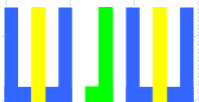


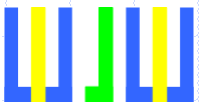
회로 이론/실습

13. 병렬 RL 회로



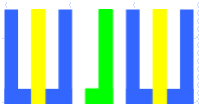
13. 병렬 RL 회로

- 13-1. 목적 및 배경
- 13-2. 소요 부품 및 장비
- 13-3. 유용한 공식
- 13-4. 주파수에 따른 임피던스
- 13-5. 주파수에 따른 위상의 변화
- 13-6. 전압과 전류의 위상



13-1. 목적 및 배경

- ✓ 병렬로 연결된 RL 회로의 특성을 이해한다.
- ✓ 주파수에 따른 임피던스의 변화를 확인한다.
- ✓ 주파수에 따른 위상의 변화를 확인한다.
- ✓ 전압과 전류의 위상변화를 확인한다.



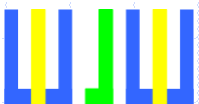
13-2. 소요 부품 및 장비

✓ 부품

- ✓ 저항 (1/4W) : 10 Ω , 1k Ω
- ✓ 인덕터 : 10mH

✓ 장비

- ✓ 브레드 보드
- ✓ 디지털 멀티미터 (Digital Multi-Meter)
- ✓ 직류 전원 공급 장치 (DC Power Supply)
- ✓ 오실로스코프 (Oscilloscope)
- ✓ 신호 발생기 (Function Generator)

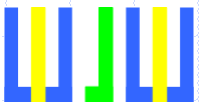


13-3. 유용한 공식

$$Z = \frac{(R \angle 0^\circ)(X_L \angle 90^\circ)}{R + jX_L} = \frac{RX_L \angle (0^\circ + 90^\circ)}{\sqrt{R^2 + X_L^2} \angle \tan^{-1}\left(\frac{X_L}{R}\right)}$$

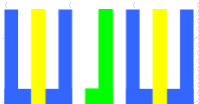
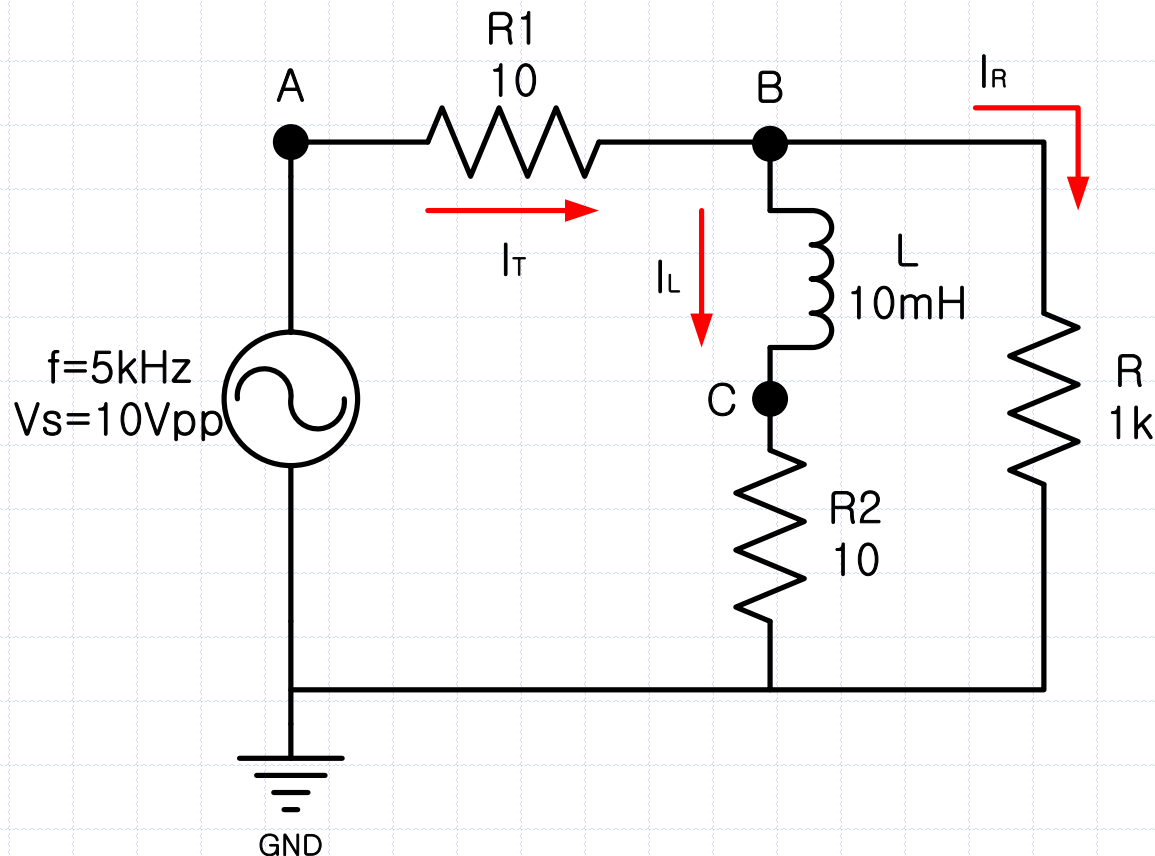
$$|Z| = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$$

