WTCS Electrical Engineering Technology Transfer Outcomes
Full Detail (1-23)

Updated 11.4.16

Fundamental Transfer Outcomes (1-17)

1. Circuit Fundamentals 1
    a. Utilize electronics terminology, schematic symbols, SI units of measure, and standards appropriately
        i. you match the name for electrical and magnetic parameters to the correct SI (International System of Units) symbols and units for each parameter
        ii. you identify wire diameter using the American Wire Gauge (AWG) standard
        iii. you convert a quantity written in engineering notation to a standard metric prefix notation for electronics applications
        iv. you convert among metric prefixed units
        v. you select the correct electrical components for a circuit assembly from a schematic diagram
        vi. You mark component current directions and voltage polarities on a schematic
        vii. you use a scientific calculator with features to perform electronic calculations
        viii. you identify relevant electrical and electronic standards
    b. Explain Voltage, Current, and Resistance
        i. you define charge and the fundamental unit of charge (Coulomb)
        ii. you describe the movement of electric charges and the effect of an electric field on charges
        iii. you define electron and conventional current flow
        iv. you define current and its fundamental unit of measurement
        v. you define voltage and its fundamental unit of measurement
        vi. you define resistance, its voltage-current relationship (Ohm's Law), and its fundamental unit of measurement
        vii. you define conductance, its mathematical relationship to resistance, and its fundamental unit of measurement
        viii. you define the general classes of electrical materials (insulators, conductors, semiconductors)
    c. Explain DC voltage and DC current sources
        i. you describe the voltage-current relationship of a DC voltage source
        ii. you state examples of DC voltage sources
        iii. you state an example of a DC current source
        iv. you describe the voltage-current relationship of a DC current source
        v. you describe the difference in DC source voltage-current relationships between electron and conventional current flow viewpoints
    d. Identify basic electrical components and their voltage - current relationships
        i. you define the voltage - current relationship of a basic switch
        ii. you identify a resistor value from its value coding (color code or other coding)
        iii. you use Ohm's Law to calculate voltage, current, or resistance when two of those three parameters are known
    e. Sketch basic electrical circuit schematics and wiring/pictorial diagrams

        i. you explain the difference between a circuit schematic and a circuit wiring diagram
        ii. you utilize AC neutral, DC common, and chassis ground symbols properly
        iii. you utilize appropriate component symbols in circuit schematic diagrams
        iv. you sketch basic electrical circuit pictorial/wiring diagrams
        v. you sketch basic electrical circuit diagrams
    f. Assemble basic circuits from circuit schematics, wiring diagrams, and/or specifications
        i. you gather components for circuit assembly by interpreting circuit diagrams and component specifications
        ii. you interconnect components matching circuit diagrams (e.g. switches, circuit protection devices, resistors, and DC power sources)
        iii. you verify expected operation according to circuit diagrams and/or descriptions of operation
    g. Measure basic DC electrical quantities (Voltage, Current, Resistance)
        i. you choose appropriate instrumentation for measuring electrical quantities
        ii. you configure instruments to measure the desired quantity correctly
        iii. you connect instruments to a circuit properly to take the desired measurement
        iv. you observe safety precautions when connecting meters in circuits and to devices
        v. you measure DC electrical quantities with a multifunction meter
    h. Calculate component voltages and currents in basic DC electrical circuits
        i. you calculate DC voltage sources in series and parallel
        ii. you calculate DC current sources in series and parallel
        iii. you calculate equivalent resistance of resistor networks
        iv. you describe at least one resistor network for which the equivalent resistance cannot be calculated, yet can be measured
        v. you use Ohm's Law to calculate resistor currents and voltages in basic resistive circuits having a single DC voltage supply
    i. Calculate power in basic DC electrical circuits.
        i. you calculate power dissipation using any two resistor parameters from among voltage, current, resistance
        ii. you calculate source power delivered to a circuit from DC source voltage and current

2. Circuit Fundamentals 2
    a. Analyze series DC resistive circuits
        i. you recognize node voltages are relative to DC common
        ii. you calculate the voltages and currents in a series circuit using the appropriate circuit laws and analysis techniques
        iii. you calculate resistor powers
        iv. you document your calculations to communicate the solution process
        v. you verify calculations of expected values in a lab exercise
        vi. you perform a complete analysis on series resistor circuits
    b. Analyze parallel DC resistive circuits
        i. you recognize node voltages are relative to DC common
        ii. you calculate the voltages and currents in a parallel circuit using the appropriate circuit laws and analysis techniques
        iii. you calculate resistor powers

        iv. you document your calculations to communicate the solution process
        v. you verify calculations of expected values in a lab exercise
        vi. you perform a complete analysis on parallel resistor circuits
    c. Analyze series-parallel DC resistive circuits
        i. you recognize node voltages are relative to DC common
        ii. you calculate the voltages and currents in a series parallel circuit using the appropriate circuit laws and analysis techniques
        iii. you calculate resistor powers
        iv. you document your calculations to communicate the solution process
        v. you verify calculations of expected values in a lab exercise
        vi. you perform a complete analysis on series parallel resistor circuits
    d. Measure basic electrical parameters in DC resistive circuits
        i. you measure properly: DC voltages from nodes to ground in resistive network circuits
        ii. you measure properly: DC voltages across components in resistive network circuits
        iii. you measure properly: DC currents throughout resistive network circuits
        iv. you measure properly: network resistances
    e. Troubleshoot DC resistive circuits
        i. you compare expected (calculated) and actual (measured) parameters
        ii. you identify conflicts between predicted and actual circuit performance
        iii. you use iterative steps of hypothesis, test, and evaluation to isolate causes of problems
        iv. you determine causes of conflicts using successive steps to efficiently isolate the cause
        v. you identify short and open circuit conditions in DC resistive circuits
        vi. you identify defective components in circuits
        vii. you identify wiring problems in circuits
        viii. you determine appropriate corrective actions

3. Circuit Fundamentals 3
    a. Apply DC Thevenin and Norton Equivalent Circuits
        i. you explain the steps to determine the Thevenin equivalent circuit
        ii. you explain the steps to determine the Norton equivalent circuit
        iii. you perform the steps to determine the Thevenin equivalent circuit
        iv. you perform the steps to determine the Norton equivalent circuit
        v. you utilize the Thevenin and Norton models to determine the load resistance for Maximum Power Transfer (MPT)
        vi. you convert DC voltage sources to DC current sources and Thevenin models to Norton models
        vii. you convert DC current sources to DC voltage sources and Norton models to Thevenin models
        viii. you verify the equivalent circuit results
    b. Analyze DC circuits with multiple sources using Superposition
        i. You analyze the circuit for each individual source
        ii. You determine the Superposed results by observing proper voltage polarities and current directions
        iii. you verify final circuit analysis

c. Analyze DC circuits using Nodal Analysis (KCL & Ohm's Law)
    i. You explain the Nodal Analysis Process
    ii. You determine Node voltages using the Nodal analysis process
    iii. You document the mathematical solution process (e.g. multiple equations, multiple unkowns)
    iv. You determine other voltages and currents in the circuit from the Node voltages
    v. You verify the results of the Nodal analysis
d. Analyze resistive bridge circuits
    i. you identify whether a resistive bridge circuit is balanced or unbalanced
    ii. you apply formulas for wye-delta and delta-wye conversions
    iii. you determine whether the bridging resistor has voltage across it or current through it
    iv. you calculate the component voltages and currents in the bridge circuit
    v. you determine an unknown resistance value using a bridge circuit
    vi. you verify the results

