EL 6673 Resonant Power Converters Mini Project

Class D Voltage-source Half-bridge Inverter

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I choose Class D FULL-BRIDGE PARALLEL-RESONANT INVERTER and the data from Problem 7.5.

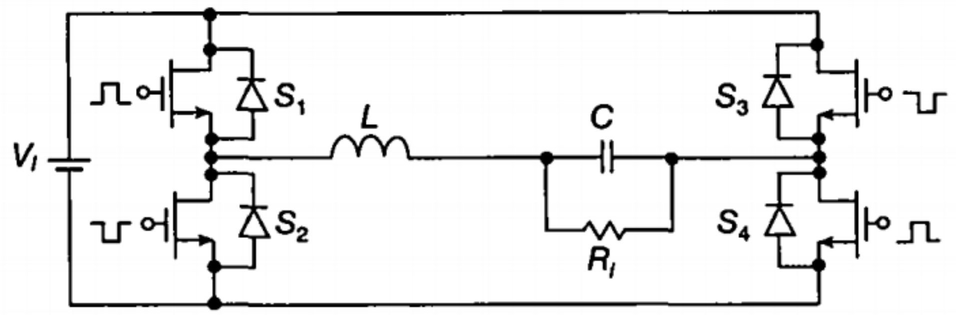
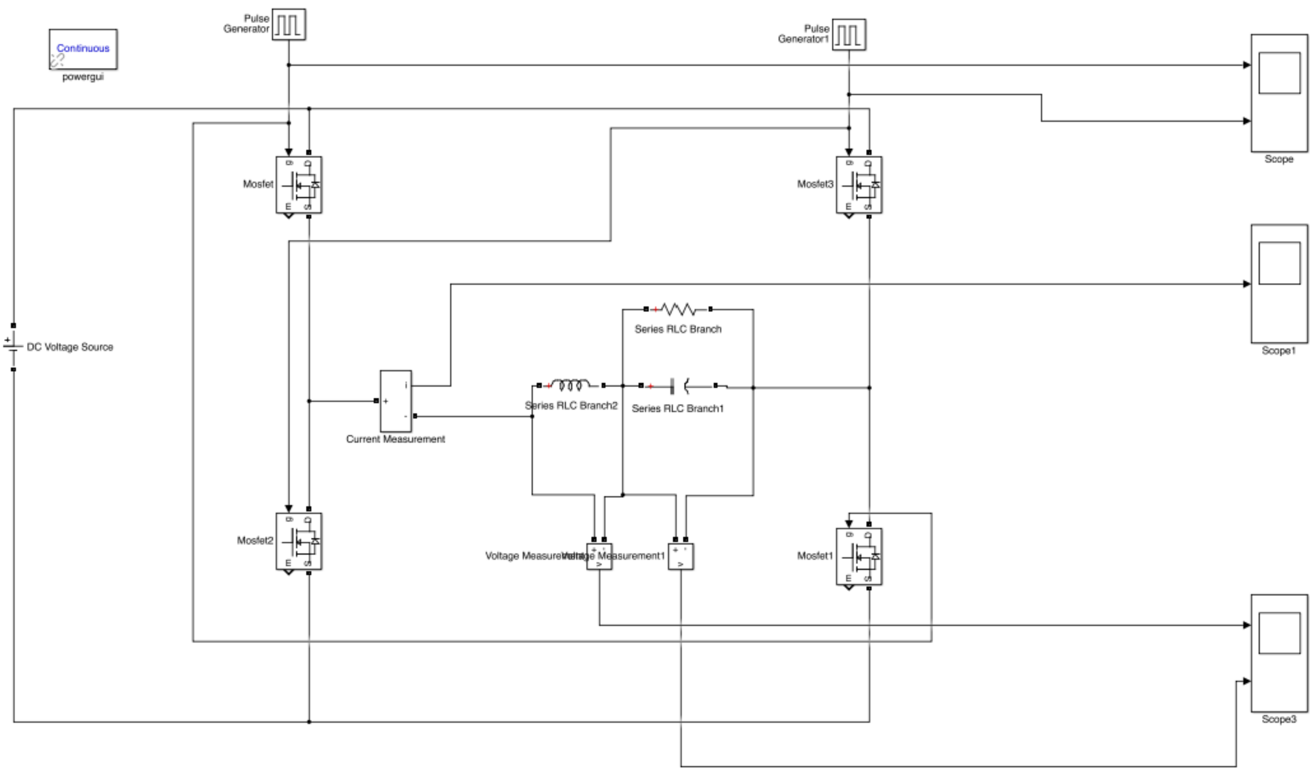


