 0. 010771605
H1: 0. 010916661
双: 2.10486296
prin. to sec. turns rotio
+KTR WIEN —

```

\subsection*{5.12.7. Chain Parameters}

\section*{Example:}

A transformer has a primary and secondary impedance of (250+23*i) ohms and \((50+10 * i)\) ohms and a turns ratio of 0.2 . The conductance and susceptance of the primary coil is \(0.001 \_\)S and -0.005 _S respectively.
Find the A, B, C and D parameters.

\section*{Solution:}
```

******)
21: (250, 01010,23, 01010)
22: (50, 01060,10, 01060)
n: 0, 201010
G% 0, 0010_S
Ec:-6, GE5G_S
Enter primary Eore suscept. (s)
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```


\subsection*{5.12.8. Transformer Performance Command Line Programs}


OCTST: Transformer Performance Open Circuit Test
SCTST: Transformer Performance Short Circuit Test
CHAIN: Transformer Performance Chain Parameters

\section*{5．13．Transmission Lines}
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\section*{5．13．9．Open Circuit Test}

\section*{Example：}

A transmission line has a series inductance of \(1 \_\mathrm{mH} / \mathrm{m}\) ，a line resistance of \(85.8 \_\Omega / \mathrm{m}\) ，a conductance of \(1.5 \times 10-9 \_\mathrm{S} / \mathrm{m}\) and a shunt capacitance of \(62 \times 10-9 \_\mathrm{F} / \mathrm{m}\) ． For a load impedance of \(75 \_\Omega\) and a frequency of \(2 \_k H z\) compute the line characteristics 3＿m away from the load．
Note：Since the unit length is the meter，all entered and calculated values are with respect to kilometer．

\section*{Solution：}



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吅： \(63,898.369564\)
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\(p:(-0,682709,0,2113 \ldots\)
SHF：E，GIEGB7E
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\subsection*{5.13.10. Line Parameters}

\section*{Example:}

A transmission line is measured to have an open circuit impedance of (103.6255-2.525*i), and an impedance under short circuit conditions of ( \(34.6977+1.7896 * i)\), at a distance 1 unit length from the load location. All measurements are conducted at \(10 \_\mathrm{MHz}\).
Compute all the line parameters.

\section*{Solution:}


\subsection*{5.13.11. Fault Location Estimate}

\section*{Example:}

A transmission line measures a capacitive reactance of -275_ת. The characteristic line impedance is \(75 \_\Omega\) and has a phase constant of 0.025 r/length.
Estimate the location of the fault.

\section*{Solution:}



\section*{5．13．12．Lossless Line Impedance}

\section*{Example：}

A transmission line has a characteristic impedance of \(50 \_\Omega\) and a load of \(75 \_\Omega\) ．The electrical length is 0.886077 ．
Find the input impedance，the open circuit stub and the short circuit stub．

\section*{Solution：}

```

    ZL:75_D
    R0:5|
    ```

```

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\section*{5．13．13．Transmission Lines Command Line Programs}


XLCHR：Transmission Lines Line Characteristics
XLPAR：Transmission Lines Line Parameters
XLFAULT：Transmission Lines Fault Location Estimate
XLZ Transmission Lines Lossless Line Impedance

\subsection*{5.14. Error Functions}
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\subsection*{5.14.1. Using Error Functions}

\section*{Example:}

What is the value of \(\operatorname{erf}(0.25)\) ?

\section*{Solution:}

5.14.2. Error Functions Command Line Programs

ERF

\section*{EAF ERFT \(\square\) CIDS}

ERF: Error Functions Error Function
ERFC: Error Functions Complementary Error Function

\section*{6．Using Equations}

Note that there might be more than one mathematical correct solution． Therefore，it is the users responsibility to ensure，that the found solution（s） match reality－and if not repeat the solution process with different guesses for the solver routine．If necessary，consult your calculator manual about the root finding algorithm implemented into the calculator．

\section*{6．1．Resistive Circuits}
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\section*{6．1．1．Resistance and Conductance}

\section*{Example：}

A copper wire 1500 ＿m long has a resistivity of 6.5 ＿Ohm＊ cm and a cross sectional area of \(0.45 \_\mathrm{cm}^{\wedge} 2\) ．Compute its resistance and conductance．

\section*{Solution：}

Upon examining the problem，two choices are noted．
Equations 1， 2 and 4 or equations 1 and 3 can be used to solve the problem．
The second choice was made here．
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Press TOOL to view all calculated results.

\subsection*{6.1.2. Ohm's Law and Power}

\section*{Example:}

A 4.7_k load carries a current of 275 _mA. Calculate the voltage across the load, power dissipated and load conductance.

\section*{Solution:}

Upon examining the problem, several choices are noted. Either equations 1, 2 and 6 or 2,3 and 5 or 2,3 and 6 or 1, 2 and 5 or all the equations.
The last choice was made here.



\section*{6．1．3．Temperature Effect}

\section*{Example：}

A 145＿Ohm resistor at 75 ＿\({ }^{9}\) F reads \(152.4 \_\)Ohm at \(125 \_{ }^{\circ} \mathrm{C}\) ．Find the temperature coefficient of the resistance．

\section*{Solution：}

Since there is only one equation in this topic，there is no need to make a choice of equations．

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\subsection*{6.1.4. Maximum DC Power Transfer}

\section*{Example:}

A \(12 \_\)V car battery has a resistive load of \(0.52 \_\)Ohm. The battery has a source impedance of 0.078_Ohm. Find the maximum power deliverable from this battery and the power delivered to this resistive load.

\section*{Solution:}

Upon examining the problem, equation 1, 2, 3 and 4 are needed to compute the solution for this problem.



Press TOOL to view all calculated results.


\subsection*{6.1.5. \(\quad V\) and I Source Equivalence}

\section*{Example:}

Find the short circuit current equivalent for a 5_V source with a 12.5_Ohm source resistance.

\section*{Solution:}

Since there is only one equation in this topic, there is no need to make a choice of equations.

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Is: G, 4EGE_H


\subsection*{6.2. Capacitance and Electric Fields}


\subsection*{6.2.6. Point Charge}

\section*{Example:}

A point charge of 14.5E-14_coulomb is located 2.4_m away from an instrument measuring electric field and absolute potential. The permittivity of air is 1.08 .
Compute the electric field and potential.

\section*{Solution:}

Upon examining the problem, both equations are needed to solve this problem. Note that \(\varepsilon 0\), the permittivity of free space does not appear as one of the variables that needs to be entered. It is entered automatically by the software, as it is a built in constant. However, \(\varepsilon\), the relative permittivity must be entered as a known value.
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\section*{6．2．7．Long Charged Line}

\section*{Example：}

An aluminum wire suspended in air carries a charge density of \(2.75 \mathrm{E}-15\)＿coulombs \(/ \mathrm{m}\) ． Find the electric field \(50 \_\mathrm{cm}\) away．Assume the relative permittivity of air to be 1.04 ．

\section*{Solution：}

Since there is only one equation in this topic，there is no need to make a choice of equations．

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\subsection*{6.2.8. Charged Disk}

\section*{Example:}

A charged disc 5.5 _cm in radius produces an electric field of .2_V/cm at a distance of \(50 \_\mathrm{cm}\) away from the surface of the disc. Assuming that relative permittivity of air is 1.04 , what is the charge density on the surface of the disc?

\section*{Solution:}

Upon examining the problem, select the first equation to solve for the unknown variable.
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Eq: 'Ez=\rho\Xi/C2*COHST\e@m
Ez: 6. 200606_V/Gm
Ps: 0_C:M% %
Er:1.0406016
2:5010m
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```


\subsection*{6.2.9. Parallel Plates}

\section*{Example:}

A silicon dioxide insulator forms the insulator for the gate of a MOS transistor.
Calculate the charge, electric field and mechanical force on the plates of a 5_V MOS capacitor with an area of \(1250 \_\mu^{\wedge} 2\) and a thickness of \(.15 \_\mu\). Use a value of 3.9 for permittivity of SiO 2 .