4. Circuit Fundamentals 4 DC-AC
    a. Define the mathematical parameters of sinusoidal AC signals and the math relationships among them
        i. you define peak, peak-to-peak, RMS, period, and frequency parameters of sinusoidal voltage and current
        ii. you convert among peak, peak-to-peak, and RMS voltage and current
        iii. you convert among period, and frequencies in Hertz and radians per second
        iv. you define sinusoidal period and frequencies (cyclical and radian) and their mathematical relationships
        v. you extract peak value, frequency, period, and phase shift from sinusoidal time-domain expressions of voltage and current
        vi. you extract peak value, frequency, period, and phase shift from time-domain plots and scope traces of sinusoidal voltage and current
        vii. you write mathematical expressions for sinusoidal voltage and current from corresponding time-domain plots
        viii. you sketch time-domain plots of sinusoidal voltage and current from sinusoidal time-domain expressions.
        ix. you define leading and lagging phase relationships between two sine waves
        x. you quantify leading and lagging phase relationships between two sine waves in degrees and in radians
        xi. you write phasor expressions that represent sinusoidal voltage and current functions of time
    b. Determine the performance of resistors in AC circuits
        i. you explain the graphical time relationship among sinusoidal AC voltage, current, and instantaneous power for a resistance
        ii. you determine the reactance and impedance of a sinusoidally excited resistance
        iii. you express the voltage-current relationship of a resistance in terms of phasor quantities of voltage, current, and impedance
    c. Determine the performance of capacitors in DC circuits
        i. you describe the basic construction of various types of capacitors
        ii. you utilize appropriate capacitor symbols in circuit schematics

iii. you explain charge displacement and energy storage in a capacitor and their relationship to voltage
iv. you state the formula for capacitance C in terms of its physical properties
v. you determine the capacitance value in Farads, the maximum DC working voltage, and the polarity restrictions of a capacitor
vi. you calculate the net capacitance of capacitors in series or parallel
vii. you calculate the DC time constant for a series RC circuit
viii. you plot the predicted time-domain voltage and current responses in a series RC circuit due to a step change in source voltage
ix. you calculate the instantaneous energy stored in a capacitor from its instantaneous voltage

d. Determine the performance of capacitors in AC circuits
   i. you explain the graphical time relationship between sinusoidal AC voltage and current for a capacitor
   ii. you determine the reactance and impedance of a sinusoidally excited capacitor
   iii. you distinguish between resistance and reactance
   iv. you differentiate between the reactance and the impedance of a capacitor
   v. you express the voltage-current relationship of a capacitor in terms of phasor quantities of voltage, current, and impedance

e. Explain basic principles of magnetism and electromagnetism
   i. you sketch the magnetic flux lines of a permanent magnet and an electromagnetic coil
   ii. you explain the effects of magnetic materials on a magnetic field
   iii. you identify the permeability of magnetic and non-magnetic materials
   iv. you describe the relationship between current magnitude and direction and magnetic field magnitude and direction, including the Right Hand Rule
   v. you describe the general construction and operation of an electromagnet, a solenoid, and a relay
   vi. you explain the basic electromagnetic cause-effect relationship expressed by Faraday's law
   vii. you explain the basic electromagnetic cause-effect relationship expressed by Lenz's Law
   viii. you determine polarity of an induced voltage
   ix. explain the sudden release of stored magnetic energy known as "magnetic kick"

f. Determine the performance of inductors in DC circuits
   i. you describe the basic construction of various types of inductors
   ii. you utilize appropriate inductor symbols in circuit schematics
   iii. you explain energy storage in an inductor and its relationship to current
   iv. you state the formula for inductance L in terms of its physical properties
   v. you determine the inductance value in Henries and the maximum DC working current
   vi. you explain why inductors also have resistance
   vii. you calculate the net inductance of inductors in series or parallel
   viii. you calculate the DC time constant for a series RL circuit
   ix. you plot the predicted time-domain voltage and current responses in a series RL circuit due to a step change in source voltage
   x. you calculate the instantaneous energy stored in an inductor from its instantaneous current

g. Determine the performance of inductors in AC circuits
    i. you explain the graphical time relationship between sinusoidal AC voltage and current for an inductor
    ii. you determine the reactance and impedance of a sinusoidally excited inductor
    iii. you distinguish between resistance and reactance
    iv. you differentiate between reactance and impedance of an inductor
    v. you express the voltage-current relationship of an inductor in terms of phasor quantities of voltage, current, and impedance
    vi. You explain the effects of internal resistance upon the net impedance of an inductor
h. Apply college algebra and trigonometry to sinusoidal circuit analysis (phase vectors)
    i. you convert phasors between polar and rectangular forms
    ii. you perform complex number addition, subtraction, multiplication, and division manually
    iii. you plot voltage, current, impedance, and the complex power triangle as phasors in polar and rectangular forms
    iv. you perform complex number calculations using an advanced scientific calculator
i. Examine the response of transformers to AC sinusoidal stimulus
    i. you describe the basic construction forms for a laminated iron core transformer
    ii. you explain why insulated laminations are used to make an iron core
    iii. you identify the two most common magnetic core materials (iron/steel and ferrites) and their relative advantages and disadvantages
    iv. you explain the concepts of DC isolation and AC coupling for a transformer
    v. you explain the purpose of tapped and multiple windings
    vi. you calculate ideal primary to secondary sinusoidal voltage ratio using the turns ratio
    vii. you calculate ideal primary to secondary sinusoidal current ratio using the turns ratio
    viii. you calculate ideal primary (input) to secondary (output) power ratio
    ix. you calculate input resistance at the primary terminals with a resistive load at the secondary terminals using the turns ratio
    x. you calculate turns ratio given primary and secondary sinusoidal voltages
    xi. you identify primary to secondary voltage and current phase relationships based on dot notation (resistive load only)
    xii. you describe the effects of too little and too much magnetic field flux in the core
    xiii. you explain why and where actual power losses occur in a transformer

5. Circuit Fundamentals 5 DC-AC
    a. Analyze series RL and RC circuits using phasor analysis
        i. you apply algebra and trigonometry to AC circuit analysis using phasors
        ii.
        iii. you recognize series connected components have the same AC current and differing AC voltages
        iv. you calculate total series circuit impedance
        v. you calculate voltages and currents in series AC circuits using basic circuit laws appropriately
        vi. you calculate complex power of components and sources