$$\theta = \tan^{-1}\left(\frac{R}{X_L}\right)$$



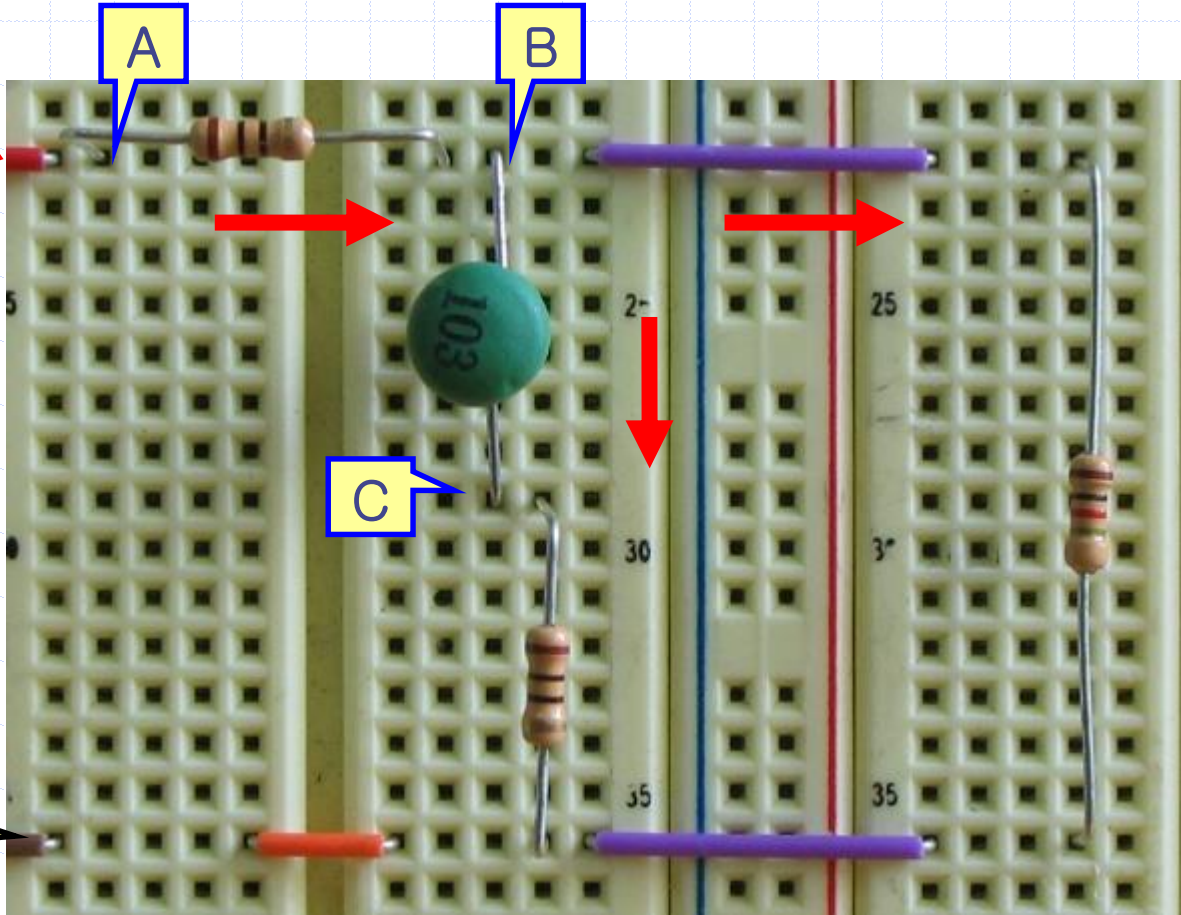
13-4. 주파수에 따른 임피던스

- 다음과 같이 회로를 연결하고, 신호 발생기를 조절하여 주파수 5kHz, 10Vpp 의 정현파가 나오도록 한다.

