minimum on the voltage across the crystal because the crystal has a series resonance. At the frequency where you observe a dip in the voltage, decrease the scan step to 10 Hz. Find the frequency, f_s, of the minimum voltage. Use averaging feature of the oscilloscope for more accurate measurements. Measure and record this frequency and this minimum peak-to-peak voltage, v_{omin}.

2. Determine the series resistance of the crystal using Eq. 1.

3. Solder a C_1=5.6 pF capacitor in series with the crystal as shown in Fig. 3. Determine the resonance frequency, f_{s1}, of the new circuit within 10 Hz. Find the difference, δf, between the resonance frequencies with and without 5.6 pF capacitor in series. Note that the minimum voltage observed in this measurement is higher than that in the measurement without the capacitor, since the capacitor, C_1, also has a finite series resistance of its own.

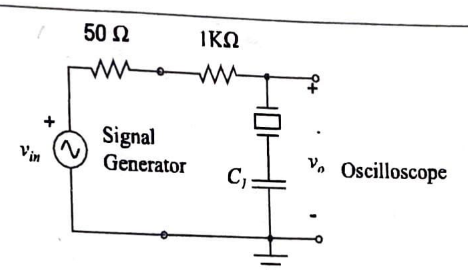


Figure 3: Quartz crystal measurement setup with a series capacitor.

4. Determine the series inductance, L_s, of the crystal using the equation

+24

124mV

$$L_s(\mu\text{H}) = \frac{25330}{2\, f_s(\text{MHz})\, \delta f(\text{MHz})\, C_1(\text{pF})}$$

127mV

→ 0.797

This method gives a better accuracy compared to measuring f_2 and f_1.

5. Determine the quality factor, Q, of the crystal using Eq. 2.

2,180,607.408

6. Find the value of the series capacitor, C_1', to shift the resonant frequency to exactly 15.000 MHz using Eq. 3 (If the resonant frequency is already higher than 15.001 MHz, ask for a different crystal from the technician). Choose the nearest standard capacitor value. Solder this capacitor in series with the crystal. Measure the shifted resonant frequency, f_s'. If the resonant frequency is not between 14.999 and 15.001 MHz try another capacitor of the same value or the next smaller or larger standard capacitor value. Once the resonant frequency is correct, keep them soldered together to preserve the association.

14,994.400MHz

First crystal (X40):

f_s=14.994 MHz r_s=13.18 Ω Δf=0,0116 MHz

L_s=12.982 mH Q=92.794

C_1'=C_{40}=15pF f_s'=15 000 050 MHz

45,1592

14 994 400

1.6. GRADE:

7. Repeat the steps above to find the center frequency of the second (X41) 15 MHz crystal and the necessary capacitance (C42) to shift the center frequency to very close to 15.000 MHz. Measure the shifted center frequency of the second crystal.

Second crystal (X41):
f_s= 14 994 300 MHz, r_s= 9.10 Ω Δf= 0.0111 MHz
L_s= 13588 mH Q= 140.673
C_1'=C_{42}= 15pF f_s'= 15 000 010

1.7. GRADE:

8. Using Eq. 4 find the value of the inverter impedance X and the corresponding termination impedance, R_o, to make a second-order band-pass-filter with your chosen bandwidth, Δf. Since L_s for two crystals may be slightly different, use the average value of L_s for X calculation. Find the nearest standard capacitor value, C_{41}=C, for the inverter using Eq. 5.

X= 188.657 Ω R_o= 177.517 Ω

1.8. GRADE:

2. IF Filter

Designator	Comment	Description
C40, C41, C42	TBD	Capacitor, 50V
R41	2.7K	Resistor
T40	T38-8/90	Toroidal Core
X40, X41	15MHz	Crystal

Figure 4: Bill of materials for IF filter

1. The IF filter of TRC-11 is given in Fig. 5. Start building the filter by placing the crystal X40 and its corresponding series capacitor C40 in their places. Solder them.
2. Place and solder the crystal X41 and its series capacitor C42.
3. Mount and solder the resistor, R40.

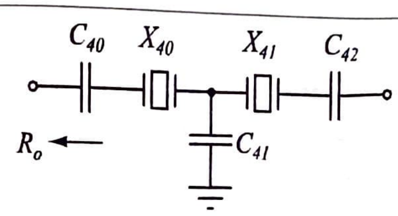


Figure 5: IF Filter schematic.

4. Solder a looped wire to the test point, TP50.

5. Mount and solder C41=C as the inverter capacitance, whose reactance is equal to X. The termination impedance for this filter is given as R_o.

3. IF Transformer

1. First, wind the primary using 35 cm long 0.35mm enameled wire. Wind 19 tight turns on T38 8/90 toroid. *Do not stretch* the windings to cover the toroid, keep them tight together. This is useful for minimizing the leakage flux since we have a small number of turns in the secondary winding. Wind six tight turns of secondary next to the secondary winding. Use about 14 cm of 0.35 mm wire. Trim all four leads leaving about 1 cm, strip the enamel, and cover with solder.

