TCET Formula Sheet

Decibel Formulas

Relative Power Gain

$$A_P = \frac{P_O}{P_I}$$

where P_O and P_I are defined as the following:

$$P_I = \frac{V_I^2}{R_I}$$

$$P_O = \frac{V_O^2}{R_O}$$

Relative Voltage Gain

$$A_V = \frac{V_O}{V_I}$$

Relative Power Gain in dB

$$A_P(db) = 10\log_{10} A_P$$

Given that $R_O = R_I$

If $R_O \neq R_I$ then the general form is given by the following:

$$A_P(db) = 10\log_{10}\left(\frac{\frac{V_O^2}{R_O}}{\frac{V_I^2}{R_I}}\right)$$

Relative Voltage Gain in dB

$$A_V(db) = 20\log_{10}\left(\frac{V_O}{V_I}\right) = 20\log_{10} A_V$$

If $R_O \neq R_I$ then the general form is given by the following:

$$A_V(db) = 20\log_{10}\left(\frac{V_O}{V_I}\right) - 10\log_{10}\left(\frac{R_O}{R_I}\right)$$

Absolute Power Gain dBm

$$A_{P(dBm)} = 10\log_{10}\left(\frac{P}{1\ \text{mW}}\right),\ \text{dBm}$$

Absolute Power Gain dBw

$$A_{P(dBw)} = 10\log_{10}\left(\frac{P}{1\ \text{W}}\right),\ \text{dBw}$$

Signal-to-Noise Ratio

$$\text{SNR} = 10\log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)$$

And given that $R_O = R_I$,

$$\text{SNR} = 10\log_{10}\left(\frac{V_S^2}{V_N^2}\right)$$

$$\text{SNR} = 20\log_{10}\left(\frac{V_S}{V_N}\right)\text{dB}$$

Impulse Noise

$$dB_S = 20\log_{10}\left(\frac{P}{0.0002\bar{\mu}}\right),\ \text{where P is sound pressure in } \bar{\mu}$$

$$\bar{\mu} = 1\frac{\text{dyne}}{\text{cm}^2} = 10^{-6} \text{ of atmospheric pressure at sea level}$$

Convert Parallel to Series Resonant Circuits

$$R_S = \frac{R_p * X_p^2}{R_p^2 + X_p^2} = \frac{R_p}{Q^2+1}$$

$$X_S = \frac{R_p^2 * X_p}{R_p^2 + X_p^2} = \frac{X_p * Q^2}{Q^2+1}$$

Convert Series to Parallel Resonant Circuits

$$R_p = \frac{R_S^2 + X_S^2}{R_S}$$

$$X_p = \frac{R_S^2 + X_S^2}{X_S}$$

Impedance Matching

$$R_{SRC} = R_L,\ \text{for DC sources.}$$

$$Z_{SRC} = Z_L,\ \text{for AC sources.}$$

$$\text{Source Resistance} = \text{Load Resistance}$$

$$P_O = P_I * 0.5$$

Key Points L-Pad Networks

1. The primary applications of L-networks involve impedance matching in RF circuits, transmitters, and receivers.
2. L-networks are useful in matching one amplifier output to the input of a following stage.
3. Any RF circuit application covering a narrow frequency range is a candidate for an L-network.
4. There are four basic versions of the L-network, with two low-pass versions and two high-pass versions.
5. Most widely used since they attenuate harmonics, noise, and other undesired signals.
6. **The impedances that are being matched determine the Q (quality factor) of the circuit, which cannot be specified or controlled.****
7. **There are limits to the range of impedances that it can match.****

Key Points Pi-Pad Networks

1. The π-networks primary application is to match a high impedance source to lower value load impedance
2. It can also be used in reverse to match a low impedance to a higher impedance.
3. The π-network also can be considered two back-to-back L-networks with a virtual impedance between them.
4. To use the L-network procedures, you need to assume an intermediate virtual load/source resistance $R_V = \frac{R_H}{Q^2+1}$
5. R_H is the higher of the two design impedances R_{SRC} and R_L
6. **The resulting R_V will be lower than either R_{SRC} or R_L depending on the desired Q.**
7. **Typical Q values are usually in the 5 to 20 range.**

Key Points T-Pad Networks

1. The main reason to employ a T-network like the π-network, is to get control of the circuit Q.
2. Like the π-network, it's used when you need to limit the bandwidth to reduce harmonics or help filter out adjacent signals without the use of additional filters.
3. The T-network also can be considered two cascaded L-networks. **This is equivalent to the π-network above.**

Note**

There is no specific formulas for low pass or high pass L-pads or T-pads, or π-pads this depends on which is higher, R_L or R_S.