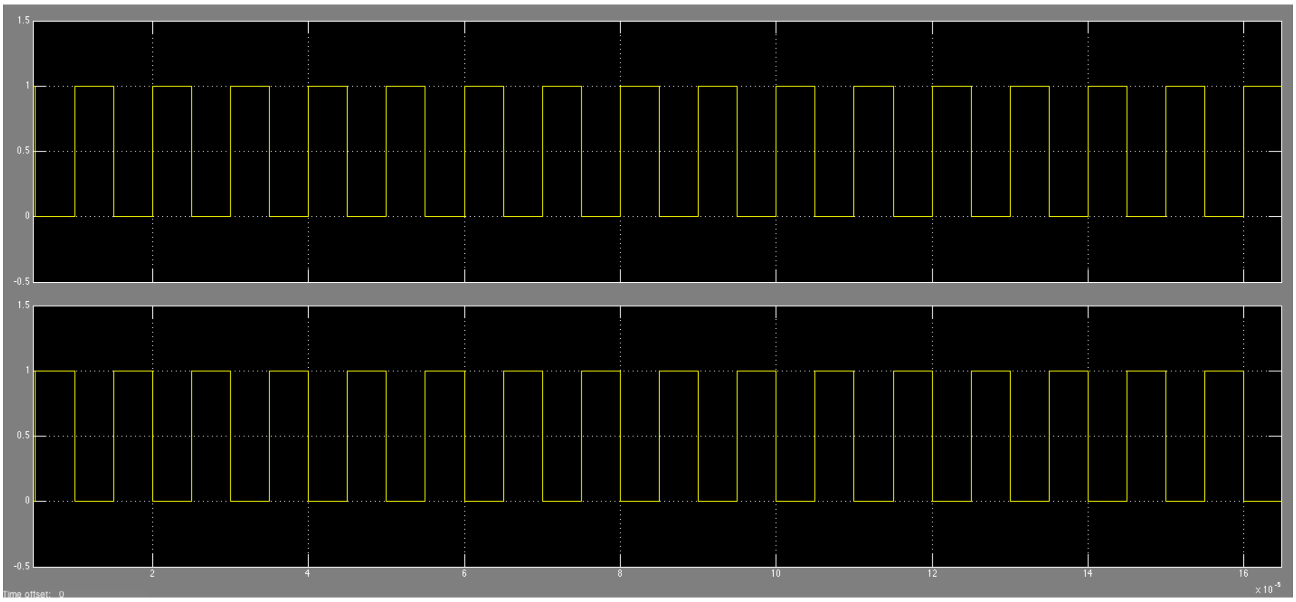
FIGURE 7.29 Circuit of the Class D full-bridge parallel resonant inverter.

Data: V_I =200 V, P_{Ri} =75 W, f=100 kHz, η_I =92%. Q=2.5; 5; 8; 10.

1. Perform time-domain simulations of your selected inverter as follow:



The pulse waveform is:



2. Show current and voltage waveforms in resonant components at various values of Q.
If Q=2.5, then according to Problem 7.5, the calculating process is shown below:
The dc supply power is

$$P_I = \frac{P_O}{\eta_I} = \frac{75}{0.92} = 81.52\,\text{W}$$

and the dc supply current is

$$I_I = \frac{P_I}{V_I} = \frac{81.52}{200} = 407.6\,\text{mA}$$

Assuming that $f = f_r$=100 kHz at full power, the corner frequency is

$$f_o = \frac{f}{\sqrt{1-\frac{1}{Q_L^{\,2}}}} = \frac{100\times10^3}{\sqrt{1-\frac{1}{2.5^2}}} = 109.1\,\text{kHz}$$

the ac load resistance of the inverter

$$R_i = \frac{8V_I^{\,2}\eta_I^{\,2}}{\pi^2 P_{Ri}\left\{\left[1-\left(\frac{\omega}{\omega_O}\right)^2\right]^2+\left[\frac{1}{Q_L}\left(\frac{\omega}{\omega_O}\right)\right]^2\right\}} = \frac{8\times200^2\times0.92^2}{\pi^2\times75\times\left\{\left[1-\left(\frac{100}{109.1}\right)^2\right]^2+\left[\frac{1}{2.5}\left(\frac{100}{109.1}\right)\right]^2\right\}} = 2287.2\ \Omega$$

the characteristic impedance is

$$Z_O = \frac{R_i}{Q_L} = \frac{2287.2}{2.5} = 914.9\ \Omega$$

the elements of the resonant circuit are

$$L = \frac{Z_O}{\omega_O} = \frac{914.9}{2\pi\times109.1\times10^3} = 1.335\,\text{mH}$$

and

$$C = \frac{1}{\omega_O Z_O} = \frac{1}{2\pi \times 109.1 \times 10^3 \times 914.9} = 1.59\,\text{nF}$$

the peak value of the switch current is

$$I_m = I_{SM} = \frac{4V_I\sqrt{{Q_L}^2+1}}{\pi Z_O} = \frac{4\times 200\times\sqrt{2.5^2+1}}{\pi\times 914.9} = 0.75\,\text{A}$$

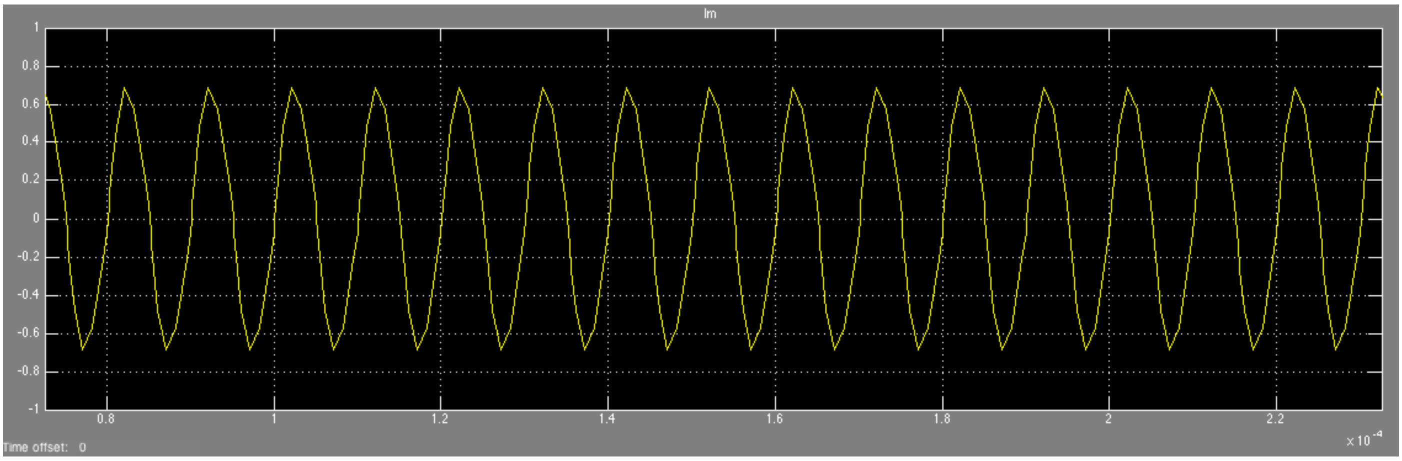
the voltage stresses of the resonant components are