2. Install the transformer T40, paying attention to the correct placement of the primary and secondary pairs of leads. Solder the leads. Install and solder the capacitor C43 with the value you calculated.

3. Place and solder the test resistor R41. This resistor should be removed after testing.

4. Solder a looped wire to TP40.

4. Testing the IF amplifier

1. The IF amplifier with two stages is already built. Now, we are ready to test it along with the IF filter. Connect the oscilloscope probe (10× setting) between the output of the IF amplifier at TP61 and GND. Turn on the power.

   Set the signal generator output to 10 mVpp sine wave (with a high-impedance load, it delivers 20 mVpp). Connect it between TP40 and GND. Vary the frequency over the passband of IF filter around 15 MHz in very small steps and find and set it to the frequency where the amplitude of the amplifier output is maximized. This frequency is the center frequency of the IF filter. Record it. Calculate the gain of the system at the center frequency in dB. You should use

$$G(dB) = 20\log_{10}\frac{v_o}{v_{in}} \qquad \frac{3520}{20}$$

   where v_o is the peak-to-peak voltage at the output (TP61), and v_{in}=20 mV is the (doubled) peak-to-peak voltage at the terminals of the signal generator (between TP40 and GND). If the gain is lower than 35 dB, you have something wrong with your circuit.

3.58V

Center frequency (MHz)= 15.001 MHz
Gain at center freq (dB)= 51,77 dB

4.1. GRADE:

15 001 970 MHz

14 998 720 MHz

1.280

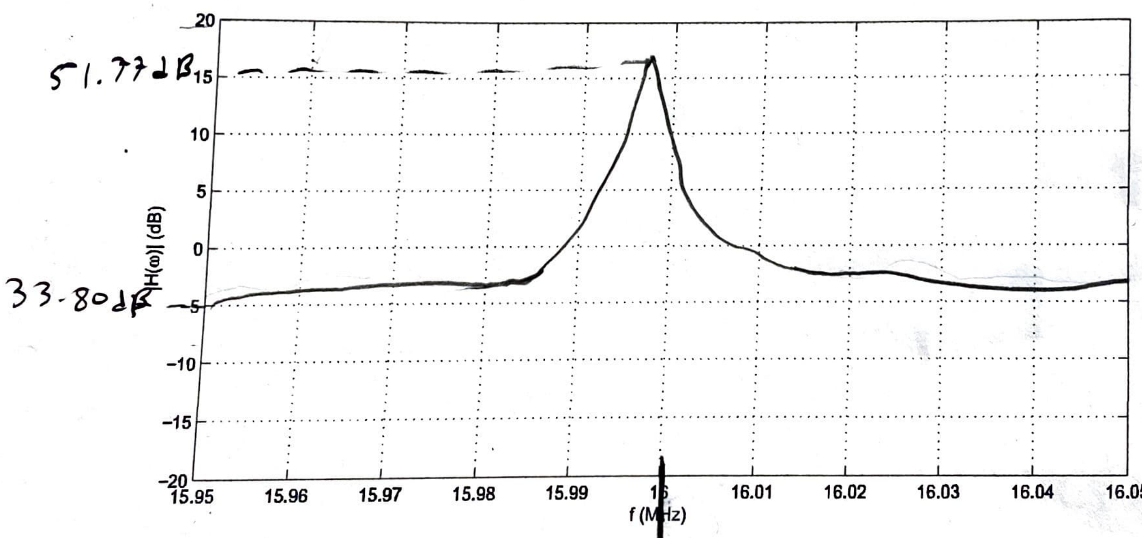
2. Measure the magnitude of the output voltage amplitude as a function frequency to determine the bandwidth (BW) of the IF filter. Recall that BW is defined as the difference between two frequency points where the gain drops by −3 dB. (−3 dB means that the gain drops by a factor of $1/\sqrt{2}=0.707$). Record it.

Bandwidth (kHz)= 3.25kHz

4.2. GRADE:

3. **CHECK POINT:** Plot the gain in decibels as a function of frequency in a 100 kHz range.

f (MHz)	$\|H(\omega)\|$(dB)	f (MHz)	$\|H(\omega)\|$(dB)	f (MHz)	$\|H(\omega)\|$(dB)
14.952	33.80	14.987	33.97	15.050	35.84
14.959	33.97	14.994	35.26	15.043	35.26
14.966	34.15	15.001MHz	51.77dB	15.036	35.26
14.973	34.32	15.008	35.26	15.029	34.96
14.980	35.56	15.015	34.32	15.022	33.80



4.3. GRADE:

Note: I couldn't get the corrected Lab report therefore I draw the graph on uncorrected graph labels.