\section*{Solution:}

Upon examining the problem, all of the equations are needed to compute the solution to this problem.
```

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    H=1/2xy`zxに
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\(F=-1 \sim 2 x V^{2} 3 x 5\)
W=1~2x




\subsection*{6.2.10. Parallel Wires}

\section*{Example:}

Compute the capacitance per unit length of a set of power lines \(1 \_c m\) radius and 1.5 _m apart. The dielectric medium separating the wires is air with a relative permittivity of 1.04 .

\section*{Solution:}

Since there is only one equation in this topic, there is no need to make a choice of equations.
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Er:1.0400
4:1.5010_m
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\section*{6．2．11．Coaxial Cable}

\section*{Example：}

A coaxial cable with an inner cable radius of \(0.3 \_\mathrm{cm}\) and an outer conductor with an inside radius of 0.5 cm has a mica filled insulator with a permittivity of 2．1． If the inner conductor carries a linear charge of \(3.67 \mathrm{E}-15\)＿coulombs \(/ \mathrm{m}\) ，find the electric field at the outer edge of the inner conductor and potential between the two conductors．Compute the capacitance per \(m\) of the cable．

\section*{Solution：}

Upon examining the problem，all of the equations are needed to compute the solution to this problem．

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Press TOOL to view all calculated results．


\subsection*{6.2.12. Sphere}

\section*{Example:}

Two concentric spheres 2_cm and 2.5_cm radius, are separated with a dielectric with a relative permittivity of 1.25 . The inner sphere has a charge of \(1.45 \mathrm{E}-14\) _coulombs. Find the potential difference between the two spherical plates of the capacitor as well as the capacitance.

\section*{Solution:}

Upon examining the problem, equations 1 and 3 are needed to compute a solution.

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\subsection*{6.3. Inductors and Magnetism}
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\subsection*{6.3.1. Long Line}

\section*{Example:}

An overhead transmission line carries a current of 1200_A at 10_m away from the surface of the earth. Find the magnetic field at the surface of the earth.

\section*{Solution:}

Since there is only one equation in this topic, there is no need to make a choice of equations.
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\subsection*{6.3.2. Long Strip}

\section*{Example:}

A strip transmission line 2_cm wide carries a current of 16025_A/m. Find the magnetic field values 1_m away and 2_m from the surface of the strip.

\section*{Solution:}

Upon examining the problem, both equations need to be used to compute the solution.

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\subsection*{6.3.3. Parallel Wires}

\section*{Example:}

A pair of aluminum wires 1.5 _cm in diameter are separated by 1_m and carry currents of 1200 A and 1600 A in opposite directions. Find the force of attraction, the magnetic field generated midway between the wires and the inductance per unit length resulting from their proximity.

\section*{Solution:}

Upon examining the problem, equations 1 and 2 and 3 are needed to compute a solution.



Press TOOL to view all calculated results.


\subsection*{6.3.4. Loop}

\section*{Example:}

Calculate the torque and inductance for a rectangular loop of width 7_m and length \(5 \_\mathrm{m}\), carrying a current of 50 A. separated by a distance of 2_m from a wire of infinite length carrying a current of \(30 \_\)A. The loop angle of incidence is 5 degrees relative to the parallel plane intersecting the infinite wire.

\section*{Solution:}

Upon examining the problem, the last two equations are needed.
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Press TOOL to view all calculated results.


\subsection*{6.3.5. Coaxial Cable}

\section*{Example:}

A coaxial cable has an inner conductor radius of 3 _mm and the outer conductor radius of 0.15 _in. Find its inductance per meter.

\section*{Solution:}

Since there is only one equation in this topic, there is no need to make a choice of equations.

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\section*{6．3．6．Skin Effect}

\section*{Example：}

Find the effect on depth of signal penetration for a 100 MHz signal in copper with a resistivity of \(6.5 \mathrm{E}-6\)＿Ohm＊cm．The relative permeability of copper is 1.02 ．

\section*{Solution：}

Upon examining the problem，both equations need to be used to compute the solution．

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\section*{6．4．Inductors and Magnetism}

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\section*{6．4．1．Electron Beam Deflection}

\section*{Example：}

An electron beam in a CRT is subjected an accelerating voltage of 1250＿V．The screen target is 40 ＿cm away from the center of the deflection section．The plate separation is \(0.75 \_\mathrm{cm}\) and the horizontal path length through the deflection region is 0.35 cm ．The deflection region is controlled by a \(100 \_\mathrm{V}\) voltage．A magnetic field of 0.456 ＿T puts the electrons in the beam in a circular orbit．What is the vertical deflection distance of the beam when it reaches the CRT screen？

\section*{Solution：}

Upon examining the problem，the first three equations are needed to solve this problem．

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Press TOOL to view all calculated results．

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\subsection*{6.4.2. Thermionic Emission}

\section*{Example:}

A cathode consists of a cesium coated tungsten with a surface area of 2.45 _cm \({ }^{\wedge} 2\). It is heated to 1200 KK in a power vacuum tube. If the Richardson's constant is \(120 \_A /\left(m^{\wedge} 2^{*} \mathrm{~K}^{\wedge} 2\right)\) and the work function is \(1.22 \_\mathrm{V}\), find the current available from such the cathode.

\section*{Solution:}

Since there is only one equation in this topic, there is no need to make a choice of equations.


\subsection*{6.4.3. Photoemission}

\section*{Example:}

A red light beam with a frequency of 1.4E14_Hz, is influencing an electron beam to overcome a barrier of \(0.5 \_\)V. What is the electron velocity and find the threshold frequency of the light.

\section*{Solution:}

Upon examining the problem, both equations need to be used to compute the solution.

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\section*{6．5．Meters and Bridge Circuits}
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\end{tabular}

\section*{6．5．1．Amp，Volt，Ohmmeter}

\section*{Example：}

What resistance can be added to a voltmeter with a current sensitivity of 10 mA and a voltage sensitivity of 5 V to read 120 V ？

\section*{Solution：}

Upon examining the problem，the second equation needs to be selected to solve this problem．

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\subsection*{6.5.2. Wheatstone Bridge}

\section*{Example:}

A Wheatstone bridge circuit has a resistor \(R 2\) of \(100 \Omega \Omega\) on the unknown side of the bridge and two \(1000 \_\Omega\) resistors connected on the known side of the bridge. A resistor of \(99 \Omega\) was connected to the bridge in the location where the unknown resistor would normally be present. The bridge is supplied by a \(10 \_\mathrm{V}\) source with a resistance of 2.5_Ohm. The galvanometric resistance is \(1 \_M \Omega\). Find the voltage across the meter and the galvanometric current.
current.

\section*{Solution:}

Upon examining the problem, the second and third equations are needed to solve the problem.





Press TOOL to view all calculated results.

\subsection*{6.5.3. Wien Bridge}

\section*{Example:}

A set of measurements obtained using a Wien bridge is based on the following input. All measurements are carried out at \(1000 \_\mathrm{Hz}\). The known resistors R1 and R3 are \(100 \_\Omega\) each, the series resistance is \(200 \_\Omega\) and Cs is \(1.2 \_\mu \mathrm{F}\). Find the values of the unknown RC circuit components and the radian frequency.

\section*{Solution:}

Upon examining the problem, the first, third and fifth equations are needed to solve the problem.



Press TOOL to view all calculated results.


\subsection*{6.5.4. Maxwell Bridge}

\section*{Example:}

Find the inductance and resistance of an inductive element using the Maxwell bridge. The bridge resistors are \(1000 \_\Omega\) each with a \(0.22 \_\mu \mathrm{F}\) capacitor and \(470 \_\Omega\) parallel resistance. Compute Lx and Rx.

\section*{Solution:}

Upon examining the problem, the first two equations are needed to solve the problem.


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Press TOOL to view all calculated results.


\subsection*{6.5.5. Owen Bridge}

\section*{Example:}

A lossy inductor is plugged into an Owen bridge to measure its properties. The resistance branch has \(1000 \_\Omega\) resistors and a capacitor of \(2.25 \_\mu \mathrm{F}\) on the nonresistor leg and \(1.25 \_\mu \mathrm{F}\) capacitor on the resistor leg of the bridge. A series resistance of 125 _ connects the C 4 leg to balance the inductive element.

\section*{Solution:}

Both equations are needed for solving the problem.




Press TOOL to view all calculated results.


\subsection*{6.5.6. Symmetrical Resistive Attenuator}

\section*{Example:}

Design a symmetrical and Bridges Tee attenuator for a \(50 \_\Omega\) load and a 6 DB loss.

\section*{Solution:}

All three equations are needed.



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\subsection*{6.5.7. Unsymmetrical Resistive Attenuator}

\section*{Example:}

A network needs to be patched by an unsymmetrical attenuator. The network to the right of the attenuator presents a resistive load of \(125 \Omega \Omega\), while the network to the left of the attenuator possesses an impedance of \(100 \_\Omega\). What is the expected loss in DB?

\section*{Solution:}

The last equation is needed to compute the signal attenuation.


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FAHp, volt, gmi ohmHeter
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Rj and Rk can be computed from the first two equations above.

\section*{6.6. \(\quad R L\) and RC Circuits}


\subsection*{6.6.1. RL Natural Response}

\section*{Example:}

An RL circuit consists of a 400 mH inductor and a \(125 \_\)_ resistor. With an initial current of \(100 \_\mathrm{mA}\), find the inductor current and voltage across the inductor \(1 \_\mathrm{ms}\) and 10_ms after the switch has been closed.

\section*{Solution:}

Upon examining the problem, the first three equations are needed to solve the problem.

Solution after 1_ms


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\end{tabular}

Press TOOL to view all calculated results.


Solution after 10_ms

\begin{tabular}{ll} 
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\(125-\Omega\) & iL: \(0-A\)
\end{tabular}
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Press TOOL to view all calculated results.

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\subsection*{6.6.2. RC Natural Response}

\section*{Example:}

An RC circuit consists of a 1.2_ \(\mu \mathrm{F}\) capacitor and a \(47 \_\Omega\) resistor. The capacitor has been charged to \(18 \_\mathrm{V}\). A switch disconnects the energy source. Find the voltage across the capacitor 100 ms later. How much energy is left in the capacitor?

\section*{Solution:}

Upon examining the problem, all of the equations are needed to solve the problem.

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Press TOOL to view all calculated results.


\subsection*{6.6.3. RL Step Response}

\section*{Example:}

An inductor circuit consisting of \(25 \_\mathrm{mH}\) inductance and \(22.5 \Omega \Omega\) resistance. Prior to applying a 100_V stimulus, the inductor carries a current of \(100 \_\mathrm{mA}\). Find the current in and the voltage across the inductor after 0.01_s.

\section*{Solution:}

Upon examining the problem, all three equations are need to be solve the problem.

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\hline L:25_mH & UL: C \\
\hline iL: 0]-A & ㄸ.0: 100_m \\
\hline W: 1006V & 1822.5060] \\
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Press TOOL to view all calculated results.


\section*{6．6．4．RC Step Response}

\section*{Example：}

A 10＿V step function is applied to an RC circuit with a \(7.5 \_\Omega\) resistor and a \(67 \_n F\) capacitor．The capacitor was charged to an initial potential of－10＿V．
What is the voltage across the \(0.1 \_\mathrm{ms}\) after the step function has been applied？

\section*{Solution：}

All three equations are needed to compute the solution for this problem．



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Press TOOL to view all calculated results．


\subsection*{6.6.5. RL Series to Parallel}

\section*{Example:}

A 24 mH inductor has a quality factor of 5 at 10000 Hz.
Find its series resistance and the parallel equivalent circuit parameters.

\section*{Solution:}

Upon examining the problem, the first six equations need to be solved as a set.



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\subsection*{6.6.6. RC Series to Parallel}

\section*{Example:}

A parallel RC Circuit consists of a \(47 \ldots \mu \mathrm{~F}\) and \(150 \_k \Omega\) at \(120 \_k H z\).
Find its series equivalent.

\section*{Solution:}

Upon examining the problem, equations 1, 3, 4, 6 and 7 are needed to solve the problem.








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\subsection*{6.7. RLC Circuits}
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\subsection*{6.7.1. Series Impedance}

\section*{Example:}

A circuit consists of a \(50 \_\Omega\) resistor in series with a \(20 \_m H\) inductor and \(47 \_\mu \mathrm{F}\) capacitor.
At a frequency of \(1000 \_\mathrm{Hz}\) calculate the impedance and phase angle of impedance.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.



Press TOOL to view all calculated results.

\subsection*{6.7.2. Parallel Admittance}

\section*{Example:}

A parallel RLC Circuit consists of a \(10 \mathrm{k} \Omega\) resistor, \(67 \mu \mathrm{H}\) and \(0.01 \mu \mathrm{~F}\). Find the circuit admittance parameters at a frequency of 10 MHz .

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

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\subsection*{6.7.3. RLC Natural Response}

\section*{Example:}

A RLC circuit consists of a \(50 \_\Omega\) resistor in series with a \(20 \_\mathrm{mH}\) inductor and 47_ \(\mu \mathrm{F}\) capacitor.
Calculate the circuit parameters.

\section*{Solution:}

All of the equations are needed to solve the parameters from these given set of variables.



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\subsection*{6.7.4. Underdamped Transient}

\section*{Example:}

A parallel RLC circuit is designed with a 1_k \(\Omega\) resistor, a \(40 \_\mathrm{mH}\) inductor and a \(2 \_\mu \mathrm{F}\) capacitor. The initial current in the inductor is \(10 \_\mathrm{mA}\) and the initial charge in the capacitor is 2.5_V.
Calculate the resonant frequency and the voltage across the capacitor \(1 \_\mu\) s after the input stimulus has been applied.

\section*{Solution:}

All of the equations need to be selected to solve this problem.





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\section*{6．7．5．Critical－Damped Transient}

\section*{Example：}

A critically damped RLC circuit consists of a 100＿\(\Omega\) resistor in series with a \(40 \_\mathrm{mH}\) inductor and a \(1 \_\mu \mathrm{F}\) capacitor．The initial inductor current is \(1 \_\mathrm{mA}\) and the initial capacitor charge is 10 ＿V．
Find the voltage across the capacitor after \(10 \_\mu \mathrm{s}\) ．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．
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Press TOOL to view all calculated results．

\subsection*{6.7.6. Overdamped Transient}

\section*{Example:}

An overdamped RLC circuit consists of a \(10 \_\Omega\) resistor in series with a \(40 \_\mathrm{mH}\) inductor and a \(1 \_\mu \mathrm{F}\) capacitor. If the initial inductor current is \(0 \_\mathrm{mA}\) and the capacitor is charged to a potential of \(5 \_\mathrm{V}\), find the voltage across the capacitor after \(1 \_\mathrm{ms}\).

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.



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si: 0_r/s
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Press TOOL to view all calculated results.


\section*{6．8．AC Circuits}
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\section*{6．8．1．RL Series Impedance}

\section*{Example：}

An RL circuit consists of a \(50 \_\Omega\) resistor and a 0.025 H inductor．At a frequency of 400 Hz ，the current amplitude is 24＿mA．
Find the impedance of the circuit and the voltage drops across the resistor and inductor after 100 ms ．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．

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\hline  & \\
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\section*{6．8．2．RC Series Impedance}

\section*{Example：}

An RC circuit consists of a \(100 \Omega\) resistor in series with a 47 mF capacitor．At a frequency of \(1500 \_\mathrm{Hz}\) ，the current peaks at an amplitude of \(72 \_\mathrm{mA}\) ．
Find all the parameters of the RC circuit and the voltage drop after \(150 \_\mu \mathrm{s}\) ．

\section*{Solution：}

Use all of the equations to compute the solution for this problem．
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Impedance

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Impedance

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I=IHNSITM4ety

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    W= Wh+NC
    ```
    W= Wh+NC
    YH=IH*ZH
```