L-Pad Formulas (Low Pass 1)**

$$Q = \sqrt{\frac{R_L}{R_{SRC}} - 1}$$

$$X_L = QR_{SRC}$$

$$L = \frac{X_L}{2\pi f}$$

$$X_C = \frac{R_L}{Q}$$

$$C = \frac{1}{2\pi f X_C}$$

$$BW = \frac{f}{Q}$$

L-Pad Formulas (Conversion Series-Parallel)

$$R_S = \text{ series resistance} = \frac{R_p}{Q^2+1}$$

$$R_p = \text{ parallel resistance} = R_S(Q^2+1)$$

$$X_s = \text{ series reactance} = \frac{X_p Q^2}{Q^2+1}$$

$$X_p = \text{ parallel reactance} = \frac{X_S(Q^2+1)}{Q^2}$$

$$Q = \sqrt{\frac{R_p}{R_S} - 1} = \frac{X_L}{R_S} = \frac{R_p}{X_C}$$

If $Q > 5, y$ you can use the simplified approximations:

$$R_p = Q^2 R_S$$

$$X_p = X_S$$

L-Pad Formulas (Low Pass 2)**

$$Q = \sqrt{\frac{R_{SRC}}{R_L} - 1}$$

$$X_L = QR_L$$

$$L = \frac{X_L}{2\pi f}$$

$$X_C = \frac{R_{SRC}}{Q}$$

$$C = \frac{1}{2\pi f X_C}$$

$$BW = \frac{f}{Q}$$

$$R_R = \frac{L}{CR} = R(Q^2+1) = \text{ resonant equivalent resistance}$$

Pi-Pad Formulas (Low Pass)**

$$BW = \frac{f}{Q}$$

$$R_V = \frac{R_H}{Q^2+1}$$

$$X_L = QR_L;\ \text{use this formula for } X_{L_1} \text{ and } X_{L_2}$$

$$L = \frac{X_L}{2\pi f};\ \text{use this formula for } L_1 \text{ and } L_2$$

$$X_{C_1} = \frac{R_{SRC}}{Q}$$

$$X_{C_2} = \frac{R_L}{Q}$$

$$C = \frac{1}{2\pi f X_C};\text{ use this formula for } C_1 \text{ and } C_2$$

$$Q = \sqrt{\frac{R_{SRC}}{R_L} - 1}; R_{SRC} = R_V$$

Add $L_1 + L_2$ to get total inductance.

T-Pad Formulas (LCC Method)

1. Select the desired bandwidth and calculate Q.
2. Calculate: $X_L = QR_{SRC}$
3. Calculate $X_{C_2} = R_L\sqrt{R_{SRC}\frac{Q^2+1}{R_L} - 1}$
4. Calculate $X_{C_1} = R_{SRC}\frac{Q^2+1}{Q}\frac{QR_L}{QR_L - X_{C_2}}$
5. Calculate the inductance $L = \frac{X_L}{2\pi f}$
6. Calculate the capacitances $C = \frac{1}{2\pi f X_C}$

Telephone Set and Loop Subscriber Interface

Number of Interconnecting Lines $= \frac{n(n-1)}{2}$
Numerical Value of the Wire Pair = Tip Color + Ring Color
Wire pair No. =
(Binder No. $-$ 1) $*$ 25 + Wire pair No. in a 25-pair binder

Telephone Circuit

1. Dialing Circuit Pulse/DTMF are used to make calls
2. On-hook/off-hok circuit
   - Off-Hook - Telephone is picked-up, off the hook
   - On-Hook - Telephone is placed on the hook, "hanged up"
3. Subscriber loop - how power is delivered to the handset (derived from -48 V (DC) from the central office)
   - Most subscriber loops are two-wire pairs
4. Hybrid Circuit - splits the two-wire pairs into four wire: two for transmitting signals, two for receiving signals.
   - Full Duplex is made possible
5. Equalizers - they compensate for different wire lengths from the central office and subcribers. They regulate voice amplitudes

Telephone Ringer

1. Rings to alert the receiver of an incoming call
2. The ringer signal (90 V_{rms} @ 20 Hz; for US Companies) is superimposed of the -48 V (DC) from the central office
3. The ringer in a telephone is composed of two bells which are struck during alternative parts of the cycle.