    vii. you differentiate between "average" (real) power and complex power
    viii. you document your calculations to record the solution process
    ix. you verify calculations of expected values in a lab exercise
b. Analyze parallel RL and RC circuits using phasor analysis
    i. you apply algebra and trigonometry to AC circuit analysis using phasors
    ii. you differentiate among total, branch, and component currents
    iii. you recognize parallel connected components have the same AC voltage and differing AC currents
    iv. you calculate total parallel circuit impedance
    v. you calculate voltages and currents in parallel AC circuits using basic circuit laws appropriately
    vi. you calculate complex power of components, branches, and sources
    vii. you differentiate between "average" (real) power and complex power
    viii. you document your calculations to record the solution process
    ix. you verify calculations of expected values in a lab exercise
c. Analyze the ideal Series RLC circuit using phasor analysis
    i. you apply algebra and trigonometry to AC circuit analysis using phasors
    ii. you recognize series connected components have the same AC current and differing AC voltages
    iii. you calculate total series circuit impedance
    iv. you calculate voltages and currents in series AC circuits using basic circuit laws appropriately
    v. you identify when resonance is present
    vi. you calculate complex power of components and sources
    vii. you differentiate between "average" (real) power and complex power
    viii. you document your calculations to record the solution process
    ix. you verify calculations of expected values in a lab exercise
d. Analyze the ideal Parallel RLC circuit using phasor analysis
    i. you apply algebra and trigonometry to AC circuit analysis using phasors
    ii. you differentiate among total, branch, and component currents
    iii. you recognize parallel connected components have the same AC voltage and differing AC currents
    iv. you calculate total parallel circuit impedance
    v. you determine admittances, conductances, and susceptances in AC parallel RLC circuits
    vi. you calculate voltages and currents in parallel AC circuits using basic circuit laws appropriately
    vii. you identify when resonance is present
    viii. you calculate complex power of components, branches, and sources
    ix. you differentiate between "average" (real) power and complex power
    x. you document your calculations to record the solution process
    xi. you verify calculations of expected values in a lab exercise
e. Analyze series-parallel AC circuits using phasor analysis
    i. you apply algebra and trigonometry to AC circuit analysis using phasors
    ii. you calculate total circuit network impedance
    iii. you calculate voltages and currents in series-parallel AC circuits using basic circuit laws.
    iv. you calculate complex power of components, networks , and sources

    v. you document your calculations to record the solution process
    vi. you verify calculations of expected values in a lab exercise
f. Measure electrical parameters in AC circuits using an oscilloscope
    i. you measure the phase relationship between two AC sinusoids with an oscilloscope
    ii. you measure AC voltages (magnitude and phase) from nodes to ground in series-parallel circuits with an oscilloscope
    iii. you determine AC voltages and currents (magnitude and phase) across components not connected to ground in series-parallel circuits from node voltage measurements
g. Troubleshoot AC (RLC) circuits
    i. you compare expected (predicted) and actual (measured) parameters
    ii. you identify discrepancies between predicted and actual circuit performance
    iii. you use iterative steps of hypothesis, test, and evaluation to isolate causes of problems
    iv. you determine causes of discrepancies using successive steps to efficiently isolate the cause
    v. you identify short and open circuit conditions in AC circuits
    vi. you identify defective components in circuits
    vii. you identify wiring problems in circuits
    viii. you determine appropriate corrective actions

6. Circuit Fundamentals 6 DC-AC
    a. Derive AC Thevenin and Norton Equivalent Circuits for basic AC circuits
        i. you explain the steps to determine the Thevenin equivalent circuit
        ii. you explain the steps to determine the Norton equivalent circuit
        iii. you perform the steps to determine the Thevenin equivalent circuit
        iv. you perform the steps to determine the Norton equivalent circuit
        v. you utilize the Thevenin and Norton models to determine the load impedance for Maximum Power Transfer (MPT)
        vi. you perform source conversions between Thevenin models and Norton models
        vii. you document your calculations to communicate your solution process
        viii. you verify the equivalent circuit results through simulation or measurement
        ix. you verify the equivalent circuit results through simulation or measurement
    b. Analyze basic AC circuits with multiple sources using Superposition
        i. you explain the superposition analysis process
        ii. you analyze the circuit for each individual source by properly deactivating other sources in the circuit
        iii. you determine the Superposed results including proper voltage polarities and current directions
        iv. you document your calculations to communicate the solution process
        v. you verify your circuit analysis through simulation or lab measurement
    c. Analyze basic AC circuits using Nodal Analysis (KCL & Ohm's Law)
        i. you identify reference, trivial (non-essential), and significant (essential) nodes of a series - parallel AC circuit
        ii. you explain the Node Voltage (Nodal) Circuit Analysis Process
        iii. you determine circuit significant Node voltages using the Nodal analysis process
        iv. you determine other voltages and currents in the circuit from the Node voltages

v. you document your calculations to communicate your solution process
vi. you verify the results of your Nodal analysis through simulation or lab measurements

d. Analyze AC bridge circuits
   i. you explain how to identify whether an AC bridge circuit is balanced or unbalanced
   ii. you determine whether an AC bridge circuit is balanced or unbalanced
   iii. you analyze balanced AC bridge circuits applying appropriate circuit analysis techniques
   iv. you analyze unbalanced AC bridge circuits applying formulas for wye-delta and delta-wye conversions
   v. you calculate the component voltages, currents, and complex power in the bridge circuit
   vi. you document your calculations to communicate your solution process
   vii. you verify your analysis results through simulation or lab measurement
e. Construct Bode approximations of frequency response for four basic filter circuits (series RL, LR, RC, & CR)
   i. you determine the general frequency dependent transfer function of basic series impedance circuits
   ii. you calculate the critical / half power frequency for series RL, RC, CR, and LR circuits
   iii. you explain decibels related to power and voltage ratios
   iv. you differentiate among dB [too advanced at this level]
   v. you sketch semi-log plots of magnitude (Vout/Vin in dB) vs. frequency using straight line approximations
   vi. you sketch semi-log plots of phase (Vouot/Vin in degrees) vs. frequency using straight line approximations
   vii. you correct straight line approximation sketches using 3 points of correction for the magnitude plot and 2 points for the phase plot
   viii. you explain the difference between high pass and low pass filters
   ix. you identify basic RL and RC filters as high pass or low pass
   x. you calculate output voltage from given input voltage and dB voltage gain
   xi. you document your calculations to communicate the solution process
   xii. you verify your analysis through simulation or lab measurement
f. Determine the resonant frequency response of the ideal series RLC circuit
   i. you describe the variation of total circuit impedance as a function of frequency
   ii. you formally define resonance
   iii. you apply the definition of resonance to a series RLC circuit
   iv. you calculate the resonant frequency in both radians per second and in Hertz
   v. you calculate impedances, voltages and currents at any frequency
   vi. you sketch total impedance magnitude and phase vs. frequency
   vii. you sketch series current magnitude and phase vs. frequency
   viii. you identify the total impedance at the resonant frequency to equal the series resistance
   ix. you identify the reactive component voltages at the resonant frequency as having equal magnitudes and opposite phases
   x. you identify that the reactive component voltage magnitudes at the resonant frequency may exceed the source voltage magnitude

xi. you identify the voltage across the resistance at the resonant frequency equals the source voltage in magnitude and phase
xii. you calculate the Q (quality factor) for the circuit
xiii. you calculate the 3 dB (half power) bandwidth from the Q factor and resonant frequency in both radians per second and in Hertz
xiv. you estimate the -3db / half power frequencies at half the bandwidth both above and below the resonant frequency
xv. you explain why the series RLC circuit can be used as a band pass filter
xvi. you document your calculations to communicate the solution process
xvii. you verify your analysis through simulation or lab measurements

g. Determine the resonant frequency response of the ideal parallel RLC circuit
    i. you describe the variation of total circuit impedance with frequency
    ii. you apply the definition of resonance to an ideal parallel RLC circuit you calculate the resonant frequency in both radians per second and in Hertz
    iii. you calculate impedances, voltages and currents at any frequency
    iv. you identify the total impedance at the resonant frequency to equal the series resistance
    v. you identify the reactive component currents at the resonant frequency as having equal magnitudes and opposite phases
    vi. you identify the reactive component current magnitudes at the resonant frequency may exceed the source current magnitude
    vii. you identify the current through the shunt resistance at the resonant frequency equals the source current in magnitude and phase
    viii. you sketch total impedance magnitude and phase vs. frequency
    ix. you sketch parallel voltage magnitude and phase vs. frequency
    x. you calculate the Q (quality factor) for the circuit
    xi. you calculate the 3 dB bandwidth from the Q factor and resonant frequency in both radians per second and in Hertz
    xii. you estimate the 3 dB frequencies at half the bandwidth both above and below the resonant frequency
    xiii. you explain why the parallel RLC circuit can be used as a band reject filter
    xiv. you document your calculations to communicate the solution process
    xv. you verify your analysis through simulation or lab measurement