    YH=IH*ZH
    ```


```

L4=3xה"F

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L4=3xה"F
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```

EXFHWGESOFICTM SI | HRLT LESLD

```
\begin{tabular}{|c|c|}
\hline E & \\
\hline Eq： \(\mathbf{c}^{1} \mathrm{I}=\mathrm{Im}\) m & \\
\hline 日＿A tis6 & V ： \(\mathrm{E}_{\text {－}}\) \\
\hline  &  \\
\hline  & ＊： \\
\hline 647＿uF 6 目 1 & ¢ 0 － \(\mathrm{r}^{-13}\) \\
\hline F15010．．． & \\
\hline tol yoltage & \\
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\hline
\end{tabular}

Press TOOL to view all calculated results．





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Total yotage


\subsection*{6.8.3. Impedance \(\leftrightarrow\) Admittance}

\section*{Example:}

Find the admittance of an impedance consisting of a resistive part of \(125 \_\Omega\) and a reactance part of 475_ת.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.


\(\mathrm{Eq}: 1{ }^{1} \mathrm{HBS}(2 \mathrm{~m})^{\wedge} 2=\mathrm{R}^{\wedge} 2+\mathrm{K}, \ldots\)
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\hline [125_岛 & E: \\
\hline  & ZH: 0 - \({ }^{\text {a }}\) \\
\hline Yн: 0_S & 昒: 0.r \\
\hline E: 0_S & 5: 0. \(0^{5}\) \\
\hline
\end{tabular}




Press TOOL to view all calculated results.


\subsection*{6.8.4. Two Impedances in Series}

\section*{Example:}

Two impedances, consisting of resistances of \(100 \_\Omega\) and \(75 \Omega\) and reactive components \(75 \_\Omega\) and \(-145 \_\Omega\) respectively, are connected in series.
Find the magnitude and phase angle of the combination.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.








\section*{Inpedance hognitude}

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HLL ESOLT

\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{Tho Inpedonces in series} \\
\hline \multicolumn{2}{|l|}{} \\
\hline \multicolumn{2}{|l|}{} \\
\hline \multicolumn{2}{|l|}{91. \(0.64 \ldots\)..W075_0} \\
\hline  & \\
\hline Inpedance hagnitude & \\
\hline EDIT Wilis wien & HLL [is \\
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\end{tabular}

Press TOOL to view all calculated results.


\section*{6．8．5．Two Impedances in Parallel}

\section*{Example：}

For two impedances in parallel possessing values identical to the previous example， calculate the magnitude and phase of the combination（resistances of 100＿\(\Omega\) and \(75 \_\Omega\) and reactive components \(75 \_\Omega\) and \(-145 \_\Omega\) respectively）．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．




Eq: \(\boldsymbol{K}^{1} \mathrm{HBS}(2 \mathrm{~m})^{\wedge} 2=(\mathrm{R} 1\) 天...




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\section*{6．9．Polyphase Circuits}
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\hline ORIHPREsE & Lircuits \\
\hline  & \(\stackrel{\text { Networc }}{ }\) \\
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\hline inesr Amp & lif iers \\
\hline EPFA Tiles & I 1 HHLT HEL \\
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\end{tabular}

\section*{6．9．1．Balanced \(\Delta\) Network}

\section*{Example：}

Given a line current of 25＿A，a phase voltage of 110 V and a phase angle of 0.125 ＿rad，find the phase current，power，total power and line voltage．

\section*{Solution：}

Upon examining the problem，all equations are needed．
```

**** ELECTFICGL EMGINEEFING******
Fobyphose Eirguits

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```

    F!=|
    IL=rS*Ip
    ```


```

    FT=[3xMLxILxC0s(0)
    Ealoned Hys fistuork
Foher megsurenents
Elsctricgl kesonumce
0p\mp@code{\#p Gircuits}
EMFADGESD FICT SI D HHLT [SOLT

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\begin{tabular}{|c|c|c|}
\hline \multicolumn{3}{|l|}{} \\
\hline \multicolumn{3}{|l|}{} \\
\hline \multicolumn{3}{|l|}{F1575，35，wo 110＿V} \\
\hline \multicolumn{3}{|l|}{Ip 14．4338．．．FT＇4725．97．．．} \\
\hline \multicolumn{3}{|l|}{VLI1日＿V TIU 25} \\
\hline ［0．1250＿r & & \\
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\end{tabular}
\begin{tabular}{|c|c|}
\hline Edanced & －fis \\
\hline Eq：\(\chi^{\prime} \mathrm{VL}=\mathrm{WP}\) & ＇＇IL＝「3× \(\mathrm{I}_{\text {．，}}\) \\
\hline \(F\) ： G＿d \(^{\text {d }}\) &  \\
\hline If ：\(\overline{0}\)－\({ }^{\text {P }}\) & FT：0．W \\
\hline WL： \(\mathrm{D}_{\text {－}}\) & TLI：3＿A \\
\hline 日6．1250r & \\
\hline Foher per phose & \\
\hline ESIT Wilis lice & HLL LESOL \\
\hline
\end{tabular}


Press TOOL to view all calculated results．

\subsection*{6.9.2. Balanced Wye Network}

\section*{Example:}

Using the known parameters in the previous example for the Balanced \(\Delta\) Network, find the phase current, power, total power and line voltage (current of 25_A, a phase voltage of 110 V and a phase angle of 0.125 _rad).

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.
```

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Folyphose Gircuits
FElonced m nethork

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```

    MO=3Nvp
    IL=Ip
    ```

```

    FT=SxpxIpx0Scos
    ```

```

FoHET HEdsuliehents
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0piнp Gircuits

```



Press TOOL to view all calculated results.


 Fiereb, 548, wion 10_V Ip: 25_A FT: 8185.63...

国 \(0.1250 r^{-}\)

Foher per phose



\subsection*{6.9.3. Power Measurements}

\section*{Example:}

Given a line voltage of 110 _V and a line current of 25_A and a phase angle of 0.1 rad, find the wattmeter readings in a 2 wattmeter meter system.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{\multirow[t]{2}{*}{}} \\
\hline & \\
\hline H1: [0] & H2: 6_N \\
\hline FT: E_W & WL: 110_V \\
\hline TL:25_A & 68.1006_r \\
\hline \multicolumn{2}{|l|}{Hottheter 1} \\
\hline
\end{tabular}

Folyphose Girgits
EGlonced
EGdaned Hys riethork

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OpiHp Gircuits
solid stote devices
Linsar AHplifists



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\subsection*{6.10. Electrical Resonance}
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\hline Elect.rical & \\
\hline \multicolumn{2}{|l|}{\multirow[t]{2}{*}{Parall Resonance}} \\
\hline & \\
\hline \multicolumn{2}{|l|}{Resonance in Los} \\
\hline \multicolumn{2}{|l|}{\multirow[t]{2}{*}{}} \\
\hline & \\
\hline \multicolumn{2}{|l|}{Solid State Device} \\
\hline Cinear Ampli & if ier \\
\hline & \\
\hline
\end{tabular}

\author{
ctifichl Engineerintukik \\ 1cal Reenninice \\ lel Resonance \\ lel Resonance \\ ance in Lossy Inductor \\ se Resonance \\ Circuits \\ St.ate Devices \\ Amplifiers \\ 
}

\subsection*{6.10.1. Parallel Resonance I}

\section*{Example:}

Calculate the resonance parameters of a parallel resonant circuit containing a \(10,000 \_\Omega\) resistor, a \(2.4 \_\mu \mathrm{F}\) capacitor and a \(3.9 \_\mathrm{mH}\) inductor. The amplitude of the current is \(10 \_\mathrm{mA}\) at a radian frequency of \(10,000 \mathrm{rad} / \mathrm{s}\).