$$V_{Cm} = \frac{4V_I Q_L}{\pi} = \frac{4\times 200\times 2.5}{\pi} = 636.6\,\text{V}$$

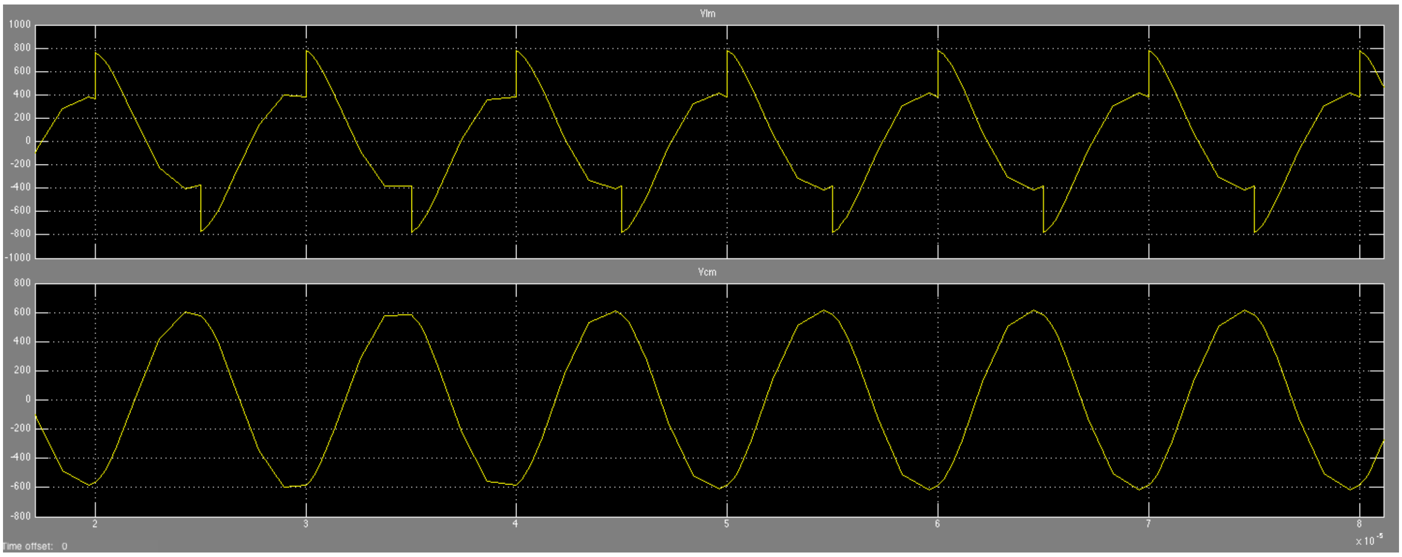
and

$$V_{Lm} = \frac{4V_I\sqrt{{Q_L}^2+1}}{\pi} = \frac{4\times 200\times\sqrt{2.5^2+1}}{\pi} = 685.6\,\text{V}$$

a) Current and voltage waveform in resonant components I_m



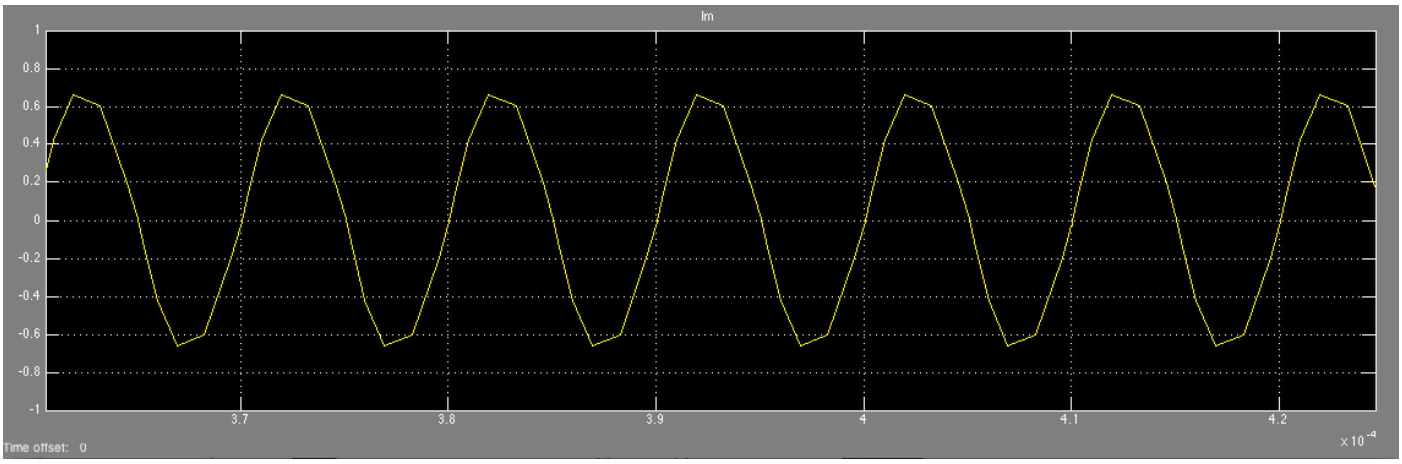
b) Voltage waveform for resonant component V_{Lm}, V_{Cm}



