正弦信号调制与解调

设计详细说明：

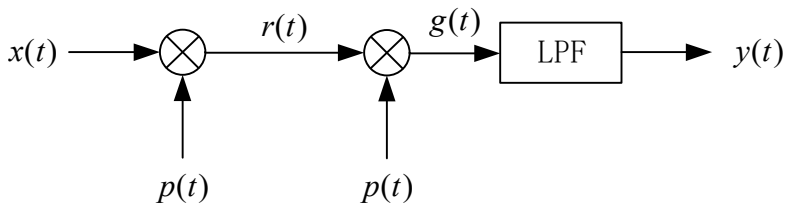


图 1 调制解调框图

根据已有的信息：$x(t) = A\,cos\omega_0\,t$，$p(t) = B\,cos\omega_c\,t$，其中 A、B、ω_0、ω_c均已知

A 为 0.2V，B 为 5V，ω_0为$2\pi * 5KHz = 10^4\pi$Hz，ω_c为$2\pi * 500KHz = 10^6\pi$Hz

$$\mathrm{x(t) = 0.2cos(10^4\pi t)V},\ \mathrm{p(t) = 5cos(10^6\pi t)V}$$

- 理论分析:

1. $\because \mathrm{x(t) = 0.2cos\,\omega_0 t = 0.1(e^{j\omega_0 t} + e^{-j\omega_0 t})} \qquad \therefore \mathrm{X(jw) = 0.1 \cdot 2\pi[\delta(\omega - \omega_0) + \delta(\omega + \omega_0)]};$
2. $\because \mathrm{p(t) = 5\,cos(\omega_c t) = \frac{5}{2}\left(e^{j\omega_c t} + e^{-j\omega_c t}\right)} \qquad \therefore P(jw) = \frac{5}{2} \cdot 2\pi[\delta(\omega - \omega_c) + \delta(\omega + \omega_c)]$
3. $\because \mathrm{r(t) = x(t)p(t)}$

$$\therefore \mathrm{R(j\omega)} = \frac{1}{2\pi}[X(j\omega) * P(j\omega)]$$
$$= \frac{\pi}{2}[\delta(\omega - (\omega_0 + \omega_c)) + \delta(\omega - (\omega_0 - \omega_c)) + \delta(\omega + (\omega_0 - \omega_c))$$
$$+ \delta(\omega + (\omega_0 + \omega_c))]$$

4. $\mathrm{r(t) = \frac{1}{4}\left(e^{j(\omega_0+\omega_c)t} + e^{-j(\omega_0+\omega_c)t} + e^{j(\omega_0-\omega_c)t} + e^{-j(\omega_0-\omega_c)t}\right)}$
5. $\because \mathrm{g(t) = r(t)p(t)},\quad \therefore \mathrm{g(t) = \frac{5}{8}\left(e^{j(\omega_0+2\omega_c)t} + e^{-j(\omega_0+2\omega_c)t} + e^{j(\omega_0-2\omega_c)t} + e^{-j(\omega_0-2\omega_c)t} + 2e^{j\omega_0 t} + 2e^{-j\omega_0 t}\right)}$
6. $\therefore \mathrm{G(j\omega) = \frac{5\pi}{4}\left[\delta\left(\omega - (\omega_0 + 2\omega_c)\right) + \delta\left(\omega + (\omega_0 + 2\omega_c)\right) + \delta\left(\omega - (\omega_0 - 2\omega_c)\right) + \delta\left(\omega + (\omega_0 - 2\omega_c)\right) + 2\delta(\omega - \omega_0) + 2\delta(\omega - \omega_0)\right]}$

- 为只保留$g(t)$信号中的ω_0频率分量，设计低通滤波器

因为$\mathrm{G(j\omega)}$有$\pm(\omega_0 + 2\omega_c)$、$\pm(-\omega_0 + 2\omega_c)$、$\omega_0$、$\omega_c$的频率分量

所以设计的低通滤波器的通过频率ω满足$\omega_0 \le |\omega| < 2\omega_c - \omega_0$

RC 低通滤波器:

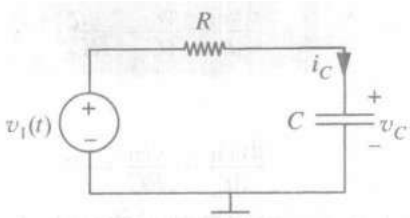


图 2 低通滤波器设计电路图

RC 低通滤波器的响应函数$H(j\omega)=\frac{1}{1+j\omega RC}$

幅值$|H(j\omega)|=\frac{1}{\sqrt{1+(\omega RC)^2}}$，相位$\angle H(j\omega)=\arctan\left(-\frac{\omega RC}{1}\right)$，转折频率$\omega'=\frac{1}{RC}$

需要满足的是$10^4\pi Hz \le \omega' < (2*10^6\pi - 10^4\pi)Hz$

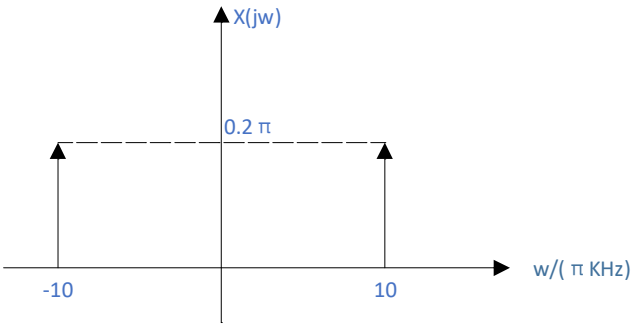
于是不妨让$R=10\Omega$，$C=1\mu F$，那么 $\omega'=10^5 Hz$

$\because y(t)=g(t)*h(t)$

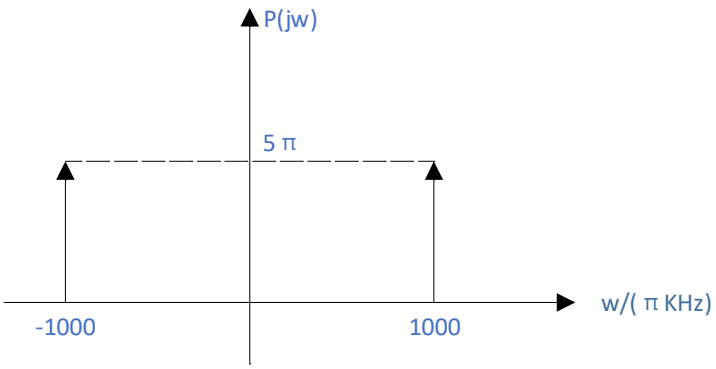
$\therefore Y(j\omega)=G(j\omega)H(j\omega)=\frac{1}{1+j10^{-5}\omega}\frac{5\pi}{4}[\delta(\omega-(\omega_0+2\omega_c))+\delta(\omega+(\omega_0+2\omega_c))+\delta(\omega-(\omega_0-2\omega_c))+\delta(\omega+(\omega_0-2\omega_c))+2\delta(\omega-\omega_0)+2\delta(\omega-\omega_c)]$

- 理论绘制频谱图：

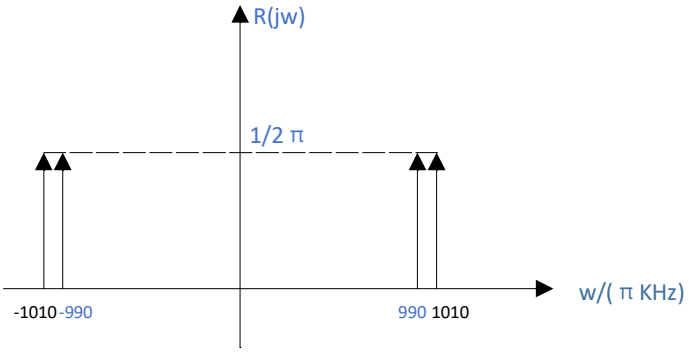
1. $X(j\omega)=0.1\cdot 2\pi[\delta(\omega-\omega_0)+\delta(\omega+\omega_0)]$