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.



Press TOOL to view all calculated results.

\subsection*{6.10.2. Parallel Resonance II}

\section*{Example:}

A parallel resonant circuit has a \(1000 \_\Omega\) resistor and a \(2.4 \_\mu \mathrm{F}\) capacitor. The Quality Factor for this circuit is 24.8069.
Find the band-width, damped and resonant frequencies.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

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Fardelel besonumes I

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    w=F(40
    *)=w0](1-1<44x&23)
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    Fiesonumge in Lossy Inductor
    ```

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\hline (1) & fornd \\
\hline  & ' ' \(\mathrm{w} 1=\mathrm{w}\) \\
\hline \%: \(0^{-1}+r^{-7}\) &  \\
\hline we: 0 - \(r^{-1}\) & [1_k \\
\hline [2. 4060_uF & wid \(0^{-1 / s}\) \\
\hline  & 40 : 0, r/s \\
\hline 624.8069 & \\
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\end{tabular}


咺416.6667, w1 10129.9... w 10546. 6... k 1 -k [2.4060_ 4 F w 10334. \(1 \ldots\) o2 \(208.3333 \ldots\) w11 \(10336.2 \ldots\)四24.8069
Endididth


Press TOOL to view all calculated results.
\begin{tabular}{|c|}
\hline \[
2 \mathrm{Farg}
\] \\
\hline m00 103 \\
\hline E: 416 \\
\hline w1: 101 \\
\hline w2: 10546.6 \\
\hline wd: 10354. \\
\hline  \\
\hline
\end{tabular}

\subsection*{6.10.3. Resonance in Lossy Inductor}

\section*{Example:}

A power source with an impedance \(\operatorname{Rg}\) of \(5 \_\Omega\) is driving a parallel combination of a lossy \(40 \_\mu \mathrm{H}\) inductor with a \(2 \_\Omega\) loss resistance, and a capacitor of 2.7_ \(\mu \mathrm{F}\). Find the frequency of resonance and the frequency for maximum amplitude.

\section*{Solution:}

Upon examining the problem, all equations are needed to solve for a solution.


 Elsctricol Fistonumes
prodel Fesondmes I
Firdidi Resonamis II



 Mres 0. 3350.., 4+107999.

[40_uH

Fesonunt Frequency EDIT WHEE WIED

Press TOOL to view all calculated results.


\section*{6．10．4．Series Resonance}

\section*{Example：}

Find the characteristic parameters of a series－resonant circuit with \(R=25 \_\Omega, L=69 \_\mu \mathrm{H}, \mathrm{C}=0.01 \_\mu \mathrm{F}\) and a radian frequency of \(125000 \mathrm{rad} / \mathrm{s}\) ．

\section*{Solution：}

Upon examining the problem，all equations are needed to solve the problem．




 2• 791 ， 的 -1 ． 5 ．．． \(1250 \ldots\) w上 \(1398 \ldots\) w \(1036 \ldots\)＋1 \(3623 \ldots\) 411 \(1203 \ldots\) ，3．32．．．图25＿0 ■69＿pH［日，61．．．

Impedances
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HLL TESOLT

Press TOOL to view all calculated results．


\subsection*{6.11. OpAmp Circuits}




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}


\subsection*{6.11.1. Basic Inverter}

\section*{Example:}

Find the gain of an inverter and its optimum value for bias resistance given an input resistance of \(1 \_k \Omega\) and a feedback resistance of \(20 \_k \Omega\).

\section*{Solution:}

Use the first and second equations to compute the solution for this problem.
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OPAHP CirGUi+{


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    FUN=-GFMI
    Fp=F1<FiF
    Fp=F1<FiF




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\hline \multicolumn{2}{|l|}{} \\
\hline Eq: \(\mathbf{C}^{1} \mathrm{Hu}=-\mathrm{R}+\) & \({ }^{1} \mathrm{R} \mathrm{P}={ }^{\prime}\) \\
\hline \multicolumn{2}{|l|}{Au:} \\
\hline \multicolumn{2}{|l|}{Fip: 0 - \({ }^{\text {a }}\)} \\
\hline \multicolumn{2}{|l|}{Fif: 1_k!} \\
\hline \multicolumn{2}{|l|}{} \\
\hline Woltage gain & \\
\hline EIIT Walis WIEM & FLL CESLI \\
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\end{tabular}





\(\square\) FCHE EATKL 就
\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{Ensic Inverter} \\
\hline Hu:-EV & \\
\hline \multicolumn{2}{|l|}{kp 952.386952_0} \\
\hline \multicolumn{2}{|l|}{Fin 1-k!} \\
\hline \multicolumn{2}{|l|}{6FIC0_k} \\
\hline \multicolumn{2}{|l|}{Woltage gain} \\
\hline EIIT Wiks luIEM & HLL CESNL \\
\hline
\end{tabular}

\subsection*{6.11.2. Non-Inverting Amplifier}

\section*{Example:}

Find the DC gain of a non-inverting amplifier with a feedback resistance of \(1 \_M \Omega\) and a resistance to the load of \(18 \_\mathrm{k} \Omega\).
Find the gain and the optimum value for a bias resistor.

\section*{Solution:}

Use the first and second equations to compute the solution for this problem.

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plosic Inumitar

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```

    Fiv=1+kF-ki
    -FF=F1*FF/(f1+FF)
    ```


```

-urrent fHplifier
Transconductonce mhp lifier
Level detector (Inuerting)
Lavel Detector (non-Inuerting)
EMFHWBESD[FICTO SI D HELT LEOLT

```


\subsection*{6.11.3. Current Amplifier}

\section*{Example:}

A current amplifier with a \(200 \_k \Omega\) feedback resistance has a voltage gain of 42 . If the source resistance is \(1 \_k \Omega\), the load resistance is \(10 \_k \Omega\) and the output resistance of the OpAmp is 100_ \(\Omega\).
Find the current gain, input and output resistances.

\section*{Solution:}

Use all of the equations to compute the solution for this problem.

\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{} \\
\hline Eq: \(\mathbf{c}^{1} \mathrm{Hi}\) &  \\
\hline Aic: & Fin 10_k \\
\hline 80: 100] &  \\
\hline 6if: 20010 k & Rout : 0_0 \\
\hline Es:1_k & [10: 42 \\
\hline \multicolumn{2}{|l|}{Current goin} \\
\hline EDIT Wirs \({ }^{\text {P }}\) & HLL CESSL \\
\hline
\end{tabular}

\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{\multirow[t]{2}{*}{***}} \\
\hline & \\
\hline \multicolumn{2}{|l|}{} \\
\hline Forl 100] & Rin \(4651.16 .\). \\
\hline FFablalk & Routr 436010 \\
\hline 建1-k & Hivi 42 \\
\hline \multicolumn{2}{|l|}{Gurrent gain} \\
\hline ELIT WHise WIEM & HLL LIESLT \\
\hline
\end{tabular}

Press TOOL to view all calculated results.
\begin{tabular}{|c|c|}
\hline \multicolumn{2}{|l|}{} \\
\hline Whlulemis Firilit & EXIT \\
\hline
\end{tabular}

\subsection*{6.11.4. Transconductance Amplifier}

\section*{Example:}

Find the transconductance and output resistance for a transconductance amplifier with a voltage gain of 48 and an external resistance of \(125 \_\Omega\).

\section*{Solution:}

Upon examining the problem, all equations are needed to solve the problem.
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Fusic Inverter

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    FHyc=1Fis
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    Levei [ugtector cInuerting)
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    [iFFErentia! AHpliFis%
    EMFAWHESOFICTD SI ם HBLT HEOLT
    ```

\(\mathrm{Eq}:\) ' \(\mathrm{Hg} \mathrm{G}=1 / \mathrm{R} \mathbf{S}^{\prime}\) 'Rout...
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Fout: 6_0
还: 125_0
베: 48
Trunsconductumes


 Eq: ' \(\mathrm{Hg}=1 / \mathrm{Rs}\) ' 'Rout... Asca ( E ,

E 5125 -
Him 48

Trunseonductumes
EIIT Whise TIIEM GLL CIEOLT

\subsection*{6.11.5. Level Detector (Inverting)}

\section*{Example:}

An inverting level detector possesses two zener diodes to set the trip level. The setting levels are \(4 \_V\) and \(3 \_V\), respectively, for the first and second diodes.
The reference voltage is \(5 \_\mathrm{V}\), the OpAmp is supported by a \(10 \_\mathrm{k} \Omega\) bias resistor and a 1_M M feedback resistor.
Find the hysteresis, the upper and lower detection thresholds, and the input resistance.

\section*{Solution:}

Upon examining the problem, all equations are needed to solve the problem.






VL 4.92079 ... Wan 5

Fin 10_k
Input resistor
EDIT WAFE TIEM
HLL HEOLT

Press TOOL to view all calculated results.