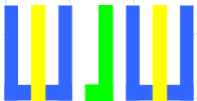


13-4. 주파수에 따른 임피던스

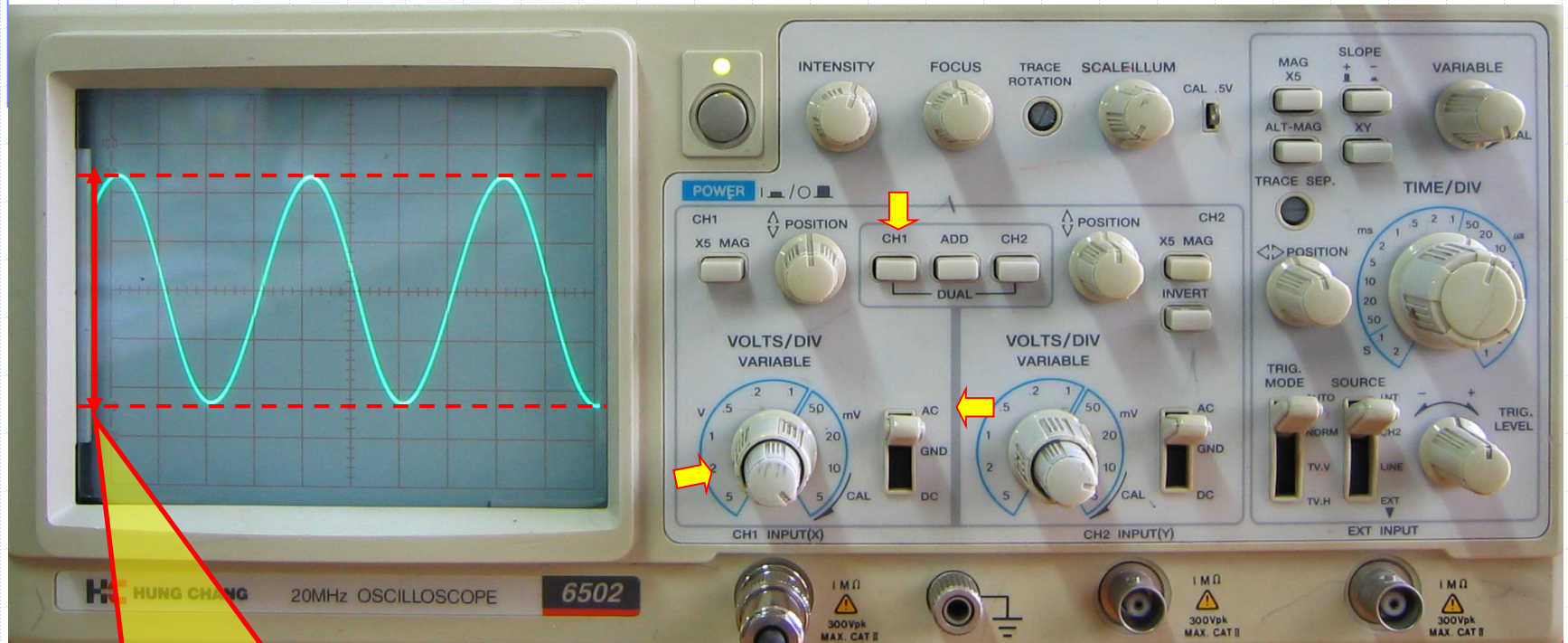
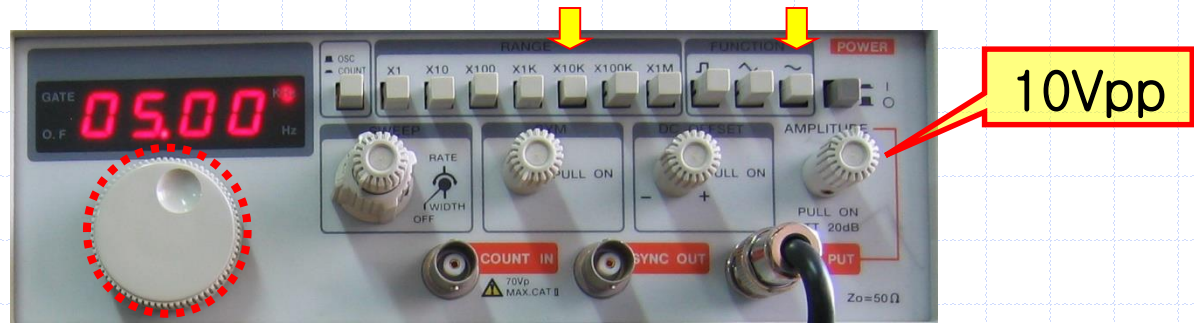
정현파
5kHz
10Vpp