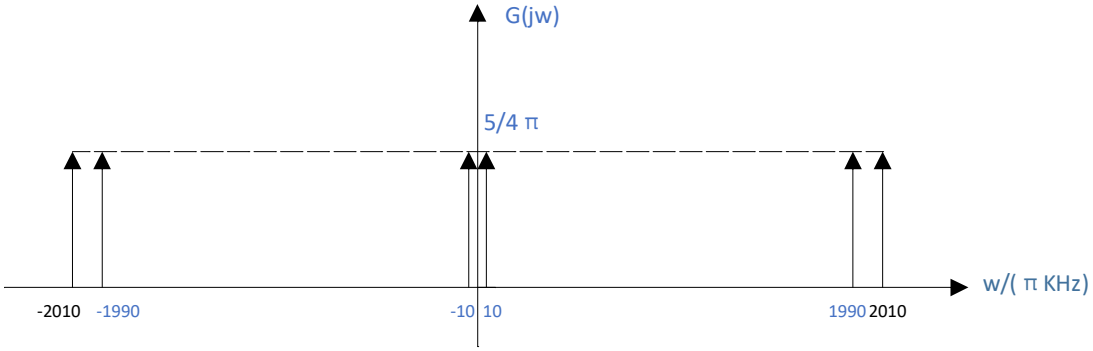
2. $P(j\omega)=\frac{5}{2}\cdot 2\pi[\delta(\omega-\omega_c)+\delta(\omega+\omega_c)]$



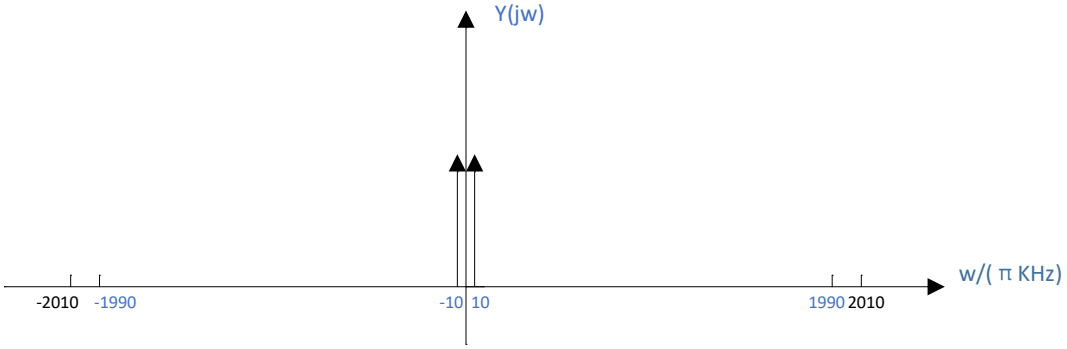
3. $R(j\omega)=\frac{\pi}{2}[\delta(\omega-(\omega_0+\omega_c))+\delta(\omega-(\omega_0-\omega_c))+\delta(\omega+(\omega_0-\omega_c))+\delta(\omega+(\omega_0+\omega_c))]$



4. $G(j\omega)=\frac{5\pi}{4}\left[\delta\left(\omega-(\omega_0+2\omega_c)\right)+\delta\left(\omega+(\omega_0+2\omega_c)\right)+\delta\left(\omega-(\omega_0-2\omega_c)\right)+\delta\left(\omega+(\omega_0-2\omega_c)\right)+2\delta(\omega-\omega_0)+2\delta(\omega-\omega_0)\right]$