\section*{6．11．6．Level Detector（Non－Inverting）}

\section*{Example：}

For a non－inverting level detector with the same specifications as the inverting level detector in the previous example，compute the hysteresis，the upper and lower detection thresholds，and the input resistance．

\section*{Solution：}

Upon examining the problem，all equations are needed to solve the problem．

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prosic Invertar

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Level detector (Inuerting

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F1: [——

\(\mathrm{VL}: 0\) - V Wi:5_V
Fir: 10_k
兩: 1 _M
Input resistor
EDIT Wiles WIEM BLL LIENLT


シLevel astector（non－Inverting）漛 Eq：＇R1＝RP＊Rf CRR＋Rf．．．



FITM_k
园目1_19

Input resistor EDIT WAES WIEM

HLL LESOLTM

Press TOOL to view all calculated results．
苶Lene！netertor（non－Inuertingi》


\subsection*{6.11.7. Differentiator}

\section*{Example:}

A differentiator circuit designed with an OpAmp has a slew rate of \(1.5 \_\mathrm{V} / \mu \mathrm{s}\). If the maximum output voltage is \(5 \_\mathrm{V}\), and the feedback resistor is \(39 \_k \Omega\), what input capacitor and resistor are needed for the amplifier with a characteristic frequency of 50_kHz?

\section*{Solution:}

Use the third and fourth equations to compute the solution for this problem.





Fif:

Input capucitor
EDIT WIFE WIEM BLL EESLT


Press TOOL to view all calculated results.


\subsection*{6.11.8. Differential Amplifier}

\section*{Example:}

Find the differential mode gain and the current gain for a differential amplifier with bridge resistors R1, R2, R3 and R4 of \(10 \_k \Omega, 3.9 \_k \Omega, 10.2 \_k \Omega\) and 4.1_k \(\Omega\), respectively. Assume a voltage gain of 90 .

\section*{Solution:}

Use the third and fourth equations to compute the solution for this problem.

```

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GUrrent AHPlifis%
Transconduttance finplifis%
Level [ustector cInNerting)
Lsuei [utactor (fonm-Inverting)
[iFFErentiator

```






\begin{tabular}{|c|c|}
\hline  & . Amplifiers \\
\hline Eq: \(<1 \mathrm{Hd}=\mathrm{P}\) & \(\mathrm{B} / \sqrt{\text { ¢ }} 1 \times 2\) \\
\hline H0: 5 & 6019 90 \\
\hline Hec: 10 & [8: 10. 2060... \\
\hline [1910180 & [我: 3.96106 \\
\hline [844.10106... & \\
\hline [ifferential hode & de grin \\
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\hline
\end{tabular}




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Differential hode guin EDIT WHES UIEN HLL HENLT

Press TOOL to view all calculated results.

\subsection*{6.12. Solid State Devices}


Note: The equations in this section are grouped under topics which describe general properties of semiconductors or devices. Equations for a variety of specific cases and are listed together under a sub-topic heading and are not necessarily a set of consistent equations which can be solved together. Choosing equations in a subtopic without regard as to whether the equations represent actual relationships could generate erroneous results or no solution at all.

\subsection*{6.12.1. Semiconductor Basics}

Remember that the result of equation five and six depends on the constant chosen for ni.

\section*{Example 1:}

Find the intrinsic and actual Fermi levels for Silicon at 300 KK if the conduction band is \(1.12 \_\mathrm{eV}\) above the valence band. The donor density is \(8 \times 10^{\wedge}-17 \_\mathrm{cm}^{\wedge}-3\). The effective masses for electrons and holes are 0.5 and 0.85 .

\section*{Solution:}

Since the dopant is a donor, use equations 6 and 7 to compute a solution. (Intrinsic Density Carrier Concentration of Silicon at 300_K: 1.45E10_1/cm^3)

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    pp=1, d>>p<[|]
    ```

```

    [pref= (%xT)<4
    ```




```

FII Junictions
-EXFHWHESQ FIET SI O HHLT HEOLM

```

```

    \(\dot{\rho}=1 \sim\left(q \times \mu \Omega_{1} \times[1 d)\right.\)
    ```



```

    \(E i=E F+k \times T \times L[(\Pi \|, \pi i)\)
    ```






Press TOOL to view all calculated results.

Eq: \({ }^{1} \mathrm{EF}=\mathrm{Ei}+\mathrm{CO} \mathrm{H} \mathrm{ST}(\mathrm{k})\) 天... EF- - 9927Bn nid B.E-17_…
Wia 14501010... Ei! 576288...
EO1.12_eV Em0
T300_K H0.85
Hill 5
Ferhi leve!
EDIT WHEE WIED \(\square\) GLL [IEOLT


\section*{Example 2:}

Find the diffusion penetration depth after one hour for phosphorus atoms with a diffusion coefficient of \(1.8 \times 10^{\wedge}-14 \_\mathrm{cm}^{\wedge} 2 / \mathrm{s}\). The carrier density at the desired depth


\section*{Solution:}

Equation 8 is needed to compute the solution for this problem.

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solid state [evices
FuHiconductor E|sics
p
pp=1/\mp@code{4xpex m;}

```

```

    [p~HE= (FxT)<4
    ```

```

    EF=Ei+F*T*L|(T|NAL)
    ```



```

E4D WHESQ FICT SI ם HBLT SOLDE

```

```

Eq: 'UWHL(UBASE(H)
n:8.E17_1/nm*
mo:4.E19_1/15m3
x:0
0:1.8E-14_ロm*2/3
t: 36010. _S
[spth Froh slmFiges
EDIT WAFE TIEM \ SOLTI

```
\begin{tabular}{|c|}
\hline \multirow[t]{4}{*}{} \\
\hline \\
\hline \\
\hline \\
\hline
\end{tabular}

Eq: 'UWHL (UBASE (N) ) =UW'..

nu: 4, E19_1/cm 3
\(x: \quad 264836 \cos 487-\mu\)
0: 1.8E-14_6m"2/s
t: 36016. -
Depth Froh surfage EDIT WiFE WIEX

IIITO SOLTE

\subsection*{6.12.2. PN Junctions}

Remember that the result of equation one and six depends on the constant chosen for ni.

\section*{Example 1:}

A PN step junction is characterized by an acceptor doping density of \(6 \times 10^{\wedge} 16 \_1 / \mathrm{cm}^{\wedge} 3\)
 temperature. For an applied voltage of \(-5 \_\mathrm{V}\), find the built-in potential and junction capacitance. Use a value of 11.8 for the relative permittivity of silicon.

\section*{Solution:}

Use the first five equations to compute the solution for this problem.
(Intrinsic Density Carrier Concentration of Silicon at 300_K: 1.45E10_1/cm^3)



Press TOOL to view all calculated results.



\section*{Example 2：}

A linearly graded junction has an area of \(100 \_\mu^{\wedge} 2\) ，a depletion layer width of \(0.318005 \_\mu\) ，a built－in voltage of \(0.8578 \_\mathrm{V}\) and an applied voltage of \(-5 \_\mathrm{V}\) ．The relative permittivity of silicon is 11.8 ．Under room temperature conditions，what is the junction capacitance and the linear－graded junction parameter？

\section*{Solution：}

Use the equations five and seven to compute the solution for this problem．



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Press TOOL to view all calculated results．


\section*{6．12．3．PN Junction Currents}

\section*{Example：}

A PN Junction is characterized as having a junction area of \(100 \_\mu^{\wedge} 2\) ，an applied voltage of \(0.5 \_\vee\) ，and diffusion coefficients for electrons and holes of \(35 \_\mathrm{cm}^{\wedge} 2 / \mathrm{s}\) and \(10 \_\mathrm{cm}^{\wedge} 2 / \mathrm{s}\) ，respectively．The diffusion lengths for electrons and holes are 25＿\(\mu\) and \(15 \_\mu\) ．The minority carrier densities are \(5 \times 10^{\wedge} 6 \_1 / \mathrm{cm}^{\wedge} 3\)（electrons）and \(25 \_1 / \mathrm{cm}^{\wedge} 3\) （holes）．
Find the junction current and the saturation current for room temperature conditions．

\section*{Solution：}

Use the equations one and two or one and three to compute the solution for this problem．
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****ELECTRICGL ENGINEERING*****
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F|| Junctions

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Press TOOL to view all calculated results．

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Sehiconductor Edsics
FII Junctions

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Press TOOL to view all calculated results．

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Junction current EDIT DNES TIEM GLL LESDLT



\subsection*{6.12.4. Transistor Currents}

\section*{Example:}

A junction transistor has the following parameters: \(\alpha\) is 0.98 , the base current is \(1.2 \_\mu \mathrm{A}\) while ICBO is \(1.8 \_\mathrm{pA}\).
Find the \(\beta\), emitter and collector currents.

\section*{Solution:}

A few different choices are available, however the results might differ slightly due to the combination of equations used. The second, third and fifth equations can be used to solve this problem.




Press TOOL to view all calculated results.


\section*{6．12．5．Ebers－Moll Equations}

\section*{Example：}

A junction transistor has a forward and reverse \(\alpha\) of 0.98 and 0.10 respectively．The collector current is \(10.8 \_\mathrm{mA}\) while the forward current is 12.5 mA ．respectively．
Compute the base，saturation and reverse currents，in addition to the forward and the reverse b．

\section*{Solution：}

The second through sixth equations are needed to solve this problem．



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Press TOOL to view all calculated results．


\subsection*{6.12.6. Ideal Currents - pnp}

\section*{Example:}

Find the emitter current gain \(\alpha\) for a transistor with the following properties: base width of \(0.75 \_\mu\), base diffusion coefficient of \(35 \_\mathrm{cm}^{\wedge} 2 / \mathrm{s}\), emitter diffusion coefficient of \(12 \_\mathrm{cm}^{\wedge} 2 / \mathrm{s}\), and emitter diffusion length of \(0.35 \_\mu\). The emitter electron density is \(30000 \_1 / \mathrm{cm}^{\wedge} 3\) and the base density is \(500000 \_1 / \mathrm{cm}^{\wedge} 3\).

\section*{Solution:}

Use the last equation to compute the solution for this problem.
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\section*{6．12．7．Switching Transients}

\section*{Example：}

Find the saturation voltage for a switching transistor at room temperature when a base current of \(5.1 \_\mathrm{mA}\) is used to control a collector current of \(20 \_\mathrm{mA}\) ．The forward and reverse a＇s are 0.99 and 0.1 respectively．

\section*{Solution：}

Use the last equation to solve this problem．
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FT| Junction Gurrents
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Eq: 'WCES日t \(=C O H S T(k) \times T .\).

IS: WEE VGt
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\subsection*{6.12.8. MOS Transistor I}

Remember that the result of equation one depends on the constant chosen for ni.