h. Determine the resonant parameters of the practical parallel RLC circuit
    i. you calculate the resonant frequency including the effect of inductor winding resistance
    ii. you calculate the quality factor Q including the effect of inductor winding resistance
    iii. you calculate the 3 dB bandwidth including the effect of inductor winding resistance
    iv. you document your calculations to communicate the solution process
    v. you verify your analysis through simulation or lab measurement

i. Document analysis and measurement according to standard practice
    i. you record information in an engineering notebook conforming to specific notebook documentation guidelines
    ii. you write engineering reports conforming to specific engineering report guidelines

7. Diodes and Rectifiers
    a. Explain the operation of diodes
        i. you explain the effects of biasing diodes
        ii. you explain diode models and characteristic curves
        iii. you select an appropriate diode using manufacturer's data sheets
    b. Determine the operation of diodes in rectifier circuits
        i. you construct diode rectifier circuits
        ii. you test diode rectifier circuits
        iii. you determine the effects of diode voltage drops on the output of a rectifier circuit
        iv. you determine ripple frequency and voltage characteristics of rectifier circuits
    c. Evaluate operation of special purpose diodes (including LED, Zener, and Schottky)
        i. you determine current-limiting resistance values for special purpose diodes
        ii. you verify the basic operation of a special purpose diode
        iii. you identify typical packages of a special purpose diode
    d. Evaluate the operation of diode clippers and clampers
        i. you explain the operation of clipper and clamper circuits
        ii. you construct diode clipper and clamper circuits
        iii. you test diode clipper and clamper circuits

8. Power Supply Circuits
    a. Analyze capacitor operation in power supplies
        i. you explain the effects of a filter capacitor on the output of a rectifier circuit
        ii. you predict the ripple voltage and frequency of a capacitor filtered power supply
        iii. you measure the ripple voltage and frequency of a capacitor filtered power supply
    b. Evaluate Zener diode regulators
        i. you interpret Zener diode specifications from a data sheet
        ii. you test the operation of a Zener diode regulator
    c. Evaluate three terminal regulators
        i. you interpret regulator specifications from a data sheet
        ii. you construct a regulated power supply that includes a three terminal IC regulator
        iii. you test a regulated power supply that includes a three terminal IC regulator
    d. Test power supply operation
        i. you identify power supply components
        ii. you explain power supply components
        iii. you test regulation and ripple voltage under varying conditions

9. MOSFET/JFET Characteristics/Basic Operation
    a. Explain the operation and operating regions of JFET and MOSFET devices

        i. you explain the operation of a JFET
        ii. you explain the JFET biasing conditions for cutoff, active and ohmic regions
        iii. you explain the operation of a MOSFET
    b. Apply the JFET/MOSFET as a switch
        i. you construct a switching transistor circuit
        ii. you test a switching transistor circuit
        iii. you explain the operation of a switching transistor circuit
    c. Predict bias values in JFET/MOSFET circuits using existing equations
        i. you determine the Q-point for an FET circuit using both a graphical approach and a mathematical approach
        ii. you construct an FET circuit
        iii. you measure the biasing voltages in an FET circuit
    d. Differentiate the characteristics among MOSFET/JFET amplifier configurations
        i. you explain the voltage gain characteristics of each amplifier configuration
        ii. you explain the input and output impedance characteristics of each amplifier configuration
    e. Predict AC mid-band gains and impedances in JFET/MOSFET circuits using existing equations
        i. you predict the bias requirements for different amplifier configurations
        ii. you predict the voltage gain characteristics of the different amplifier configurations
        iii. you predict the input and output impedance characteristics of the different amplifier configurations
    f. Measure bias levels, gains, and impedances of JFET/MOSFET amplifier circuits
        i. you construct an amplifier
        ii. you test the input and output impedances
        iii. you test the voltage gain
        iv. you test the bias levels
        v. you compare predicted and measured values

10. BJT Characteristics/Basic Operation
    a. Explain the basic operation and operating regions of a BJT
        i. you explain the internal construction of a BJT
        ii. you explain the different regions of operation which includes cutoff, active and saturation regions
    b. Apply the BJT as a switch
        i. you construct a switching transistor circuit
        ii. you test a switching transistor circuit
        iii. you explain the operation of a transistor switching circuit (including open collector)
    c. Apply equations for bias levels in BJT amplifier circuits
        i. you determine the Q-point for a BJT amplifier circuit using existing equations

        ii. you draw the DC load line for a BJT amplifier circuit
        iii. you construct a BJT amplifier circuit
        iv. you test a BJT amplifier circuit for bias levels
    d. Differentiate the attributes among the three BJT amplifier configurations
        i. you explain the voltage gain characteristics of each configuration
        ii. you explain the input and output impedance characteristics of each configuration
    e. Differentiate among amplifier classes (A, AB, B, C)
        i. you explain the bias requirements for the different classes of operation
        ii. you explain the operating characteristics of the different amplifier classes
    f. Calculate AC mid-band gains and impedances in BJT circuits using existing equations
        i. you predict the bias requirements for different amplifier configurations
        ii. you predict the voltage and current gain characteristics for different amplifier configurations
        iii. you predict the input and output impedance characteristics for different amplifier configurations
        iv. you test BJT amplifier circuits
        v. you compare your predicted and measured values

11. OP-AMP Characteristics
    a. Explain the basic characteristics of a differential transistor amplifier
        i. you explain the common and differential mode gains
    b. Explain the characteristics of an operational amplifier
        i. you explain basic operational characteristics (including open loop gain, gain-bandwidth product, input and output impedance)
        ii. you explain output saturation voltages
        iii. you differentiate between the ideal and practical models of the op-amp using data sheets

12. OP-AMP Circuits
    a. Evaluate basic active filters
        i. you select op amp circuit configurations for various filter applications
        ii. you predict the frequency response of a given active filter
        iii. you construct active filter circuits to meet stated specifications
        iv. you measure the frequency response (amplitude) of a given active filter
        v. you compare the predicted and measured values of a given active filter
    b. Examine the trade-off between the closed-loop gain and bandwidth of op-amp amplifier circuits
        i. you measure the effects of the gain-bandwidth product on circuit frequency response
        ii. you measure the effects of open-loop gain on closed-loop gain using existing equations

c. Verify the operation of basic OP-AMP circuits
    i. you construct inverting and non-inverting amplifiers
    ii. you measure the characteristics of inverting and non-inverting amplifiers
    iii. you design inverting and non-inverting amplifiers using existing equations
    iv. you compare the designed and measured values
    v. you explain the uses of a buffer amplifiers
    vi. you explain the operation of summing and difference amplifiers
    you explain the operation of a basic op-amp comparator