5. $Y(j\omega)$（低通滤波器）

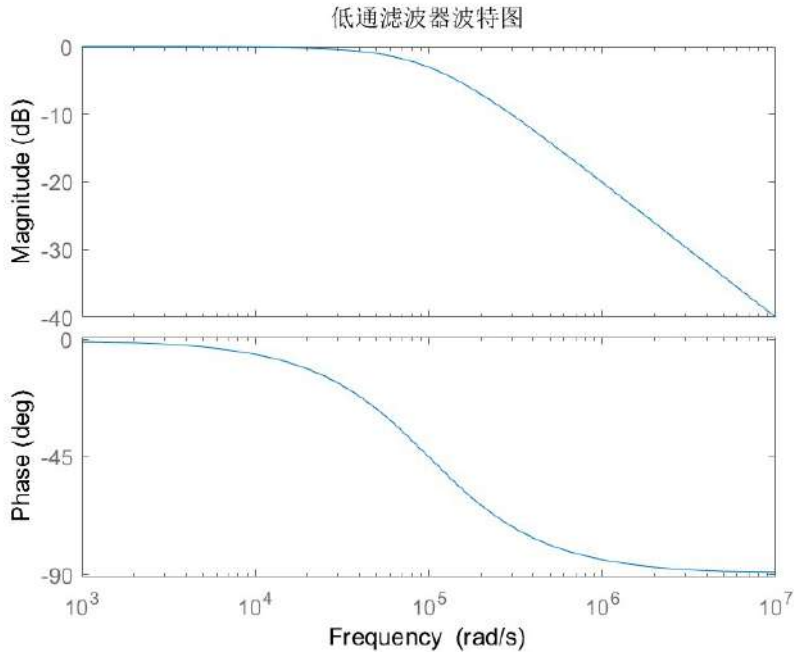


6. $H(j\omega)=\frac{1}{1+j\omega RC}$

Matlab 代码：(Hjw.m 文件)

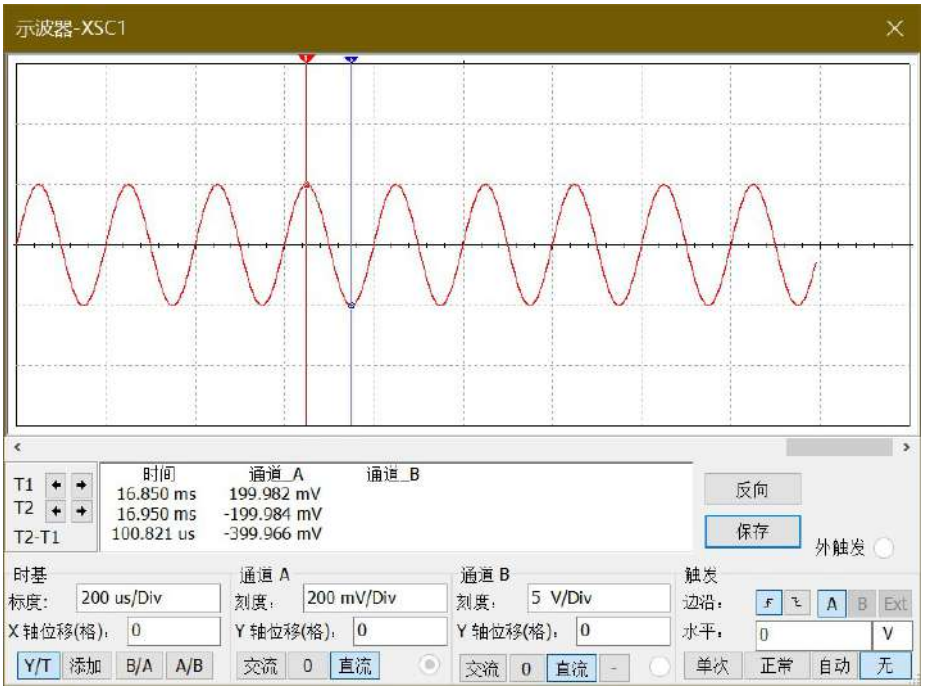
```
figure
HJW=tf([1],[10^(-5),1]);
bode(HJW);
title('低通滤波器波特图')
```