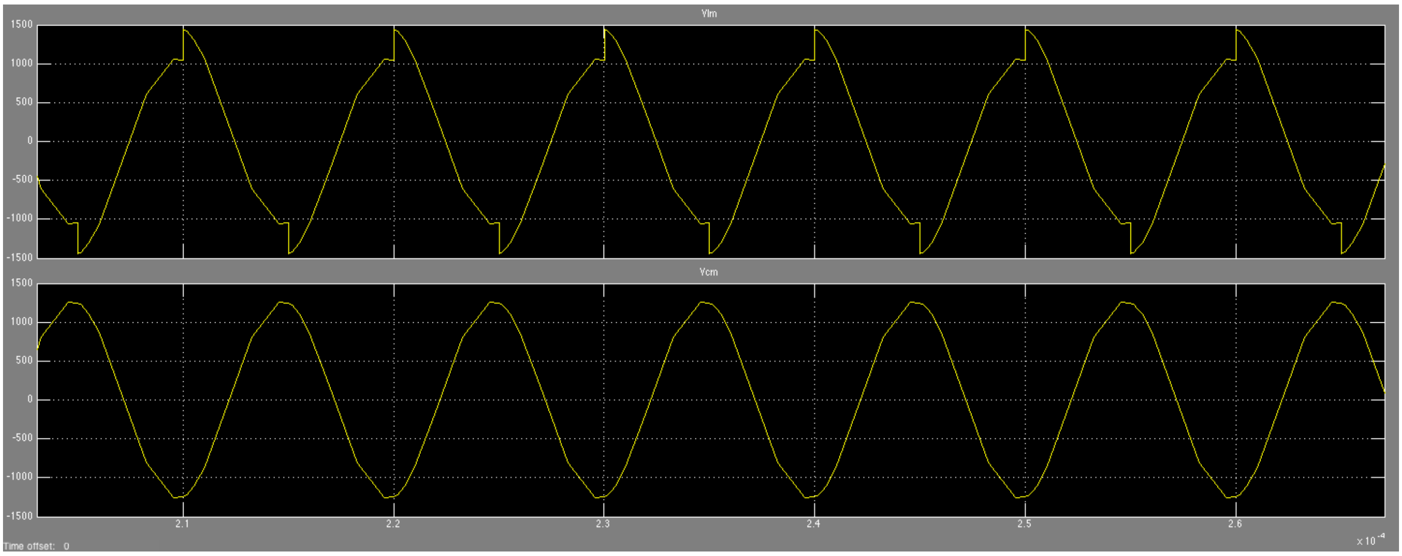
If Q=5, then f_O =102.06 kHz, R_i =9147.9 Ω, L=2.85 mH, C= 0.8523 nF, I_m =0.7097A, V_{Lm} =1273.24V,

V_{Cm} =1298.45V.

c) Current and voltage waveform in resonant components I_m :