13. Digital Electronics 1a
    a. Analyze Digital number systems
        i. you identify the base or radix of a number system
        ii. you convert among numbering systems (binary, decimal, hexadecimal,)
        iii. you identify number code systems (binary coded decimal (BCD), ASCII)
    b. Test functions of basic logic functions
        i. you verify the truth table of an AND logic gate
        ii. you verify the truth table of an OR logic gate
        iii. you verify the truth table of an INVERTER/NOT and BUFFER logic gates
        iv. you verify the truth table of a NOR logic gate
        v. you verify the truth table of an XOR logic gate
        vi. you verify the truth table of a NAND logic gate
    c. Implement Boolean expressions using combinational logic circuits
        i. you confirm the correct operations
        ii. you complete a truth table
        iii. you compare it back to the expression
    d. Identify electrical signals or characteristics
        i. you identify the supply specifications
        ii. you apply ESD precautions in working with digital circuitry
        iii. you identify the input/output voltage specs for a logic low and a logic high
        iv. you identify the input/output current specs for logic low and logic high
    e. Test the operation of logic blocks
        i. you verify the function table of encoders
        ii. you verify the function table of decoders
        iii. you verify the function table of multiplexers

14. Digital Electronics 1b
    a. Test the operation of display devices
        i. you verify function table for LCD
        ii. you verify function table for LED
        iii. you describe the concept of multiplex displays
    b. Test the operation of sequential logic devices
        i. you verify the function table for latches

    ii. you verify the function table for flip/flops
    iii. you verify the function table for asynchronous counters
    iv. you verify the function table for synchronous counters
    v. you verify the function table for shift registers
  c. Determine functions of electronic memory
    i. you identify the types of memory (static and dynamic)
    ii. you observe the memory function characteristics (ROM, RAM, volatile, nonvolatile)
    iii. you verify the function table of memory
  d. Interface digital to field devices
    i. you control an output device using a digital circuit
    ii. you connect an input device to drive a digital circuit
    iii. you connect an opto-isolator to control a device
    iv. you connect a relay to control a device

15. Digital Electronics 2a
  a. Apply Boolean tools and other simplification techniques
    i. you convert minterm to maxterm and maxterm to minterm using DeMorgan's Theorem
    ii. you verify the conversion produces the same output for the given input, theoretically
    iii. you verify the implementation produces the same output for the given input
    iv. you reduce a logic circuit or a minterm Boolean expression using Karnaugh mapping
    v. you verify the reduction produces the same output for the given input
  b. Differentiate specifications among logic families
    i. you extract pertinent information from the data sheet
    ii. you extract physical characteristics
    iii. you extract electrical characteristics
    iv. you select appropriate components for interfacing between logic families
  c. Build encoders, decoders, and multiplexers into a system
    i. you build a bcd encoder
    ii. you interface to a seven segment display
    iii. you interface encoders and decoders with LED and LCD displays
    iv. you troubleshoot the system using instrumentation
  d. Generate pulses and timing signals
    i. you build a timing (such as 555) circuit to be a one shot
    ii. you build a timing circuit to create a pulse train
    iii. you build a timing circuit to create asymmetrical pulses
    iv. you investigate alternatives to the 555 timing circuit
    v. you discover hysteresis using a Schmitt trigger

16. Digital Electronics 2b
    a. Build clocked logic circuits to drive encoders, decoders and multiplexer systems with asynchronous and/or synchronous counters
        i. you construct a four-bit asynchronous counter using discrete components
        ii. you troubleshoot a four-bit asynchronous counter
        iii. you determine a test procedure for several types of logic circuits (e.g. circuit, keypad encoder circuit, multiplexed display system)
        iv. you follow the test procedure to troubleshoot several types of logic circuits (e.g. memory circuit, keypad encoder circuit, multiplexed display system)
        v. you describe the operation of a sequential logic circuit using a state-diagram
    b. Implement a design using programmable logic devices
        i. you download the tool (such as Xlinx or Altera)
        ii. you use schematic capture or Verilog/VHDL to modify or design a logic function
        iii. you simulate your design
        iv. optional: you download the design to hardware
    c. Explain digital design considerations (relate to real world)
        i. you describe low-voltage/battery operation
        ii. you analyze debounced switches
        iii. you analyze power-up/power-down sequencing
        iv. you analyze input and output coupling/driving
        v. you analyze interface considerations
        vi. you analyze noise considerations
        vii. you analyze transmission of digital signals
    d. Test an analog to digital interface
        i. you explain the function of D/A
        ii. you explain the function of A/D
        iii. you apply D/A and A/D conversion to an application (e.g. temperature controller)

17. Microcontrollers/Microprocessors and Embedded Systems *(old #20)*
    a. Describe microcontroller/microprocessor architecture
        i. you describe fundamental computer architecture concepts like Von Neumann/Harvard
        ii. you describe an instruction set architecture (ISA)
        iii. you describe the basic instruction cycle: Fetch, Decode, vs. Execute.
        iv. you describe microcontroller's memory architecture: program memory, registers, RAM.
    b. Program microcontrollers/microprocessors (target) using microprocessor language (preferably C)
        i. you implement computer programs
        ii. you debug/troubleshoot simple programs

iii. you describe data types (float, int, char)
iv. you describe variables defined by different data types
v. you implement conditional instructions to make decisions. Such as - if, if else, if else if, switch case
vi. you implement loops to repeat code. Such as -
vii. for loops
viii. while loops
ix. do-while loops
x. you describe a function declaration and description
xi. you implement library/third party functions with function declaration and descriptions.
xii. you create user defined functions
xiii. you create user defined header files
xiv. you manipulate data arrays
xv. you describe indirect addressing in C language
xvi. you describe structures and pointers to structures in C language
xvii. you determine how to set, reset, toggle and read a bit using bitwise operators in C language
xviii. you implement compiler dependent functions to program a microcontroller
xix. you link pointers to memory mapped registers
xx. you describe bit masking using pointers for bit setting, resetting, toggling and reading.
xxi. you link pointers-to-structures to memory mapped registers

c. Apply Hexadecimal numbering system to memory mapped registers
   i. you describe hexadecimal numbers
   ii. you describe memory mapped registers
   iii. you access memory mapped registers using Hexadecimal numbers
d. Analyze General Purpose Digital I/O
   i. you determine GPIOs on a microcontroller by reading the manufacturers data sheet.
   ii. you describe the difference between tri-state, latch and port registers
   iii. you implement program to engage internal pull up resistors
   iv. you interface LEDs and Switches to the GPIO
   v. you analyze the details of the GPIO
e. Evaluate Parallel Communications
   i. you apply program instructions to operate a parallel port
   ii. you apply pointers to structures to exercise parallel ports
   iii. you apply pointers to structures to exercise parallel port subsets
   iv. you demonstrate how to interface alphanumeric LCD panels
   v. you demonstrate how to interface keypads
f. Analyze Analog to Digital Conversion
   i. you describe the A/D conversion process
   ii. you implement a microcontrollers A/D converters using manufacturers data sheet
   iii. you calculate the resolution, quantization and other metrics used in A/D conversion
   iv. you interface linear output temperature sensors using A/D modules
g. Analyze Interrupts

i. you describe a microcontrollers interrupt process
ii. you describe external interrupts
iii. you setup external interrupts using manufacturers data sheet
iv. you program external interrupts using C language
v. you analyze the effects of the external interrupts
vi. you describe timer units with overflow interrupts
vii. you setup timer units with overflow interrupts using manufacturers data sheet.
viii. you program timer units with overflow interrupts using C language
ix. you analyze the effects of timer units with overflow interrupts
x. you describe timer units with capture interrupts
xi. you setup timer units with capture interrupts using manufacturers data sheet
xii. you program timer units with capture using C language
xiii. you analyze the effects of timer units with capture interrupts
xiv. you describe timer units with compare interrupts
xv. you setup timer units with compare interrupts using manufacturers data sheet
xvi. you program timer units with compare interrupts using C language.
xvii. you analyze the effects of timer units with compare interrupts
xviii. you describe Analog to Digital interrupts
xix. you describe USART transmit and receive Interrupts