GND



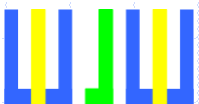
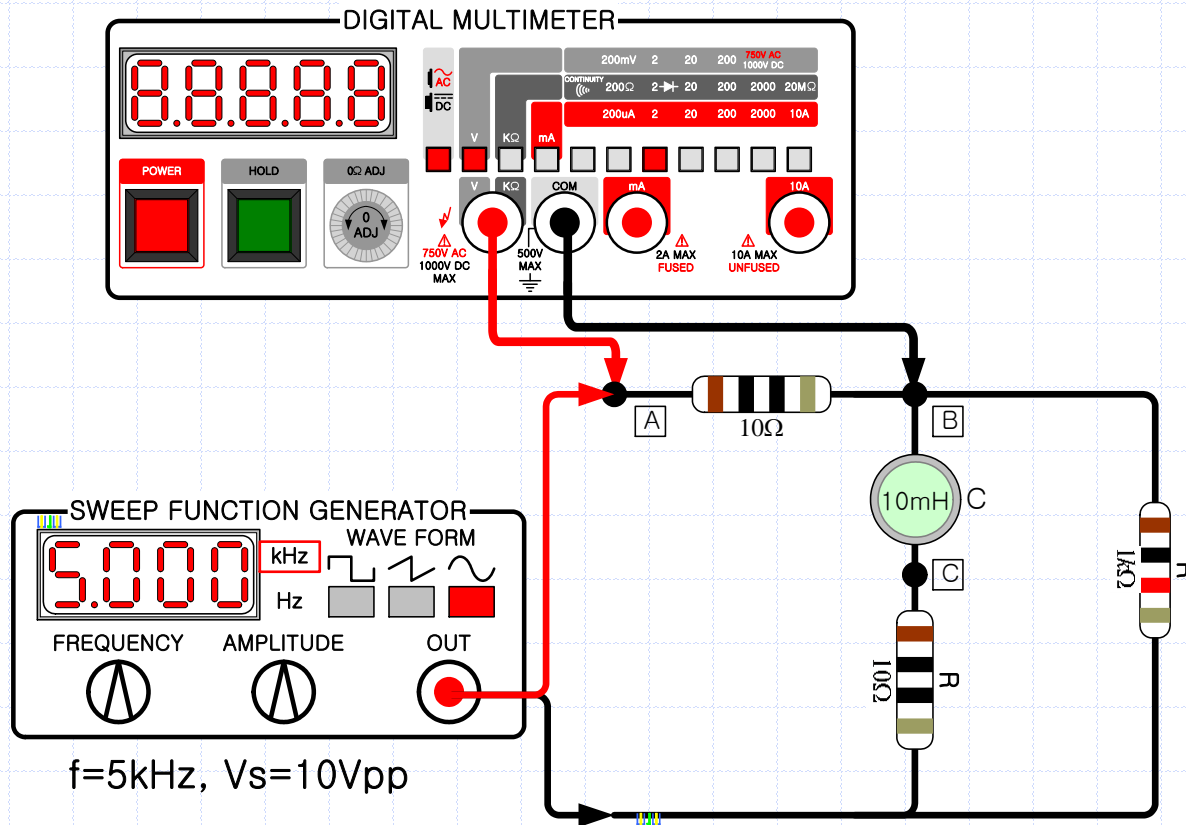
13-4. 주파수에 따른 임피던스



5칸 X 2V/DIV = 10Vpp

13-4. 주파수에 따른 임피던스

- ✓ 디지털 멀티미터를 이용하여 저항 양단의 전압을 측정한다.