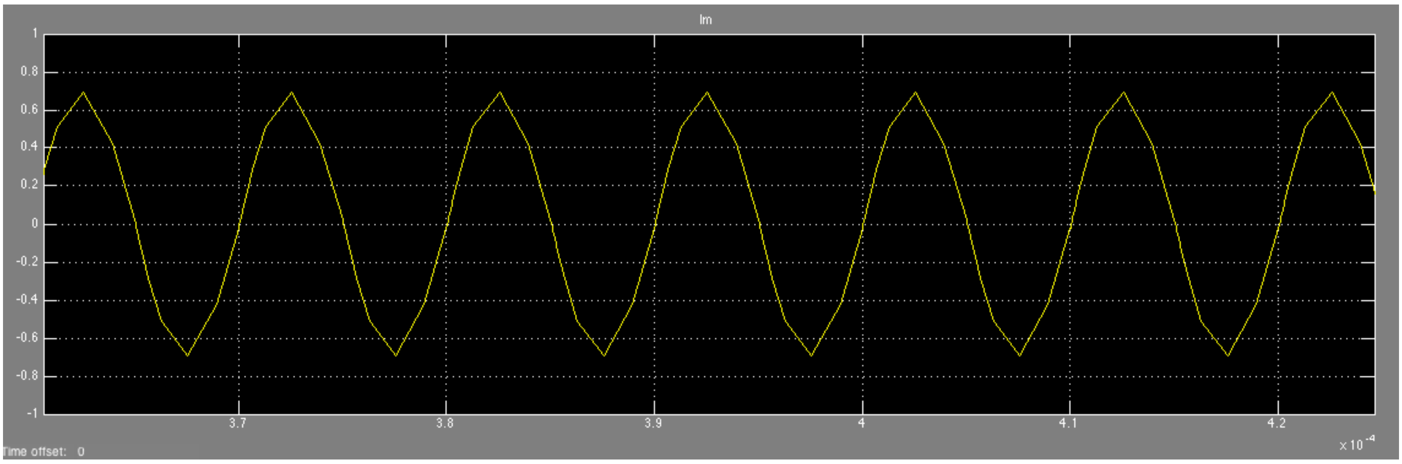


d) Voltage waveform for resonant component V_{Lm} , V_{Cm}

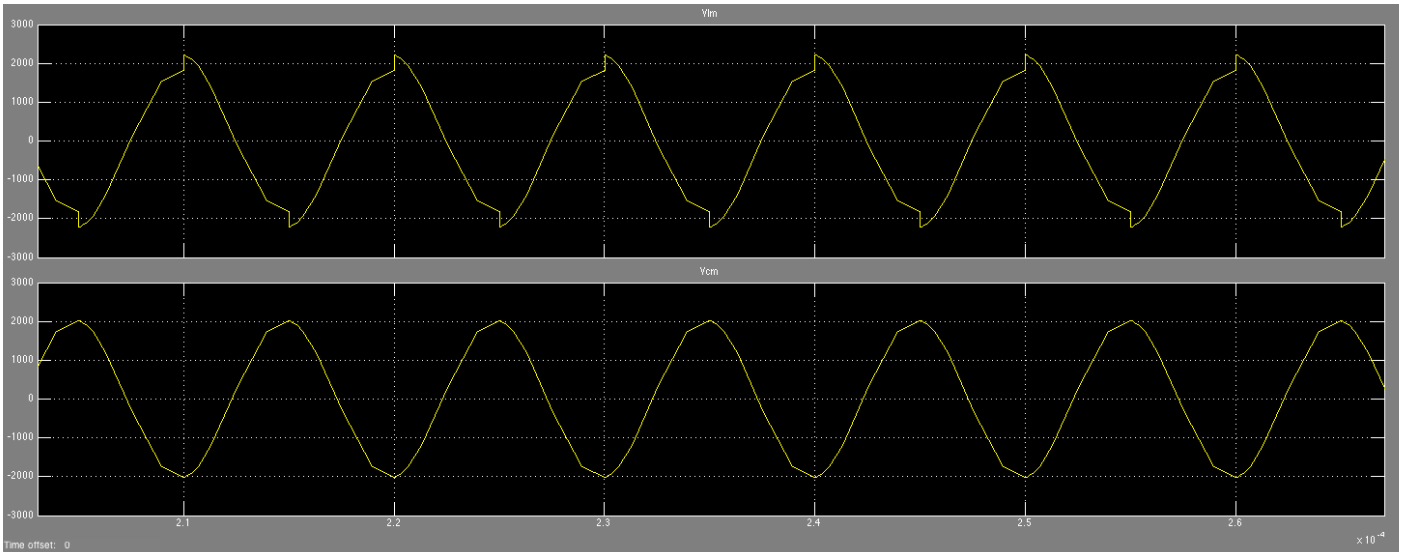


If Q=8, then f_O =100.79kHz, R_i =2.3418 $\times 10^4$ Ω, L=4.622 mH, C=0.5394 nF, I_m =0.701 A, V_{Lm} =2037.18 V, V_{Cm} =2053.04 V.