Telephone Hybrid

1. Most subscriber loops are two-wire pairs
2. The Hybrid Circuit splits the two-wire pairs into four wire: two for transmitting signals, two for receiving signals.
3. Sidetone is the small feedback that allows the user to here him/her-self and adjust their volume accordingly. This is done through a balancing network in the Hybrid Circuit.

Dual Tone Multifrequency

1. There's a key pad instead of a rotary for dialing. There are 10 digits (0-9), 2 special characters (star, and pound), and an optional extra 4 buttons for special functionality ("A", "B", "C", "D").
2. Altogether they form a "4 X 4" frequency matrix consisting of low-band and high-band frequencies.
3. The frequency of each button are seperated with a difference of about 10
4. The frequency between low-band and high-band frequencies are 25
5. When a button is pressed two frequences are sent to the phone company, a low-band and high-band frequency.
6. The frequencies, both low-band and high-band, for each number are unique (their harmonics are unique, too) and don't conflict with each other.
7. The major advantage of DTMF (Touch Tone) over rotary is speed and control.

Centralized Switching

1. Centralized Switching rectifies the problem of having all phones in an area interconnecting. This is done by having a temporary connection between the two parties that want to communicate.

Local Loop

1. In order for phones to be useful they have to be connected to other phones to form a communications link. Check

Telephone Cable Color Codes

1. Wires are colored coded according to a standard for troubleshooting ease.
2. Ten colors are used to identify tip (5 for tip) and ring (5 for ring) wire pairs. Check Numerical Value of the Wire Pair and Wire pair No. equation above.
   (a) Tip Colors: White = 0; Red = 5; Black = 10; Yellow = 15; Violet = 20
   (b) Ring Colors: Blue = 1; Orange = 2; Green = 3; Brown = 4; Slate = 5

Resonance

- Below steady state solution where voltage leads current, transient phenomenon dies out, when ϕ is positive:

$$I = \frac{V_O}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}\cos(\omega t - \phi)\tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R}$$

$$\text{Let } \omega L - \frac{1}{\omega C} = X = \text{reactance}$$

$$\text{Let } \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} = \sqrt{R^2 + X^2} = Z = \text{impedance}$$

$$I = \frac{V_O}{Z}\cos(\omega t - \phi)\tan\phi = \frac{X}{R}$$

- The Transient solution occurs when current leads voltage ϕ is negative. The above doesn't hold yet.

$$\text{Let } \frac{V_O}{Z} = I_{max}$$

- Resonance occurs when $X = 0$; $\omega L = \frac{1}{\omega C}$; $\omega_O = \frac{1}{\sqrt{LC}}$, $Z = R$; and $\phi = 0$ causing $I_{max} = \frac{V_O}{R}$
- Width of the of the resonant curve (similar to bandwidth) $\Delta W = \frac{R}{L} = 0.707 I_{max}$
- Quality Factor $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

PB Filter Series

$$X_L = X_C, \text{ at resonance}$$

$$V_{O(max)} = \frac{R}{R + R_l} * V_i$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

$$Q_s = \frac{X_L}{R + R_l}$$

$$BW = \frac{f_s}{Q_s}$$

PB Filter Parallel

$$Z_{T_p} = \text{ is a maximum value at resonance} = Q_l^2 R_l$$

$$V_{O(max)} = \frac{Z_{T_p}}{R + Z_{T_p}} * V_i$$

$$f_p = \frac{1}{2\pi\sqrt{LC}}$$

$$Q_p = \frac{X_L}{R_l}$$

$$BW = \frac{f_p}{Q_p}$$

SB Filter Series

$$X_L = X_C, \text{ at resonance}$$

$$V_{O(min)} = \frac{R_l}{R + R_l} * V_i$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

$$Q_s = \frac{X_L}{R + R_l}$$

$$BW = \frac{f_s}{Q_s}$$

SB Filter Parallel

$$Z_{T_p} = \text{ is a maximum value at resonance} = Q_l^2 R_l$$

$$V_{O(min)} = \frac{R}{R + Z_{T_p}} * V_i$$

$$f_p = \frac{1}{2\pi\sqrt{LC}}$$

$$Q_p = \frac{X_L}{R_l}$$

$$BW = \frac{f_p}{Q_p}$$