13-4. 주파수에 따른 임피던스

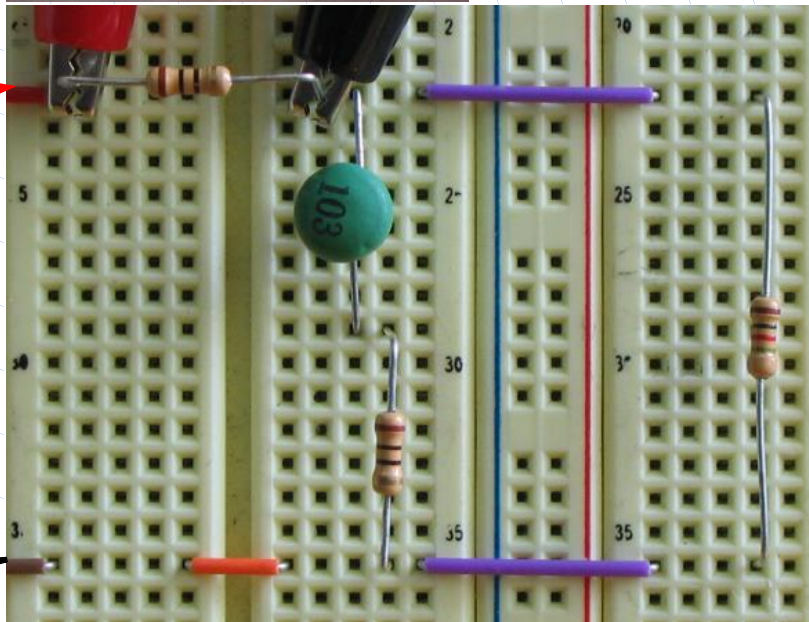
✓ 주파수 : 5kHz

$$V_{R1(rms)} = 111.05mV$$

$$V_{R1(p-p)} = 111.05mV \times 2 \times 1.414 = 314.05mV_{pp}$$

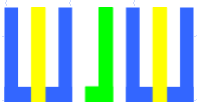


정현파
5kHz
10Vpp



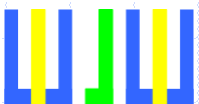
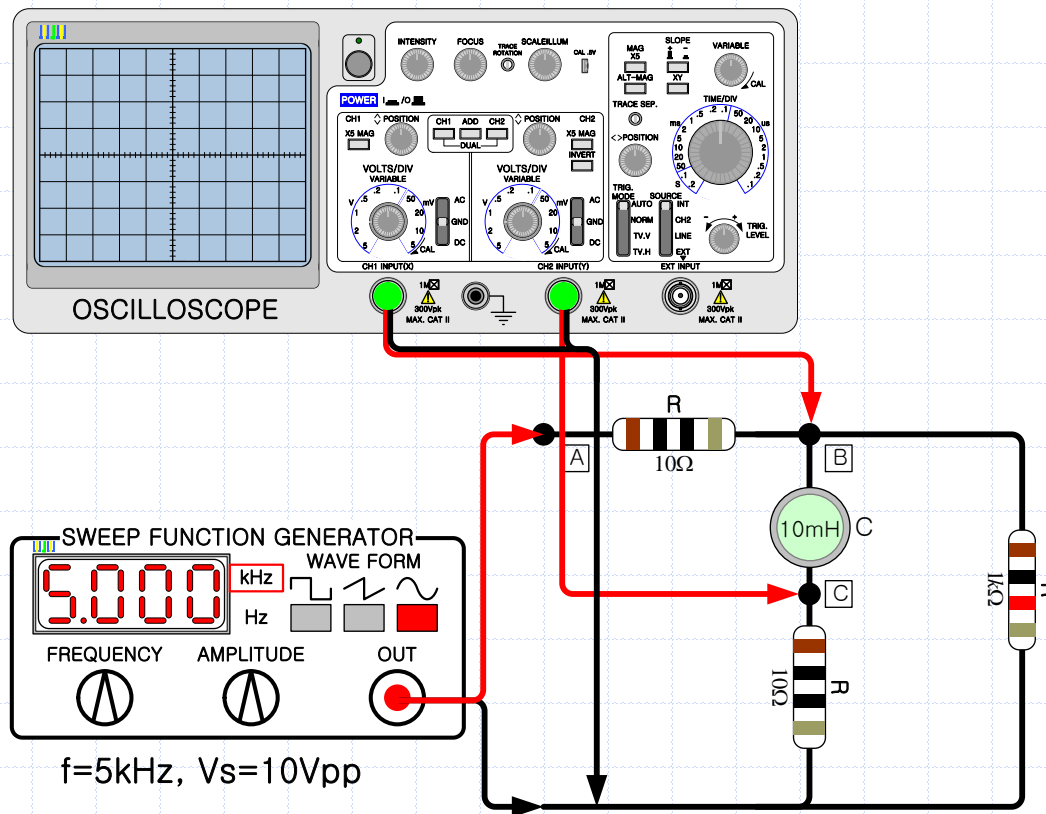
GND