e) Current and voltage waveform in resonant components I_m

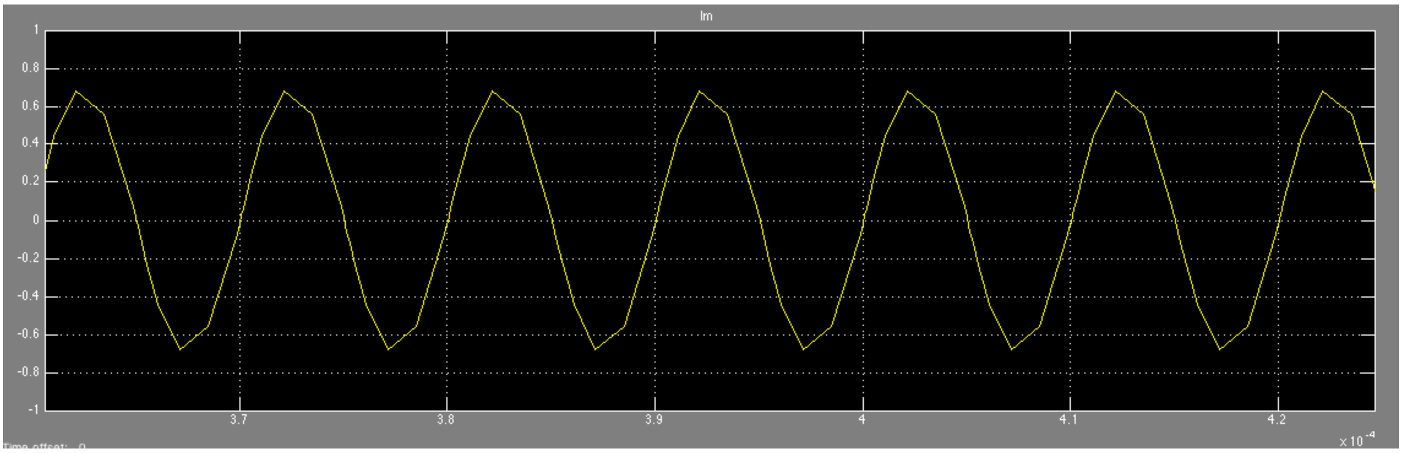


f) Voltage waveform for resonant component V_{Lm} V_{Cm}

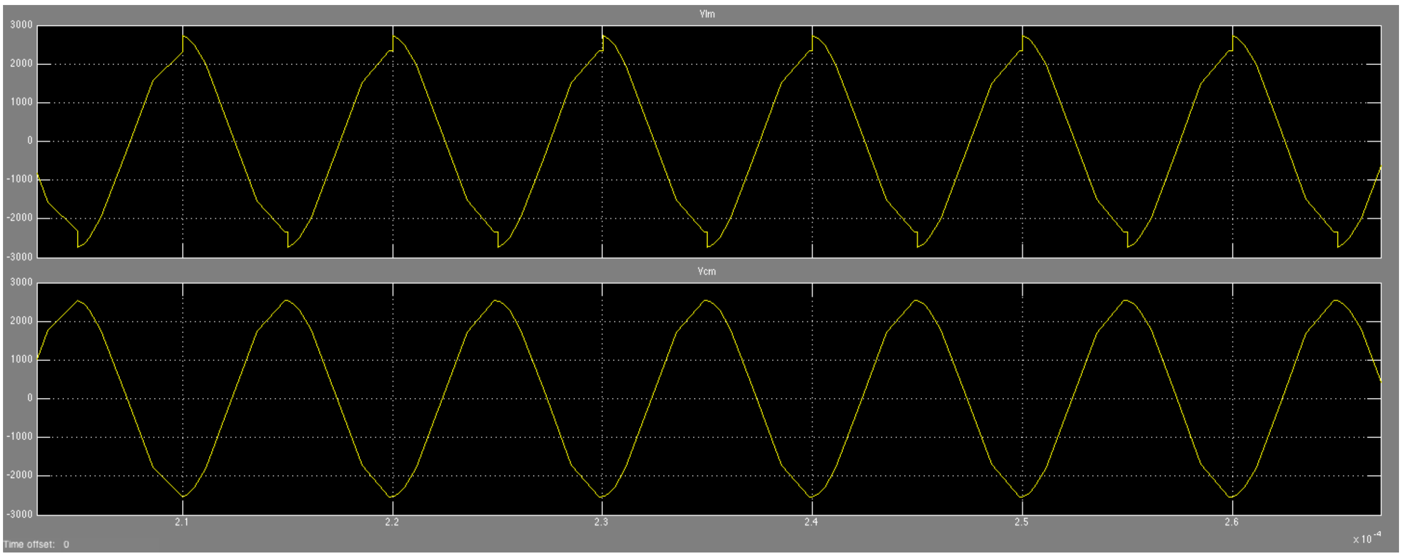


If Q=10, then f_O =100.5 kHz, R_i =36593 Ω, L=5.795 mH, C=0.4328 nF, I_m =0.699 A, V_{Lm} =2546.48 V, V_{Cm} =2559.18 V.

g) Current and voltage waveform in resonant components I_m



h) Voltage waveform for resonant component V_{Lm} V_{Cm}



3. Show how the voltage transfer function varies with the switching frequency.
The magnitude of DC-to-AC voltage transfer function of the lossless Class D inverter is:

$$|M_{VI}| = \frac{V_{Ri}}{V_I} = \frac{2\sqrt{2}}{\pi\sqrt{\left[1-\left(\frac{\omega}{\omega_O}\right)^2\right]^2+\left[\frac{1}{Q_L}\left(\frac{\omega}{\omega_O}\right)\right]^2}} = \frac{2\sqrt{2}}{\pi\sqrt{\left[1-\left(\frac{f}{f_O}\right)^2\right]^2+\left[\frac{1}{Q_L}\left(\frac{f}{f_O}\right)\right]^2}}$$

For the lossy inverter,

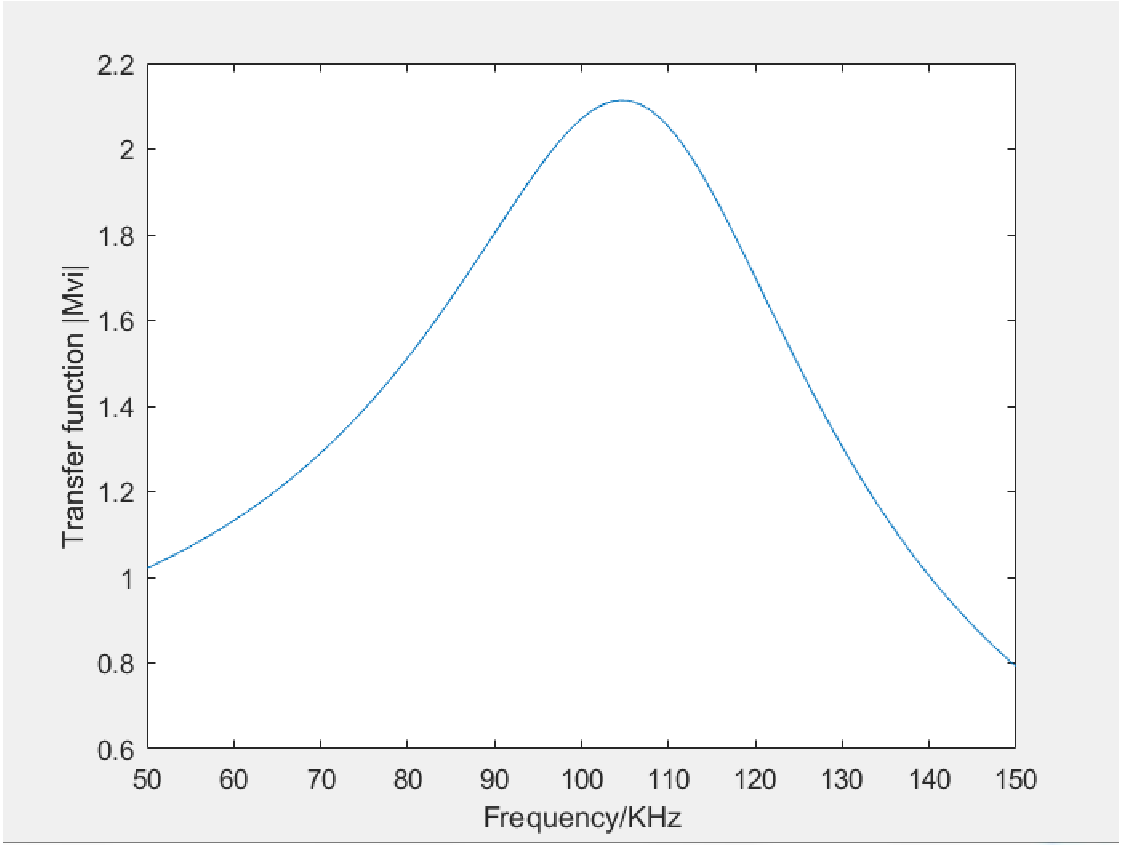
$$M_{VIa} = \eta_I M_{VI}$$

The range of $|M_{VI}|$ is from 0 to ∞.