h. Implement Pulse Width Modulation (PWM)
    i. you describe PWM in terms of frequency and duty cycle.
    ii. you setup a PWM module using manufacturers data sheet.
    iii. you program a PWM signal of adjustable frequency and duty cycle

i. Implement Serial Communications
    i. you describe the serial communications process and principles.
    ii. you describe USART serial communication modules
    iii. you setup a USART module using manufacturers data sheet
    iv. you program a USART for Transmit (Tx) and Receive (Rx)
    v. you program a USART using interrupts for character transfer
    vi. you describe I2C serial communication modules
    vii. you setup an I2C module using manufacturers data sheet
    viii. you program an I2C module for basic character transfer
    ix. you describe SPI serial communication modules
    x. you setup an SPI module using manufacturers data sheet
    xi. you program an SPI module for basic character transfer
    xii. you troubleshoot Serial communications

Advanced Transfer Outcomes (18-23)

18. Power and Motor Systems 1 *(old #17)*
    a. Explain magnetic principles as related to electromechanical equipment
        i. you define magnetic characteristics and units
        ii. you describe a simple magnetic circuit in terms of magnetic flux, magnetomotive force, and reluctance.

iii. you describe magnetic saturation as it relates to the B-H curve.
iv. you explain Faradays law as applied to rotating equipment
v. you explain Lenz's law as applied to rotating equipment
vi. you define stator magnetics
vii. you define rotor magnetics
viii. you define Faraday's law and Lenz's law as applied to transformers

b. Analyze single phase power transformers
   i. you explain transformer ratings
   ii. you explain the operation of an ideal single phase transformer
   iii. you describe transformer losses both fixed and variable
   iv. you determine transformer losses from models
   v. you measure transformer parameters (such as short-circuit and open-circuit tests)
   vi. you compare transformer measurements to models

c. Apply formulas to balanced three-phase circuits including transformer applications
   i. you calculate primary, secondary and load line and phase voltages, currents and power for a given three phase balanced transformer circuit
   ii. you explain typical three- phase transformer configurations (delta and wye)
   iii. you calculate three phase circuit line and phase parameters (voltage, current and power)
   iv. you measure (preferred) or simulate three phase circuit line and phase parameters (voltage, current and power)
   v. you describe the effects of an unbalanced three-phase load connected to a balanced three-phase source on the line and phase currents [Note: Analysis completed in DC AC Electronics 3]

d. Calculate component values for power factor correction
   i. you determine reactive power for power factor correction
   ii. you determine component type and value from reactive power

19. Power and Motor Systems 2 *(old #18)*

a. Predict motor operation from motor properties and calculations
   i. you describe the motor principle of forces on a current-carrying conductor in a magnetic field.
   ii. you describe the generator principle of induced voltage in a conductor due to the relative motion between a conductor and a magnetic field.
   iii. you describe the construction of a squirrel cage induction motor
   iv. you describe the construction of a synchronous wound motor
   v. you apply AC motor models to calculate the electrical parameters for three-phase induction motors and three-phase synchronous motors in steady state operation
   vi. you describe AC motor starting characteristics (direction and current)

vii. you calculate mechanical parameters for AC motors (torque and speed) from Nameplate data
viii. you predict load characteristics of an AC motor (torque and speed)

b. Implement motor control circuits for start, stop and speed/torque for DC and/or AC motors
   i. you describe the electrical parameters used to control start, stop and speed/torque control for DC motor.
   ii. you describe the electrical parameters used to control start, stop and speed/torque control for AC motor.
   iii. you design discrete motor control circuits for starting and stopping, and speed/torque control
   iv. you build/simulate motor control circuits
   v. you verify motor control operation
c. Program a PLC or PAC or similar controller for motor control
   i. you control motor operation through a programmable controller
   ii. you use programming environment to create a simple program
   iii. you use programming environment to verify program operation
d. Describe other motor applications
   i. you describe servo motor characteristics
   ii. you describe servo motor applications
   iii. you describe variable reluctance principles as applied to stepper motor operation
   iv. you describe stepper motor characteristics
   v. you describe stepper motor applications

20. PLC *(old #19)*
   a. Describe the architecture of a programmable logic controller (PLC)
      i. you summarize the PLC program scan sequence
      ii. you identify the main parts of a PLC system
      iii. you describe the function of the hardware components used in PLC systems
      iv. you list the advantages of PLC over fixed logical controls
      v. you describe the difference between Tag-based and Rack/Slot addressing
      vi. you describe input and output image table files and types of data files
      vii. you explain how ladder logic diagram language is used to communicate information to the PLC
   b. Utilize Boolean ladder logic to optimize circuits
      i. you utilize Boolean ladder logic to create a program specific to a logic description
      ii. you describe the program flow of a series of Boolean ladder rungs
      iii. you download/Run a ladder logic program
      iv. you compare the optimized program to the original logic description
   c. Associate I/O addresses to field devices

        i. you download a properly addressed program
        ii. you configure I/O hardware for PLC project
        iii. you verify proper program with the field devices
        iv. you identify addresses for discrete I/O modules
        v. you identify addresses for analog I/O modules
        vi. you differentiate file based and tag based I/O addressing for a PLC

d. Interface programming environment to PLC
    i. you configure communication with PLC using programming environment
    ii. you configure PLC using programming environment
    iii. you create new PLC programs using programming environment
    iv. you document PLC programs using programming environment
    v. you verify program operation using programming environment
    vi. you edit program operation using programming environment
e. Apply instructions to PLC programs
    i. you select the programming symbols
    ii. you utilize bit instructions
    iii. you utilize timer instructions
    iv. you utilize counter instructions
    v. you utilize word instructions
f. Design a PLC program using timers, counters, and comparison arithmetic to meet a system specification
    i. you list the program input and output specifications
    ii. you create a flow chart of the algorithm that meets the specifications
    iii. you create new PLC programs using programming environment
    iv. you troubleshoot PLC using programming environment
    v. you verify PLC program meets system specification
g. Develop Human-Machine Interfaces (HMI) for PLC systems
    i. you describe the functions of an Human-Machine Interface (HMI) and an Operator Interface Terminal
    ii. you differentiate between Human Machine Interface and Operator Interface Terminal
    iii. you utilize appropriate software to integrate an Operator Interface Terminal into a PLC-based system
    iv. you adhere to written specifications in developing OIT and HMI screens
    v. you utilize advance functions of Operator Interface Terminals
    vi. you develop a PLC program with assigned tags
    vii. you develop screen objects for a complete HMI system
    viii. you verify the Human Machine Interface Terminal application meets the written specification
    ix. you establish communication between programming terminal, HMI, and PLC
h. Comply with established industry safety guidelines
    i. you identify established industry safety standards

ii. you identify the unsafe characteristics of PLCs to avoid unsafe machine operation
iii. you state the special characteristics that make a PLC a "safety PLC."
iv. you practice proper safety protocols (e.g. lockout/tagout, download protocols, etc.)