$$\begin{aligned} I_T(\text{실험}) &= \frac{V_{R1}}{R_1} \\ &= \frac{314.05mV_{PP}}{10\Omega} \\ &= 31.405mA_{PP} \end{aligned}$$



13-4. 주파수에 따른 임피던스

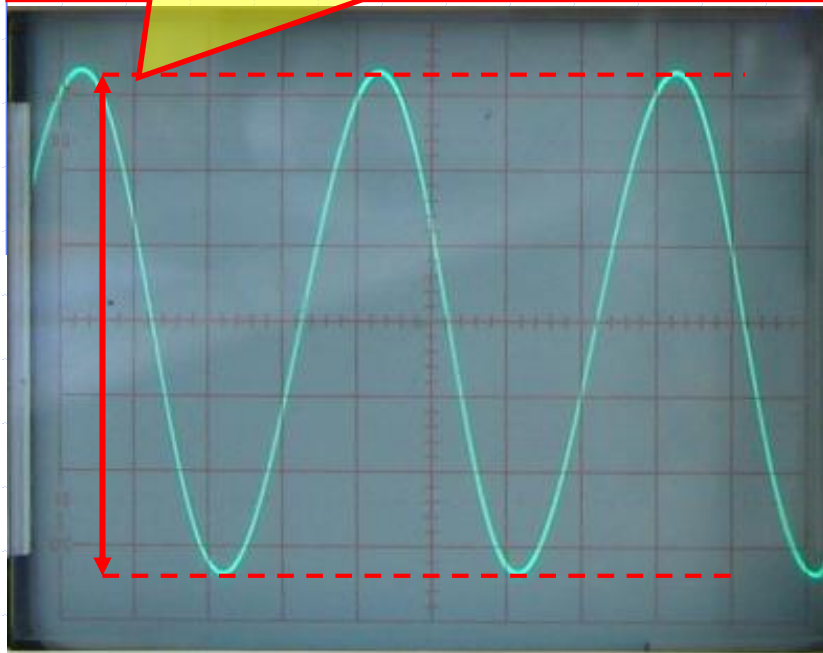
- ✓ 오실로스코프의 CH 1 을 B점과 접지에, CH 2 를 C점과 접지에 연결하여 전압을 측정하라.



13-4. 주파수에 따른 임피던스

✓ 주파수 : 5kHz, CH 2, V_{R2} 의 전압

$V_{R2} : 6.7\text{칸} \times 50\text{mV/DIV} = 335\text{mVpp}$



50mV/DIV, 50uS/DIV

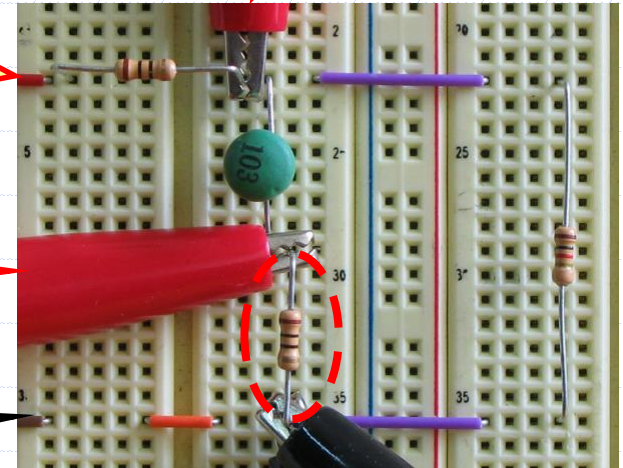
$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{335\text{mV}_{PP}}{10\Omega} = 33.5\text{mA}_{PP}$$