图像：

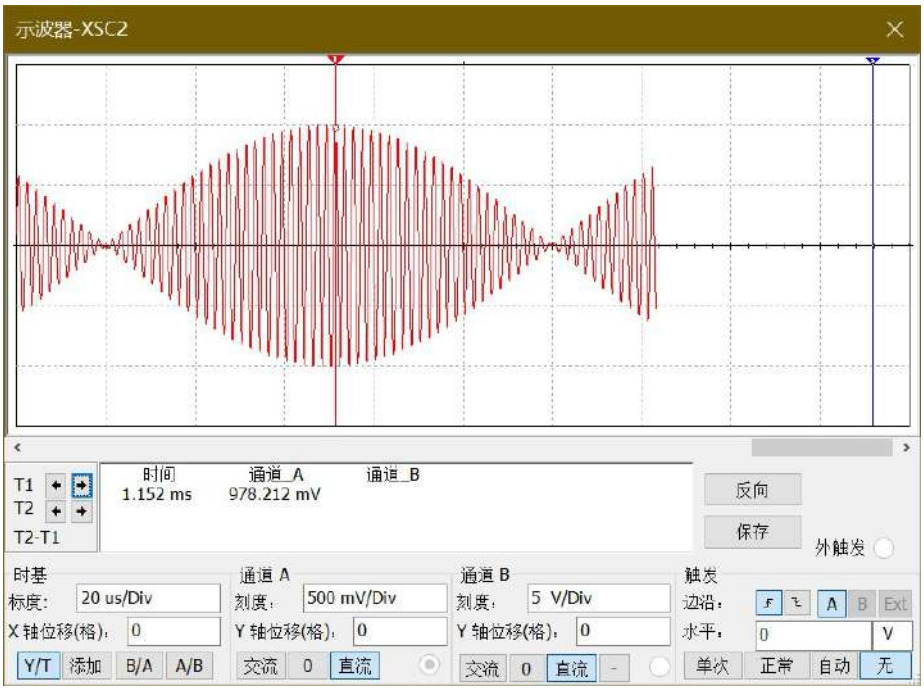


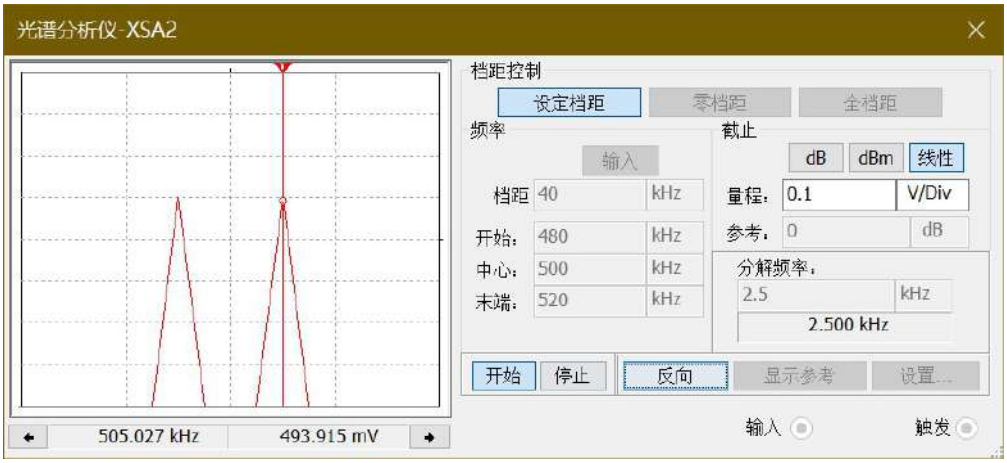
- Multisim 实现：（仿真.ms14 文件）

1. $x(t)$的波形图和频谱图：

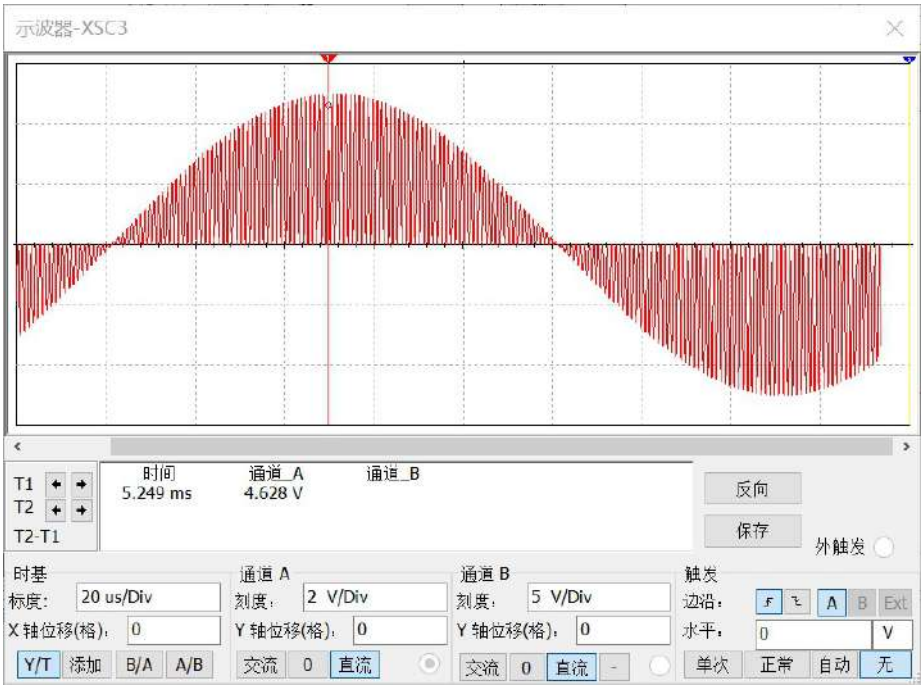


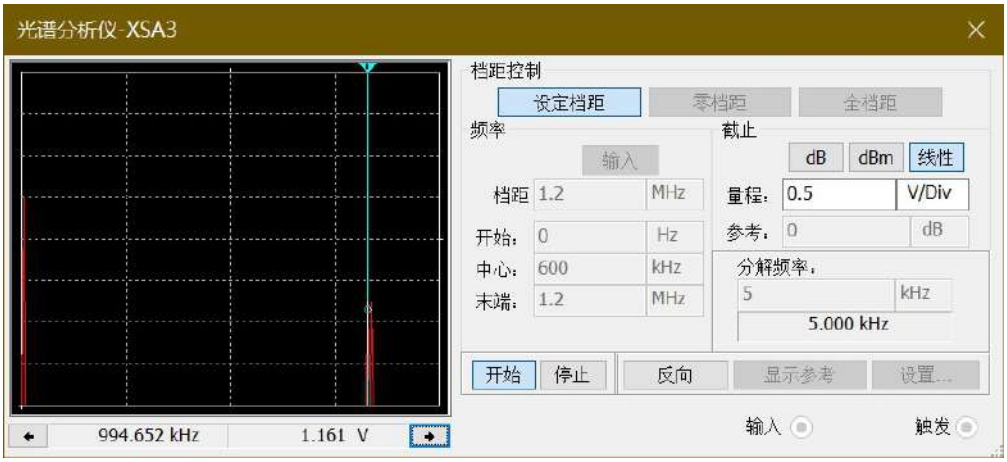
2. $r(t)$的波形图和频谱图：



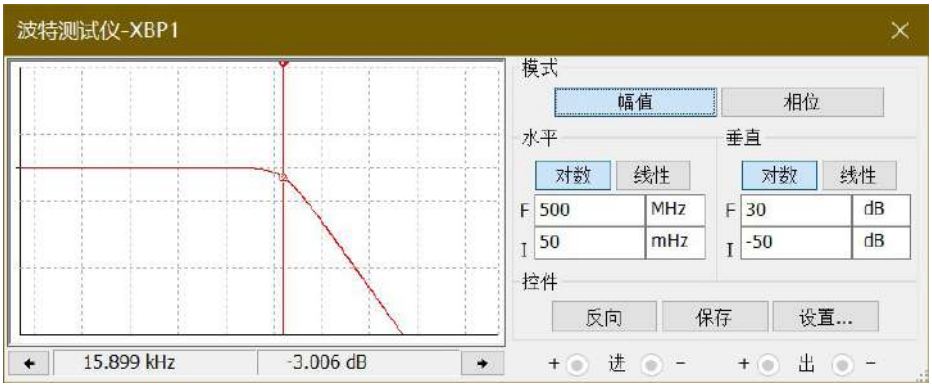