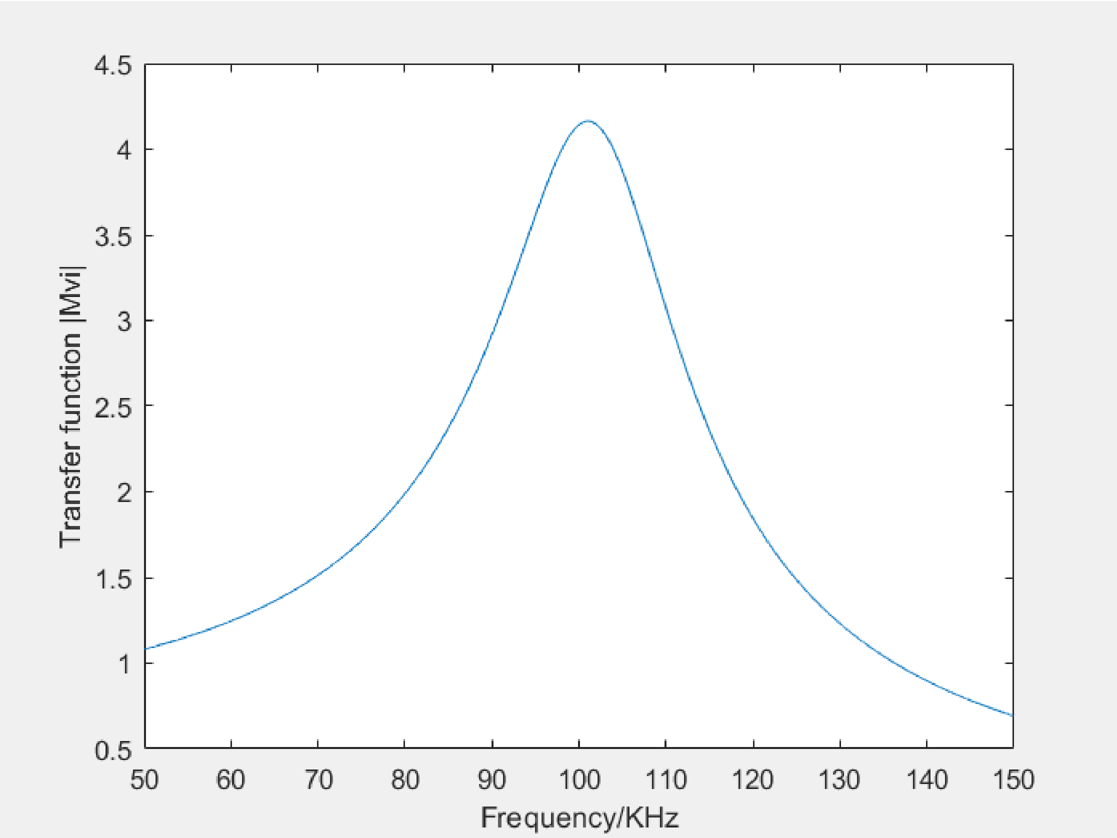
The codes and diagrams showing transfer function $|M_{VI}|$ as a function of frequency f:

```
Q = 2.5;
f0 = 109.1;
n =0.92;
syms f;
f = 50:0.01:150;
Mvi = 2*sqrt(2)*n/pi./sqrt((1-(f/f0).^2).^2+((f/f0)/Q).^2);
figure;
plot(f,Mvi);
xlabel('Frequency/KHz');
ylabel('Transfer function |Mvi|');
```