21. DC & AC Electronics 3 *(old #24)*
    a. Analyze DC series-parallel circuits
        i. you deconstruct a DC series-parallel circuit into series sub-circuits and parallel sub-circuits.
        ii. you analyze the circuit and sub-circuits to determine resultant resistance, conductance, voltage and current values
    b. Express alternating current sinusoidal signals in the time domain and the phasor domain mathematically
        i. you perform operations of addition, subtraction, multiplication, and division on complex numbers.
        ii. you define a phasor
        iii. you explain phasor applications
        iv. you can explain the difference between a signal in the time domain and phasor domain and convert between them.
        v. you convert between polar and rectangular notation expressions of sinusoidal waveforms
        vi. you extract magnitude and phase components of an AC signal expression.
        vii. you combine magnitude and phase components into a single AC phasor expression
    c. Explain reactance and impedance of an ideal resistor
        i. you express resistance in terms of the real part of impedance.
        ii. you associate resistance with energy conversion.
        iii. you associate a resistor and at least one other device with the property of resistance
    d. Explain DC and AC characteristics of an ideal inductor
        i. you explain inductance and associate it with energy storage.
        ii. you explain the difference between an ideal inductor and a practical inductor.
        iii. you explain the behavior of an inductor in a DC steady-state circuit.
        iv. you explain the fundamental action of an inductor to oppose instantaneous change in current.
        v. you explain the phase relationship between voltage and current for an inductor in an AC circuit.
        vi. you determine the impedance in rectangular and polar form of an inductor at a given frequency
    e. Explain DC and AC characteristics of an ideal capacitor
        i. you associate capacitance with energy storage.

    ii. you explain the behavior of a capacitor in a DC steady-state circuit.
    iii. you explain fundamental action of a capacitor to oppose instantaneous change in voltage.
    iv. you explain the phase relationship between voltage and current for a capacitor in an AC circuit.
    v. you determine the impedance of a capacitor in rectangular and polar form at a given frequency

f. Analyze an AC series electrical circuit using phasors
    i. you express AC voltages and currents as phasors
    ii. you express components as impedances
    iii. you analyze the circuit to determine phasor voltages and currents.
    iv. you compare AC series circuit analysis techniques with DC series circuit analysis techniques

g. Analyze an AC parallel electrical circuit using phasors
    i. you express AC voltages and currents as phasors
    ii. you express components as impedances.
    iii. you analyze the circuit to determine phasor voltages and currents.
    iv. you Compare AC parallel circuit analysis techniques with DC parallel circuit analysis techniques

h. Analyze AC series-parallel circuits using phasors
    i. you decompose a AC series-parallel circuit into series sub-circuits and parallel sub-circuits.
    ii. you analyze the circuit and sub-circuits to determine resultant impedance, admittance, voltage and current values. you Compare AC series-parallel analysis technique with DC series-parallel analysis technique

i. Analyze multiple-source AC electrical circuits using superposition
    i. you explain why all sources of a multi-source circuit must be at the same frequency in order to perform superposition analysis.
    ii. you deconstruct an AC multi-source circuit into multiple single-source circuits enabling superposition.
    iii. you analyze single-source AC circuits individually using series-parallel analysis techniques.
    iv. you determine the superposed voltages and currents for the multi-source circuit

j. Determine complex power in an AC circuit containing reactances
    i. you explain complex, real, reactive, and apparent power associating correct units of measure with each
    ii. you explain power factor.
    iii. you identify the appropriate equation to calculate the desired complex power quantity
    iv. you calculate the desired complex power quantity using the appropriate equation.
    v. you determine complex power for a series-parallel circuit.

vi. you determine power factor and the required component value required to correct power factor.
vii. you explain how power factor is key in maximizing power transfer efficiency and minimizing line current

k. Analyze DC and AC circuits using nodal analysis technique
   i. you explain the Nodal analysis process.
   ii. you label the circuit showing circuit quantities in preparation for nodal analysis.
   iii. you apply KCL to non-trivial nodes in a systematic manner to formulate a set of simultaneous equations in terms of node voltages.
   iv. you solve the simultaneous equations to determine node voltages.
   v. you determine other voltages and currents in the circuit from the node voltages.
l. Determine the Thevenin equivalent circuit for a given DC or AC circuit
   i. you explain the process in determining a Thevenin equivalent circuit.
   ii. you determine the Thevenin equivalent circuit.
   iii. you determine the voltage, current and complex power of the load reconnected to the Thevenin equivalent circuit.
   iv. you explain why an AC Thevenin equivalent circuit containing reactance is only valid at one frequency
m. Determine the Norton equivalent circuit for a given DC or AC circuit
   i. you explain the process in determining a Norton equivalent circuit.
   ii. you determine the Norton equivalent circuit.
   iii. you determine the voltage, current and complex power of the load reconnected to the Norton equivalent circuit.
   iv. you explain why an AC Norton equivalent circuit containing reactance is only valid at one frequency
n. Determine load impedance for maximum power transfer between source and load
   i. you determine that load impedance which enables maximum power transfer.
   ii. You determine that load resistance which enables maximum power transfer.
   iii. you specify the load for maximum power transfer in a given circuit
o. Analyze AC circuits that contain ideal transformers
   i. You differentiate between an ideal and a practical transformer in terms of operation and performance
   ii. You describe the effects of transformer losses on circuit performance
   iii. you determine voltage, current, impedance, and complex power in circuits containing an ideal transformer
p. Analyze balanced and unbalanced three-phase circuits
   i. you describe three-phase circuits along with explanations of their key features, benefits, and applications.
   ii. you draw three-phase delta and wye configurations with labels.
   iii. you discuss the voltage and current phase relationships in balanced three-phase delta and wye configurations.
   iv. you convert between delta and wye configurations.

v. you analyze balanced and unbalanced delta source-delta load, wye source-wye load, delta source-wye load, and wye source-delta load three-phase circuits to determine line and phase voltages, currents, and complex power

q. Demonstrate proper use of DC and AC electronic instrumentation in the laboratory
   i. you select correct equipment to measure voltages, currents, and frequency response of DC and AC electrical circuits.
   ii. you determine measurement approaches for voltages and currents in DC and AC electrical circuits.
   iii. you measure voltages and currents in series-parallel DC and AC electrical circuits

r. Create technical documentation
   i. you document laboratory work in a formal engineering record.
   ii. you use appropriate terminology
   iii. you apply technical writing skills