\section*{Example:}

A p-type silicon with a doping level of \(5 \times 10^{\wedge} 15 \_1 / \mathrm{cm}^{\wedge} 3\) has an oxide thickness of \(0.01 \_\mu\) and oxide charge density of \(1.8 \times 10^{\wedge}-10 \_\mathrm{C} / \mathrm{cm}^{\wedge} 2\). A -5_V bias is applied to the substrate which has a Fermi potential of 0.35 _V. Assume the relative permittivity of silicon and silicon dioxide is 11.8 and 3.9 , respectively, and the work function is 0.2_V.

\section*{Solution:}

Use the second through last equations to compute the solution for this problem.



Press TOOL to view all calculated results.
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\end{tabular}

\section*{6．12．9．MOS Transistor II}

\section*{Example：}

An nMOS transistor has a \(6 \_\mu\) width and \(1.25 \_\mu\) gate length．The electron mobility is \(500 \mathrm{~cm}^{\wedge} 2 /\left(\mathrm{V}^{*} \mathrm{~s}\right)\) ．The gate oxide thickness is \(0.01 \_\mu\) ．The oxide permittivity is 3．9．The zero bias threshold voltage is \(0.75 \_\mathrm{V}\) ．The bias factor is \(1.1 \_\mathrm{V} \wedge 1 / 2\) ．The drain and gate voltages are 5＿V and the substrate bias voltage is \(-5 \_\overline{\mathrm{V}}\) ．
Assuming that \(\lambda\) is \(0.05 \_1 / \mathrm{V}\) and \(\Phi F\) is \(0.35 \_\mathrm{V}\) ，find all the relevant performance parameters．

\section*{Solution：}

Use all of the equations to compute the solution for this problem．




Press TOOL to view all calculated results．

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\end{tabular}



\subsection*{6.12.10. MOS Inverter (Resistive Load)}

\section*{Example:}

Find the driver device constant, output and mid-point voltages for a MOS inverter driving a \(100 \_k \Omega\) resistive load. Driver properties include a 3_ \(\mu\) wide gate, a length of \(0.8 \_\mu\), Cox of \(345313 \mathrm{pF} / \mathrm{cm} 2\). The electron mobility is \(500 \mathrm{~cm}^{\wedge} 2 /(\mathrm{V} * \mathrm{~s}), \mathrm{VIH}=2.8 \_\mathrm{V}\), \(\mathrm{VT}=1 \_\mathrm{V}\) and \(\mathrm{VDD}=5 \_\mathrm{V}\).

\section*{Solution:}

Use all of the equations to compute the solution for this problem.
By examining the equations, it is clear that there is more than one solution.
However, the root finding algorithm stops, after the first solution has been found.
In this example VOH, VOL, VIH, Vo and VM have to be positive and between 0 and VDD.

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\#Hos Transistor II

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    Hos Inverter cugeletionj
    CHOS Transistor Fomir
    Junction FET
    ```




Press TOOL to view all calculated results.


In total, there are eight solutions for this example.
Calculate the other solutions by providing adequate guess(es) through the variables for the root finding algorithm.

Computed results:

Solution 1



Solution 5


WFILU EMIS FFiIIT
Solution 7


Solution 2


Solution 4


Solution 6


Solution 8


\subsection*{6.12.11. MOS Inverter (Saturated Load)}

\section*{Example:}

A MOS inverter with a saturated MOS transistor as its load. The driver has a length of \(1 \_\mu\) and a width of \(6 \_\mu\) while the load has a length of \(3 \_\mu\) and a width of \(6 \_\mu\). The Fermi level for the substrate material is \(0.35 \_\mathrm{V}\), a zero-bias threshold of \(0.75 \_\mathrm{V}\). Assume a drain supply voltage of 5 _V and an output voltage of \(3.1 \_\mathrm{V}\). The electron mobility is \(500 \_\mathrm{cm}^{\wedge} 2 /\left(\mathrm{V}^{*} \mathrm{~s}\right)\), the oxide capacitance per unit area is \(345313 \_\mathrm{pF} / \mathrm{cm}^{\wedge} 2\) and the bias factor is \(0.5 \_\mathrm{V}^{\wedge} 1 / 2\).
Find the output high voltage, the input high voltage, and the threshold of the load device.

\section*{Solution:}

Use equations one, two, three, four, six and seven in order to get a complete solution for the problem





\section*{}

W0H=N0L-





TL= \(\mathrm{L}-3 \mathrm{HL}\)
trh=rL





Solving for \(\mathrm{YOH}^{-}\) जロH: 3.6281229487_v Zero

Press TOOL to view all calculated results.

\subsection*{6.12.12. MOS Inverter (Depletion Load)}

\section*{Example:}

A MOS inverter with a depletion mode transistor as the load has a driver transistor \(5 \_\mu\) wide and \(1 \_\mu\) long while the load is a depletion mode device with a zero-bias threshold of \(-4 \_V, 3 \_\mu\) long and \(3 \_\mu\) wide. The Fermi level for the substrate material is \(0.35 \_\mathrm{V}\), a zero-bias threshold of \(1 \_\mathrm{V}\).
Given an electron mobility of \(500 \_\mathrm{cm}^{\wedge} 2 /\left(\mathrm{V}^{*} \mathrm{~s}\right)\) and a depletion threshold of \(-4 \_\mathrm{V}\); for the load device, compute VOL and VTL when the output voltage is 2.5 V. Assume VOH to be \(4 \_\mathrm{V}\) and 0.5 for Y , the oxide capacitance per unit area is \(34500 \_\mathrm{pF} / \mathrm{cm}^{\wedge} 2\).

\section*{Solution:}

The problem can be solved with the equations one, two, three and four.




Press TOOL to view all calculated results.


Solution 1


Solution 2

\subsection*{6.12.13. CMOS Transistor Pair}

\section*{Example:}

Find the transistor constants for an N and P MOS transistor pair given:
\(N\) transistor: \(\mathrm{WN}=4 \_\mu, \operatorname{IN}=2 \_\mu, \mu \mathrm{n}=1250 \_\mathrm{cm}^{\wedge} 2 /\left(\mathrm{V}^{*} \mathrm{~s}\right), \mathrm{Cox}=34530 \_\mathrm{pF} / \mathrm{cm}^{\wedge} 2\), VTN=1_V \(P\) transistor: VTP \(=-1 \_\mathrm{V}, \mathrm{Wp}=10 \_\mu, \mu \mathrm{p}=200 \_\mathrm{cm}^{\wedge} 2 /(\mathrm{V} * \mathrm{~s}), \mathrm{IP}=2 \_\mu\)
VDD=2_V, VIH=5_V

\section*{Solution:}

The solution can be calculated by selecting the first four equations.



Solving for kP
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Press TOOL to view all calculated results.
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\hline \multicolumn{2}{|l|}{\multirow[t]{2}{*}{}} \\
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\subsection*{6.12.14. Junction FET}

\section*{Example:}

Find the saturation current when the drain current at zero bias is \(12.5 \_\mu \mathrm{A}\), the gate voltage is \(5 \_\mathrm{V}\) and the pinch off voltage is 12 V . The channel width is \(3 \_\mu\), use a value of 11.8 for the relative permittivity of silicon, for the donor density use a value of \(1 \times 10^{\wedge} 16 \_\mathrm{cm}^{\wedge}-3\). The built-in voltage is \(0,85 \_\mathrm{V}\) and the gate voltage is \(-8 \_\mathrm{V}\)

\section*{Solution:}

Use the third equation to solve this problem.


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Es:11.8
nd: 1.E16_1/にm
Vbi: .8S_V
Wosat: (6)
N: -8_V
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\subsection*{6.13. Linear Amplifiers}


\subsection*{6.13.1. BJT (Common Base)}

\section*{Example:}

A common base configuration of a linear amplifier has an emitter resistance of 35_ \(\Omega\), collector and base resistances of \(1 \_\mathrm{M} \Omega\) and \(1.2 \_\mathrm{k} \Omega\) resistances, respectively. The load resistor is \(10 \_k \Omega\). If the source resistance is \(50 \_\Omega\) and \(\alpha 0\) is 0.93 , find \(\beta 0\) and the gains for this amplifier.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

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output resistance
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Press TOOL to view all calculated results.

\section*{6．13．2．BJT（Common Emitter）}

\section*{Example：}

A common base configuration of a linear amplifier has an emitter resistance of \(35 \_\Omega\) ， collector and base resistances of \(1 \_\mathrm{M} \Omega\) and \(1.2 \_\mathrm{k} \Omega\) resistances，respectively．The load resistor is \(1 \_k \Omega\) and the output resistance is \(1 \_M \Omega\) ．
If the source resistance is \(50 \_\Omega\) and \(\alpha 0\) is 0.93 ，find \(\beta 0\) and the gains for this amplifier．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．

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Press TOOL to view all calculated results．

\subsection*{6.13.3. BJT (Common Collector)}

\section*{Example:}

An amplifier in a common collector configuration has a gain \(\alpha 0\) of 0.99 . The emitter, base and collector resistances are \(25 \_\Omega\), \(1000 \_k \Omega\), and \(100000 \_\mathrm{M} \Omega\) respectively. The load resistor is \(100 \_\Omega\). If the source resistance is \(25 \_\Omega\) find all the mid-band characteristics.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.
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Press TOOL to view all calculated results.

\subsection*{6.13.4. FET (Common Gate)}

\section*{Example:}

A FET amplifier connected in a common gate mode has a load of \(10 \_k \Omega\). The external gate resistance is \(1 \_\mathrm{M} \Omega\) and the drain resistance is \(125 \_\mathrm{k} \Omega\). The transconductance is \(1.6 \times 10^{\wedge}-3\) _Siemens.
Find the midband parameters.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

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FE.j (G)HHON EOSC)
E.JT CoHHON EHitter')

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Press TOOL to view all calculated results.

\subsection*{6.13.5. FET (Common Source)}

\section*{Example:}

Find the voltage gain of a FET configured as a common-source based amplifier. The transconcductance is \(2.5 \times 10^{\wedge}-3\) Siemens, a drain resistance of \(18 \_\mathrm{k} \Omega\) and a load resistance of 100_k \(\Omega\).
Find all the parameters for this amplifier circuit.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.


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Press TOOL to view all calculated results.