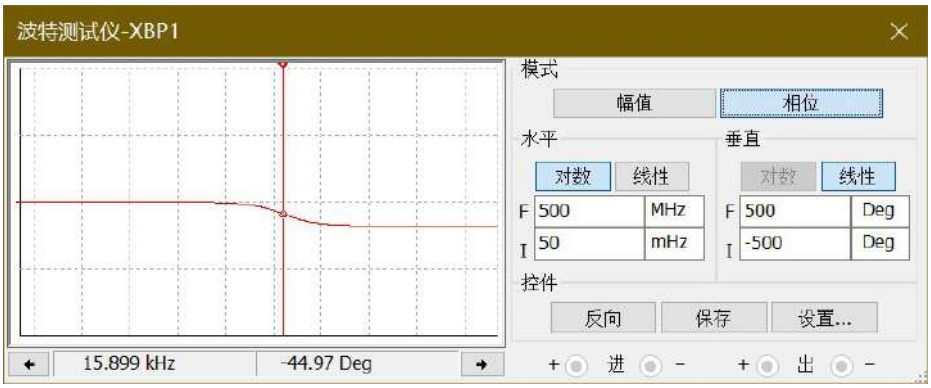
3. $g(t)$的波形图和频谱图：



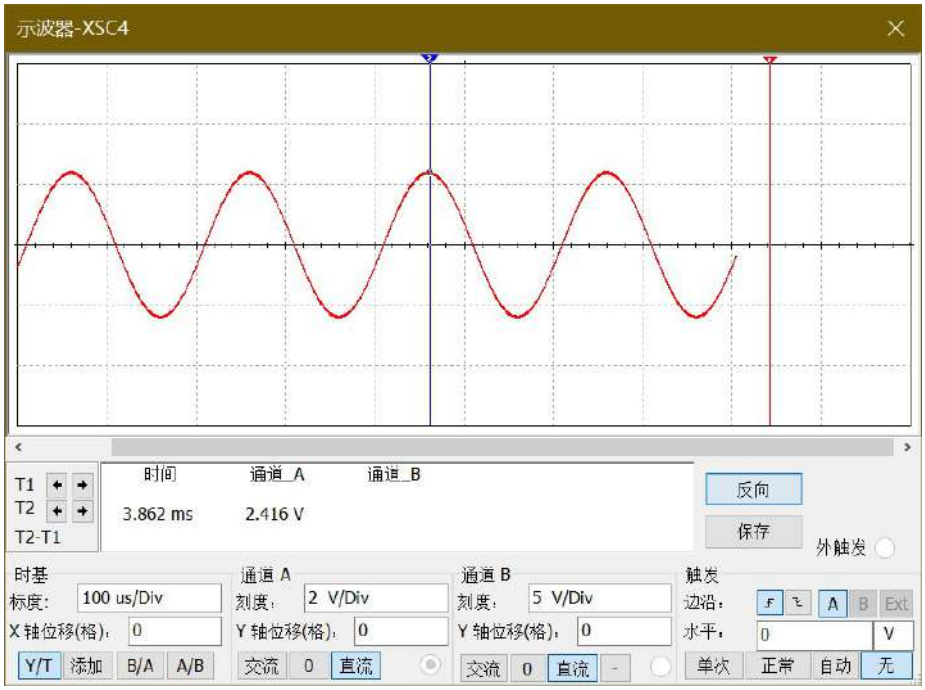


4. 低通滤波器频率响应曲线:





5. $y(t)$的波形图和频谱图



可以看到频谱图上有冲激的频率与理论分析的频率相同

$y(t)$的波形图上出现细微的小波动曲线可以看出的确过滤了高频波

低通滤波器的波特图与 matlab 绘制的相同，仿真结果与理论结果相同

- 思考与建议

1. 算了半天发现$y(t)$就是$x(t)$，整个过程就是一个加高频波然后低通率高波的过程，获得的波与$x(t)$差不多一样（高频还有微小分量）；
2. 和上次的周期方波分解课设相联系了，做起来挺顺利的，课设安排的顺序非常合理!!
3. Visio 不太好安装还有试用期限制，而且电脑上如果装了 office，电脑是不兼容再单独安装 visio，会显示报错，最好可以给大家先提供一下安装的方法，

   提供一个免费好用的绘图网站 https://app.diagrams.net/，可能会比 visio 方便的多（虽然我用 visio+CAD 画的）
4. 第一次没有参考文献的作业，看来各种软件的水平上升不少了