22. Electronic Circuit Analysis *(old #25)*
   a. Analyze first-order Resistor-Inductor (RL) and Resistor-Capacitor (RC) Alternating Current (AC) circuits.
      i. you apply appropriate circuit laws and analysis techniques with frequency as the independent variable.
      ii. you utilize complex algebra to analyze circuits as a function of frequency
      iii. you algebraically simplify the complex number circuit expressions
   b. Develop the transfer function into Bode form for Resistor-Inductor (RL) and Resistor-Capacitor (RC) circuits
      i. you utilize circuit analysis to develop expressions that relate the input and output variables of RC and RL circuits
      ii. you execute the steps to develop a transfer function into Bode form for two and three component RL and RC circuits
      iii. you determine the break frequencies from the transfer function in Bode form
   c. Generate magnitude (in dB) and phase Bode Plots from a transfer function in Bode form
      i. you separate transfer function into magnitude (in deciBels (dB)) and phase expressions
      ii. you identify the type of line segments corresponding to each type of term in the magnitude and phase expressions
      iii. you plot the individual line segments on Bode plots of each term in the transfer function
      iv. you sum the individual line segments to obtain the total response on each Bode plot
   d. Explain the Bode plot response of first-order low-pass and high-pass filters from the transfer functions
      i. you describe general circuit operation of low-pass filters and high-pass filters
      ii. you explain mathematically the slopes and corner frequency within the magnitude Bode plot from the transfer function

iii. you explain mathematically the break and two corner frequencies within the phase Bode plot from the transfer function
iv. you explain circuit operation from the transfer function for RL and RC circuits
v. you explain circuit operation from the magnitude and phase Bode plots for RL and RC circuits

e. Characterize the response of Resistor-Inductor-Capacitor (RLC) resonant circuits
    i. you derive resonant frequency expressions for series, ideal parallel, and parallel including inductor winding resistance
    ii. you define resonance for RLC circuits
    iii. you explain resonant circuit parameters (resonant frequency, quality factor (Q), 3dB frequencies, and bandwidth (BW))
    iv. you determine (by analysis, simulation, and measurement) resonant frequency, quality factor (Q), bandwidth (BW), and 3 dB frequencies for resonant circuits
    v. you calculate voltages, currents, and impedances within RLC resonant circuits
    vi. you estimate voltage and current levels using resonant circuit rules of thumb

f. Determine Direct Current (DC) bias performance of linear transistor amplifier circuits
    i. you derive the DC bias expressions for Bipolar Junction Transistor (BJT) and Field Effect Transistor (FET) single-stage linear transistor amplifier configurations
    ii. you calculate the DC bias levels of various single-stage linear transistor amplifier configurations
    iii. you correlate the predicted, computer simulated, and experimental DC transistor bias results

g. Determine AC mid-band performance for BJT and FET linear transistor amplifier circuits
    i. you derive expressions for the voltage gain, the current gain, the input impedance, and the output impedance of various single-stage linear transistor amplifier configurations
    ii. you calculate the voltage gain, the current gain, the input impedance, and the output impedance of various single-stage linear transistor amplifier configurations
    iii. you correlate predicted, simulated, and experimental mid-band gain and impedance results
    iv. you incorporate an AC model for the transistor into the AC equivalent circuit of the small-signal linear amplifier

h. Design first-order filters, resonant circuits, and linear transistor amplifiers in guided exercises from given specifications
    i. you design a first order filter to meet break frequency and impedance specifications
    ii. you design series and parallel resonant circuits to meet resonant frequency, resonant impedance, and 3 dB bandwidth specifications

iii. you design a single-stage linear BJT amplifier for a given transistor to meet a small-signal mid-band gain specification for a given load (includes bias circuit design)
iv. you design a single-stage linear FET amplifier for a given transistor to meet a small-signal midband gain specification for a given load (includes bias circuit design)
v. you validate designs using simulation and/or measurements

i. Execute measurement test plan of filters, resonant circuits, and linear transistor amplifiers
    i. you plan measurement of voltages, currents, and frequency response of first order filters, resonant circuits, and transistor amplifier circuits
    ii. you perform measurement of voltages, currents, and frequency response of first order filters, resonant circuits, and transistor amplifier circuits

23. Data Communications and Networking *(old #27)*
    a. Describe Fundamental Communication and Networking Concepts
        i. you describe a fundamental communication link consisting of a transmitter, transmission medium, and receiver.
        ii. you describe differences between serial and parallel communications.
        iii. you describe advantages and disadvantages of serial and parallel communications.
        iv. you define commonly used terms in data communications, networking, and standards.
        v. you describe various network topologies (bus, ring, star, and mesh).
        vi. you differentiate between physical and logical topologies.
        vii. you select an appropriate network topology for a given application.
        viii. you describe client-server communication for distributed processing in a networked system.
        ix. you define protocols as used in network and data communications
    b. Describe Serial Data Interface
        i. you describe characteristics of a commonly used serial data interface.
        ii. you describe interface hardware and operation of data control functions of a typical standardized serial data interface
    c. Describe Open Systems Interconnect (OSI) Model and TCP/IP Layers
        i. you describe peer-to-peer communication processes at each layer of a layered architecture of protocols.
        ii. you describe the roles of each of the physical, data link, network, and transport layers of the OSI model
        iii. you categorize commonly used protocols by the appropriate OSI layer.
        iv. you describe the layers of the TCP/IP protocol suite
    d. Analyze the Physical Layer

i. you describe physical layer protocols including network topology (bus, ring, star, and mesh).
ii. you describe the concept of frequency content in a signal.
iii. you describe transmission impairments associated with signaling on transmission media.
iv. you calculate maximum data rate for information through a channel having specified bandwidth and signal-to-noise ratio, using the Shannon capacity equation.
v. you calculate the minimum bandwidth of a cable that uses two signal levels at a specified baud rate to transfer serial information, using the Nyquist limit

e. Determine Line Coding and Modulation Waveforms
    i. you sketch the time waveform of a line-coded data signal given the binary data sequence being transferred and the line coding method (including NRZ, RZ, and Manchester).
    ii. you describe the time waveform of a digitally modulated signal given the binary data sequence being transferred and the modulation method (including ASK, FSK, PSK, and OFDM)

f. Analyze A-to-D Conversion
    i. you describe the sampling and quantization processes within A-to-D conversion.
    ii. you determine the minimum sampling rate required for A-to-D conversion of an analog signal having a specified bandwidth.
    iii. you determine the signal-to-noise ratio for an analog signal recovered from an A-to-D converted signal, when quantization has a specified number of levels

g. Describe Modems and Multiplexers
    i. you describe multiplexing.
    ii. you describe time division multiplexing, frequency division multiplexing, and their differences.
    iii. you describe typical signal processing functions of a modem.
    iv. you compare specifications of commonly used broadband technologies

h. Select Transmission Media for Various Applications
    i. you identify various physical transmission media.
    ii. you describe advantages and disadvantages of various physical transmission media.
    iii. you identify relevant cabling standards, codes, and safety practices.
    iv. you select an appropriate transmission medium for an application

i. Describe Data Link Layer Protocols
    i. you describe the use of error detection and correction methods.
    ii. you define error control and flow control achieved by commonly used data link layer protocols.
    iii. you describe the operation of the Stop-and-Wait data link layer protocol.
    iv. you describe the operation of the Sliding Window data link layer protocol.

v. you describe commonly used network medium access control methods (including random, token, and pre-assigned).
vi. you describe Ethernet operation and Ethernet frames.
vii. you describe the function of bridges in Ethernet LANs.
viii. you interpret information gathered by a network analyzer

j. Describe Local and Wide Area Networks
   i. you describe local area network (LAN) concepts.
   ii. you describe commonly used local area network technologies.
   iii. you identify specifications of commonly used local area network technologies.
   iv. you describe the use of Ethernet as a LAN multiple access technology.
   v. you describe wide area network (WAN) concepts.
   vi. you identify commonly used wide area network technologies

k. Describe Network, Transport, and Higher Layer Devices, Protocols, and Services
   i. you describe IP addressing as logical addresses used in TCP/IP networking.
   ii. you describe the functions of routers, gateways, and switches.
   iii. you interpret a routing table.
   iv. you describe the function of transport layer protocols.
   v. you describe establishing, maintaining, and terminating sessions
   vi. you describe the Domain Name System (DNS) used for addressing.
   vii. you describe commonly used Internet protocols such as Simple Network Management Protocol (SNMP) and File Transfer Protocol (FTP)