\subsection*{6.13.6. FET (Common Drain)}

\section*{Example:}

Compute the voltage gain for a common-drain FET amplifier. The transconcductance is \(5 \times 10^{\wedge}-3 \_\)Siemens, a drain resistance of \(25 \_\mathrm{k} \Omega\) and a load resistance of \(100 \_\mathrm{k} \Omega\). Find all the parameters for this amplifier circuit.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.

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Solving for fy
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Zero

EDIT WHES WIEM HLL HENLT


Press TOOL to view all calculated results.

\section*{6．13．7．Darlington（CC－CC）}

\section*{Example：}

Transistors in a Darlington pair having a \(\beta 0\) value of 100 are connected to a load of \(10 \_k \Omega\) ．The emitter，base and source resistances are \(25 \_\Omega, 1500 \_k \Omega\) and \(1 \_k \Omega\) ， respectively．The external base resistance is \(27 \_\mathrm{k} \Omega\) ．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．

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Press TOOL to view all calculated results．

\subsection*{6.13.8. Darlington (CC-CE)}

\section*{Example:}

An amplifier circuit has a base, emitter, and load resistance of \(1.5 \_k \Omega, 25 \_\Omega\), and \(10 \_k \Omega\), respectively. The configuration has a value of \(\beta 0\) equal to 100 . The source and collector resistances are 1_k \(\Omega\) and \(100 \_k \Omega\).
Find the voltage gain, input and output resistances.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.


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Press TOOL to view all calculated results.

\section*{6．13．9．Emitter－Coupled Amplifier}

\section*{Example：}

An emitter coupled pair amplifier is constructed from transistors with \(\alpha 0=0.98\) ．The emitter，base and collector resistances are \(25 \_\Omega\) ， \(2 \_k \Omega\) and \(56 \_k \Omega\) ，respectively．If the load resistance is \(10 \_k \Omega\) ，find the mid－band performance factors．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．



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Press TOOL to view all calculated results．

\subsection*{6.13.10. Differential Amplifier}

\section*{Example:}

A differential amplifier pair has a transconductance of 0.005 _Siemens, \(\alpha 0=0.98\), \(\beta 0=49\). The external collector and external emitter resistances are \(18 \_\mathrm{k} \Omega\) and \(10 \_k \Omega\) respectively. If the emitter resistance is \(25 \_\Omega\) and the base resistance is \(2 \_k \Omega\), find the common mode, differential resistance and gains.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.






Press TOOL to view all calculated results.

\section*{6．13．11．Source－Coupled JFET Pair}

\section*{Example：}

Find the gain parameters of a source－coupled JFET pair amplifier if the external drain resistance is \(25 \_\mathrm{k} \Omega\) ，and the source resistance is \(100 \_\Omega\) ．The drain resistance is \(12 \_k \Omega\) and the transconductance is \(6.8 \times 10^{\wedge}-3 \_\)Siemens．

\section*{Solution：}

All of the equations are needed to compute the solution for this problem．

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Press TOOL to view all calculated results．

\subsection*{6.14. Class A, B and C Amplifiers}


Note: The equations in this section are grouped under topics which describe general properties of semiconductors or devices. Equations for a variety of specific cases and are listed together under a sub-topic heading and are not necessarily a set of consistent equations which can be solved together. Choosing equations in a subtopic without regard as to whether the equations represent actual relationships could generate erroneous results or no solution at all.

\subsection*{6.14.1. Class A Amplifier}

\section*{Example:}

A Class A power amplifier is coupled to a \(50 \_\Omega\) load through the output of a transformer with a turn ratio of 2 . The quiescent operating current is \(60 \_\mathrm{mA}\), and the incremental collector current is \(50 \_\mathrm{mA}\). The collector-to-admitter voltage swings from \(6 \_\mathrm{V}\) to \(12 \_\mathrm{V}\). The supply collector voltage is \(15 \_\mathrm{V}\). The maximum current is \(110 \_\mathrm{mA}\). Find the power delivered and the efficiency of power conversion.

\section*{Solution:}

All of the equations are needed to compute the solution for this problem.
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Press (TOOL to view all calculated results.

\subsection*{6.14.2. Power Transistor}

\section*{Example:}

A power transistor has a common emitter current gain of 125. A 750_ \(\Omega\) base resistance is coupled to an external emitter resistance of \(10 \_\mathrm{k} \Omega\). The ambient temperature is \(75 \_\mp\) and the thermal resistance of the unit is \(10 \_\mathrm{C} / \mathrm{W}\). The power that needs to be dissipated is \(12.5 \_W\). The base emitter voltage is 1.25 _V while ICBO is \(1 \_\mathrm{mA}\).
Find the junction temperature, collector current and the instability factor.

\section*{Solution:}

We note from the equation set that IC is computed in three different ways. To make the calculations consistent given the data, we use equations \(1,2,4\) and 5 to solve for this problem.



EDIT WHES WIEN HLL HENLT


Press TOOL to view all calculated results.

\subsection*{6.14.3. Push-Pull Principle}

\section*{Example:}

Find the output power for a push-pull circuit with a collector voltage of 15 _V and a load resistance of \(50 \_\Omega\). The push-pull transformer secondary winding amplifies voltage by a factor of 2.5 .

\section*{Solution:}

Use the third equation to compute the solution for this problem.


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Fush-Fu!! Frimciple
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    FF=WCOLH0
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    FO=NOCO(2\timesF)
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EMII WHESOPICTD SI D HFLT SOLDE

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ne: 2.5
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WC: 15_W
R2: 50_0

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[11: 1
voc: 15_V
R2: 50_0

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\subsection*{6.14.4. Class B Amplifier}

\section*{Example:}

A Class B amplifier provides 5_W to an effective load of \(50 \_\Omega\). The collector voltage is \(25 \_\mathrm{V}\). If the peak current is \(500 \_\mathrm{mA}\), find the average DC current and the efficiency of power conversion.

\section*{Solution:}

Use the first, second, fourth and fifth equations to compute the solution for this problem.







\subsection*{6.14.5. Class C Amplifier}

\section*{Example:}

A Class \(C\) amplifier is supplying a tuned circuit, with a quality factor of 5 . If the output voltage is \(15 \_\mathrm{V}\) and the power delivered is \(75 \_\mathrm{W}\).
Find the capacitive reactance of the circuit needed in the tank circuit.

\section*{Solution:}

Use the second equation to compute the solution for this problem.
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vo: 15_V
e: 5
Fo: 75_N

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\section*{6．15．Transformers}

\section*{6．15．1．Ideal Transformer}

\section*{Example：}

An ideal transformer has 10 primary turns and 36 secondary turns．The primary side draws \(500 \_\mathrm{mA}\) when subjected to a \(110 \_\mathrm{V}\) input．If the load impedance is \(175 \_\Omega\) ， find the input impedance at the primary side of the transformer in addition to the voltage and current on the secondary end．

\section*{Solution：}

Use all of the equations to compute the solution for this problem．

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Solid state deuices
Linedr amplifiers

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\hline v2： V＿W \(^{\text {l }}\) &  \\
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Press TOOL to view all calculated results．

\section*{6．15．2．Linear Equivalent Circuit}

\section*{Example：}

The transformer in the above problem has a primary and secondary resistance of \(18 \_\Omega\) and \(5 \_\Omega\) ，respectively．Therefore，the ideal transformer has 10 primary turns and 36 secondary turns．The primary side draws \(500 \_\mathrm{mA}\) when subjected to a \(110 \_\mathrm{V}\) input．The corresponding coils have a reactance of \(6 \_\Omega\) and \(2.5 \_\Omega\) ．The secondary side is loaded with an impedance of \(12.5 \_k \Omega\) ．The reactive part of load is \(10 \_\Omega\) Find the voltage and current on the secondary side in addition to the equivalent impedance on the primary side．

\section*{Solution：}

Upon examining the problem，all of the equations are needed to compute the solution to this problem．

\begin{tabular}{|c|c|}
\hline W：110＿V &  \\
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\hline 圂：5－9 & E12．5＿k \\
\hline Kin： 0 －\({ }^{\text {a }}\) & 欧： 6 － \\
\hline ［ilis 10 & ［1］：36 \\
\hline 限：2．5＿0 & ［1010＿0 \\
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\begin{tabular}{|c|c|}
\hline W110－V & － \\
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\hline หin＇6．96450．．． & W106， \\
\hline Will 10 & ［120 36 \\
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Press TOOL to view all calculated results．

\subsection*{6.16. Motors and Generators}
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Note: The equations in this section are grouped under topics which describe general properties of semiconductors or devices. Equations for a variety of specific cases and are listed together under a sub-topic heading and are not necessarily a set of consistent equations which can be solved together. Choosing equations in a subtopic without regard as to whether the equations represent actual relationships could generate erroneous results or no solution at all.

\subsection*{6.16.1. Energy Conversion}

\section*{Example:}

A conductor having a length of 15 _cm and a cross sectional area of \(0.5 \_\mathrm{cm}^{\wedge} 2\) is subjected to a magnetic induction of \(1.8 \_\)T and a field intensity of \(2.8 \_\mathrm{A} / \mathrm{m}\). The magnetic reluctance is \(0.46 \_\)A/Wb. The conductor has 32 turns and is moving at a rotational speed of 62 rrad/s. Find the magnetic flux, the magnetic energy, the induced electric field and the mechanical pressure on the coil.

\section*{Solution:}

All of the equations are needed to solve this problem.

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    F=1/2xE*2/nil
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Press TOOL to view all calculated results.

\subsection*{6.16.2. DC Generator}

\section*{Example:}

A six-pole DC generator rotates at a mechanical speed of 31_rad/s. The armature sweeps across a flux of \(0.65 \_\mathrm{Wb}\). There are eight parallel paths and 64 coils in the armature. The armature current is 12_A. The field is supplied by a 25_V source delivering a current of 0.69_A.
Find the torque and the voltages generated in the armature.

\section*{Solution:}

Upon examining the problem, equation one to six are needed to compute the solution for this problem.



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Press TOOL to view all calculated results.