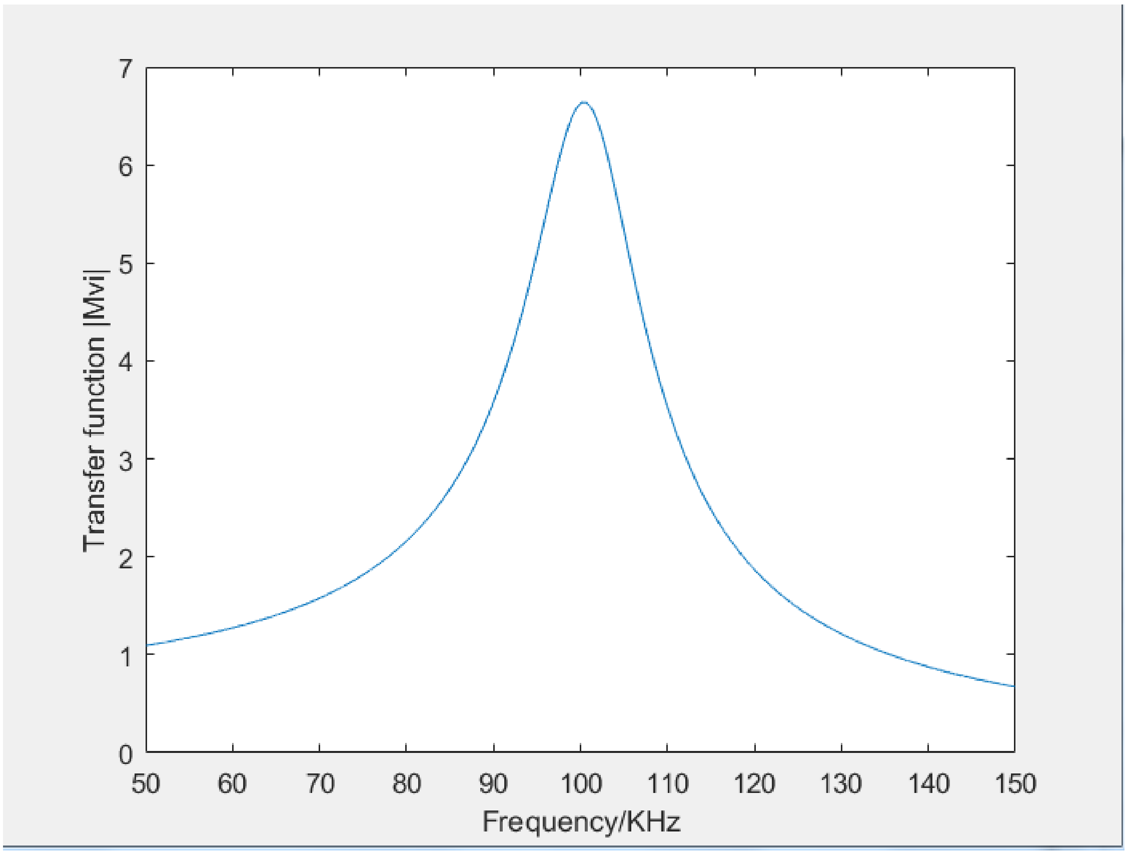
a. Q=2.5



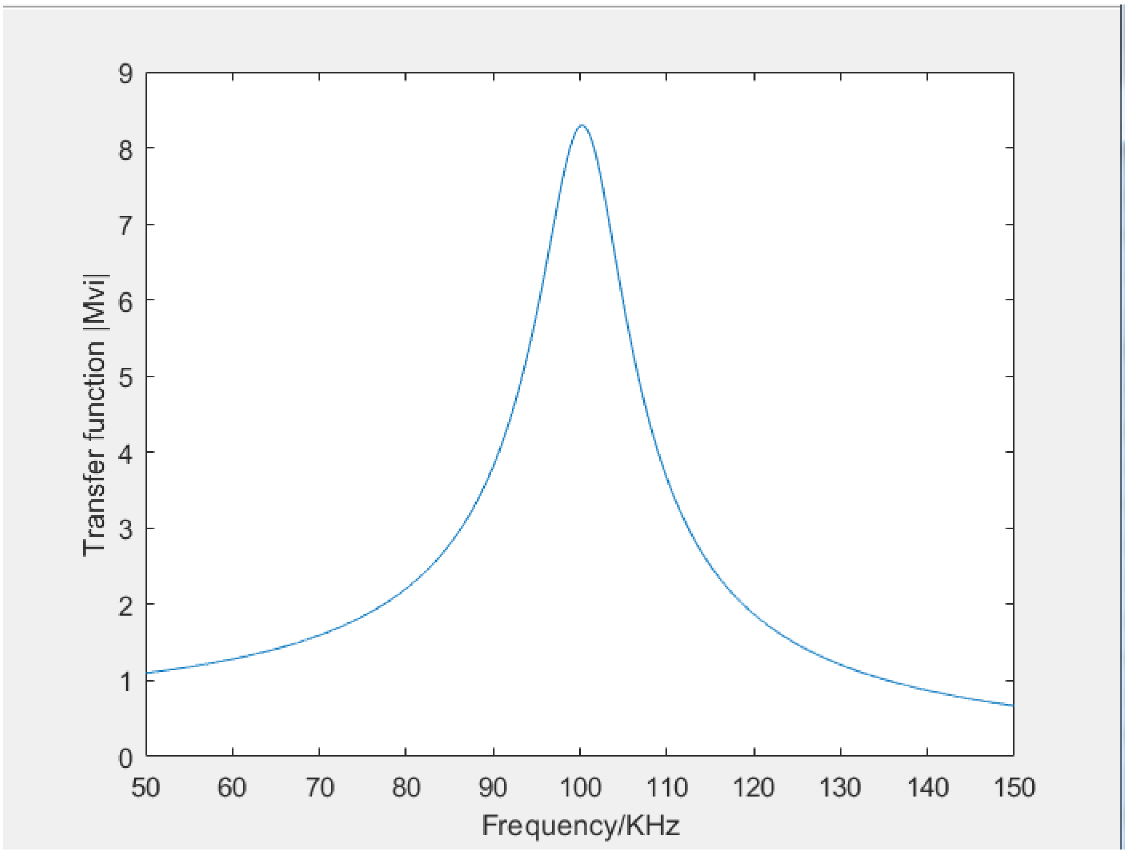
b. Q=5


Transfer function |Mvi|
Frequency/KHz
4.5
4
3.5
3
2.5
2
1.5
1
0.5
50 60 70 80 90 100 110 120 130 140 150

c. Q=8


Transfer function |Mvi|
Frequency/KHz
7
6
5
4
3
2
1
0
50 60 70 80 90 100 110 120 130 140 150

d. Q=10



4. Conclusion

In conclusion, the transfer function changes more and more fast as the Q increases. The waveform becomes shaper and shaper. From these diagrams, we know when the value of Q increases, the values of I_m, V_{Lm} and V_{Cm} rise. Otherwise, those values reduce.