\subsection*{6.16.3. Separately-Excited DC Generator}

\section*{Example:}

A DC generator with a machine constant of 3.8 is driving a load of \(46 \_k \Omega\) and rotates at a speed of \(31 \_\mathrm{rad} / \mathrm{s}\). The magnetic flux is \(1.6 \_\mathrm{Wb}\). The field is driven by a \(24 \_\mathrm{V}\) source. The field coil resistance is \(10 \_\Omega\). The armature resistance is \(13 \_\Omega\) in series with an external resistance of 55_ת.
Find the field current, armature induced voltage and the terminal voltage.

\section*{Solution:}

Use all the equations to compute the solution for this problem.


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Press TOOL to view all calculated results.

\section*{6．16．4．DC Shunt Generator}

\section*{Example：}

Find the machine constant of a shunt generator running at 31＿rad／s and producing 125 ＿V with a 1.8 ＿Wb flux．

\section*{Solution：}

Use the first equation to solve this problem．

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\(4+31 \_r^{-} / \mathrm{s}\)

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\subsection*{6.16.5. DC Series Generator}

\section*{Example:}

Find the terminal voltage of a series generator with an armature resistance of \(0.068 \_\Omega\) and a series resistance of \(0.40 \_\Omega\). The generator delivers a 15_A load current from a generated voltage of 17 _V.

\section*{Solution:}

Use the second equation to solve this problem.

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## 6．16．6．Separately－Excited DC Motor

## Example：

Find the terminal voltage，field current and machine constant for a motor with an armature current 0.5 A and resistance of $100 \_\Omega$ rotating at an angular velocity of $31 \_\mathrm{rad} / \mathrm{s}$ ．The back emf is $29 \_\mathrm{V}$ ．The field is driven by a $15 \_\mathrm{V}$ source driving a $50 \_\Omega$ load．The flux available in the armature is $2.4 \_\mathrm{Wb}$ ．

## Solution：

Solve the first，second，fourth and fifth equations to solve this problem．



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| :---: | :---: |
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| ［60：100］ | E9：29＿V |
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Solving for K K：． 389784946237 Zero



Press TOOL to view all calculated results．

### 6.16.7. DC Shunt Motor

## Example:

Find the back emf for a motor with a machine constant of 2.1 , rotating at 62 rad/s in a flux of 2.4_Wb.

## Solution:

Use the fourth equation to solve this problem.

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[iN Shunt jendrator
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Saparategy-ExGited [ug Hotor
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[II Shunt fotor
FT+=(FR+FF)

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FT+=(FR+FF)
```




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```

```
    -TL=FxpxIN-T (0S5
```






```
    T=T Loss+TL
```

    T=T Loss+TL
    T=K\timesp<I_
T=K\timesp<I_
ENIIWHESD FICT SI C HHLT SOLTE

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ENIIWHESD FICT SI C HHLT SOLTE
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## Ed:

H: 2. 1
4 4 : 62 _r/s
か:2.4_怗
hus. enf induced in drhatur
ELIT Wiles WIEM $\square$ SOLTE



### 6.16.8. DC Series Motor

## Example:

A series motor, with a machine constant of 2.4 , rotating at 62 rad/s, is supplied with a terminal voltage of $110 \_\mathrm{V}$ and produces a torque of $3 \_\mathrm{N}^{*} \mathrm{~m}$. The armature resistance is $10 \_\Omega$, the series resistance is $5 \_\Omega$, and the adjustable resistance is 0.001_ $\Omega$.

Find the average voltage induced in the armature, the flux, and the load current.

## Solution:

The first, third and fifth equations are needed to compute a solution.






EDIT WHES WIEA HLL HEOLT


Press TOOL to view all calculated results.

## 6．16．9．Permanent Magnet Motor

## Example：

Find the machine constant for a permanent motor rotating at 62．5＿rad／s in a magnetic flux field of $1.26 \_$Wb．Assume a $110 \_$V back emf．

## Solution：

The first equation is needed to compute the solution．

```
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```



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    V+:EN+FMNI|
    T=T 05s+TL
```



```
Induction Motor I
Indu\tion Hotor II
EAD WHESQ FICT SI a HBLT SOLDE
```



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Ed:110_V
H:
*:1.26_帖
4,62,5_r/s
Hochime constont
EIIT WARE TIED \ SOLNE
```



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    NTC Shunt Hotor
    ouT Series Motor
    F&rm St.art.ing
        Solver...
    T=T\0s5+TL
```



```
    Induction Hotor I
Induction Hotor II
```




```
Eq: 'Eョ=K`关亲心m'
En:110_V
H:1,396825019682
p:1.26_竌
4+62,5_r/s
Haching gonstant
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## 6．16．10．Induction Motor I

## Example：

Find the mechanical power for an induction motor with a slip of 0.95 ，a rotor current of 75 ＿A and a resistance of $1.8 \_\Omega$ ．

## Solution：

Upon examining the problem，equation ten is needed to compute a solution．

 Induction Hotor I


Fi Gt．ヨrti i
FH Gロ1 ver＂．．
FH

$\mathrm{FH}=\mathrm{Fi}_{i} \times \mathrm{I}_{r} \times 2+(1-5)_{2} \leq \times \mathrm{Fi}_{i} \times \mathrm{I}_{\mathrm{r}} \times 2$




5：．95
Fir：1．8＿ת
Ir：75＿H

Hechonical poher
EDIT WHFE TIEN IIFO゙ SOLTE

### 6.16.11. Induction Motor II

## Example:

An applied voltage of $125 \_\mathrm{V}$ is applied to an eight pole motor rotating at 245_rad/s. The stator resistance and reactance is $8 \_\Omega$ and $12 \_\Omega$ respectively.
Find the maximum torque.

## Solution:

Use the fourth equation to compute the solution.



$\boldsymbol{*}: 245 \_r / s$
p: 8
$\mathrm{W}: 125 \_\mathrm{V}$
Rst: 8_n
HL: 12_気
Moximun positive torque
EDIT WHES WIEM DSOLTE



w : $245 \_r^{-/ s}$
p: 8
$\mathrm{Va}: 125 \mathrm{~V}$
Fst: 8_
XL: 12-
Hoximur positive torque


### 6.16.12. Single-Phase Induction Motor

## Example:

Find the forward slip for an eight pole induction motor with a stator frequency of 245 _rad/s and a mechanical radian frequency of 62.5_rad/s.

## Solution:

The first equation is needed to compute the solution.

| dithute hexti <br> Fur series hotor hot hotor <br>  <br> Single-Fhose Induction <br> Fratepuxerviver <br> $\mathrm{Tb}=-\mathrm{p} \cdot \mathrm{Z} \times 1 / 4 \mathrm{~m} \times \mathrm{I} 5 \mathrm{~b} \times 2 \times \mathrm{Fir}$ <br> Synchronous Hachines |
| :---: |
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| :---: | :---: |
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|  |  |



$5 F$ : - G, VEG4EB16
p: 8
w: 245_r/s


Slip For Formard flux


### 6.16.13. Synchronous Machines

## Example:

Find the stator radian frequency and the maximum torque for a synchronous machine with a mechanical rotational velocity of 31_rad/s. The motor has eight poles, a field current of 1.8_A and experiences an applied voltage of 130_V.

## Solution:

The first and second equations are needed to compute the solution.


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FErHament hogmet Hotor
Induction Hotor
Induction Hotor II
Singl:q-Fhuse Induction Hotor
```



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    F%=2FPxus
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```
    FHD=NaNIaNC0S (0)
    T=FHE*4H
```



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EEXFTWAESD FICT SI O HFLT LESOLT
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| w: 0 -r/s |  |
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| Fuldout torque |  |
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| w 124_rss |  |
| If 1.8 BCO |  |
| W13014 |  |
| Fuldout torque |  |
| ELIT Wilis wiEn |  |



Solving for ws
ws: 124_r/s Zero



Press TOOL to view all calculated results.

## 7. Used Keys

The following keys are used by the TreeBrowser application, which provides the environment for Electrical Engineering.

Keys while the TreeBrowser is active:
MEX: opens a tree
\#\#\#\#n : closes a tree
 lowest level


 61)
 and 61)

 stack. One has complete control over the calculator at this point. If an error happens by another program, for example, which is not covered by TreeBrowser your calculator may crash. The purpose of these functions is to allow simple calculations so that it is not necessary to leave TreeBrowser for this. $\leftarrow$ CONT brings you back to the TreeBrowser.
WE: starts the solver if one is on the lowest level and the equation contains $=$. System flag 30 controls if the solver of the HP 48SX or the solver of the HP 48GX is used.
HXEW: starts the Multiple Equation Solver, all equations of the lowest level are grouped together. The equations should be related by topic to each other if you want usable results (also see user guide of the HP 48GX).
$\rightarrow$ CONT brings you back to the TreeBrowser.
 double click opens or closes a tree
APPS : starts the solver if the equation contains =
MODE : toggles between the way equations are shown, if you provide a program which tests system flag 13 it is possible to have two different appearances of the equation.
TOOL : opens a choose box to select the equations which will be passed to the Multiple Equation Solver.
VAR : shows variables (if there are any)
HIST : shows picture (if there is any)
ON: ends TreeBrowser
ENTER: opens or closes a tree
$\rightarrow$ A arrow keys to navigate or to move the screen

: one page up
: one page down
: first entry
: last entry
: move screen to the right
$\Gamma$ : move screen to the left
EEX: choose font
${ }^{+}$_/ : toggle fonts
$x$ : hide / show title
1/x : hide / show menu
$\div$ : integrated help

Keys while an equation is shown:
TOOL: previous equation
STO: copies the current equation to the stack
NXT : next equation

+ +_ : toggles between big and small appearance of the equation (changes system flag 80)
ON: leaves the equation view and jumps back to the TreeBrowser
SPC: previous equation
ENTER : next equation
(4) $\square$ : arrow keys to navigate or to move the screen


## 8. Things To Do

In principle, it would be possible to extend Electrical Engineering with more equations and/or more functionality.
Contact me directly in this case to examine what would be needed for this. mailto:Software49G@gmx.de
Suggestions, criticism and/or improvements are welcome.

## 9. Version History

09.04.2012 Version 1.0 First public version.
01.01.2014 Version 1.01 Revised all equations.
01.12.2014 Version 1.10 Added Analysis.

## 10. Known Bugs

Version 1.01
Revised all equations, added some missing equations, fixed some bugs in some equations.