정현파
5kHz
10Vpp

CH 2

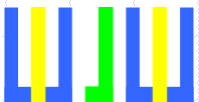
GND

CH 1



$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{V_L}{I_L} = \frac{V_R}{I_L} = \frac{10\text{V}_{PP}}{33.5\text{mA}_{PP}} = 298.5\Omega$$

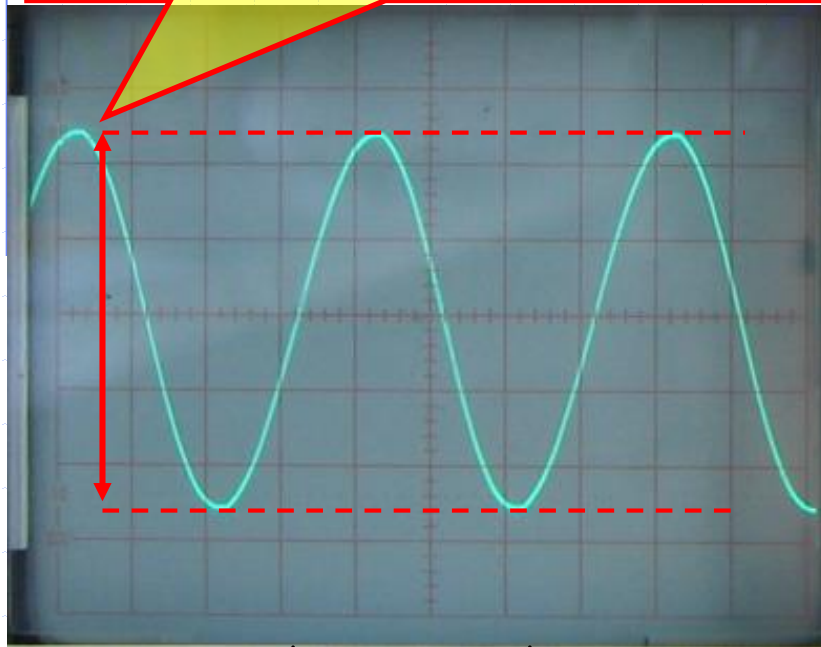
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10\text{V}_{PP}}{31.405\text{mA}_{PP}} = 318.42\Omega$$



13-4. 주파수에 따른 임피던스

✓ 주파수 : 5kHz, CH 1, V_R 의 전압

V_s, V_C, V_{R2} : 5칸 X 2V/DIV = 10Vpp



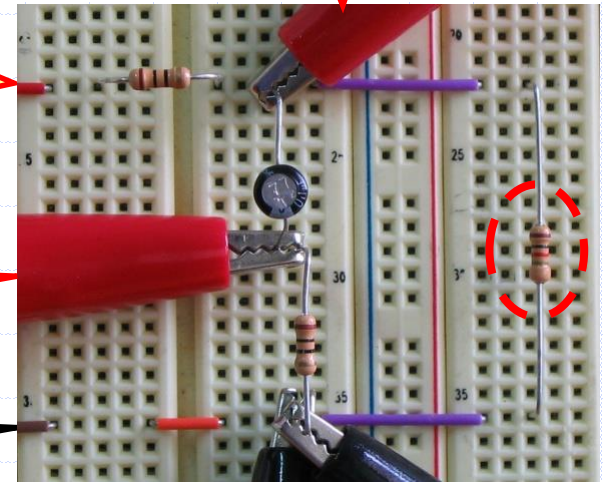
2V/DIV, 50uS/DIV

정현파
5kHz
10Vpp

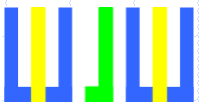
CH 2

GND

CH 1



$$I_R(\text{실험}) = \frac{V_R}{R} = \frac{10V_{PP}}{1k\Omega} = 10mA_{PP}$$



13-4. 주파수에 따른 임피던스

✓ 주파수 : 6kHz

$$\begin{aligned} V_{R1(\text{rms})} &= 95.89\text{mV} \\ V_{R1(\text{p-p})} &= 95.89\text{mV} \times 2 \times 1.414 \\ &= 271.18\text{mVpp} \end{aligned}$$



$$I_T(\text{실험}) = \frac{V_{R1}}{R_1} = \frac{271.18\text{mV}_{PP}}{10\Omega} = 27.118\text{mA}_{PP}$$

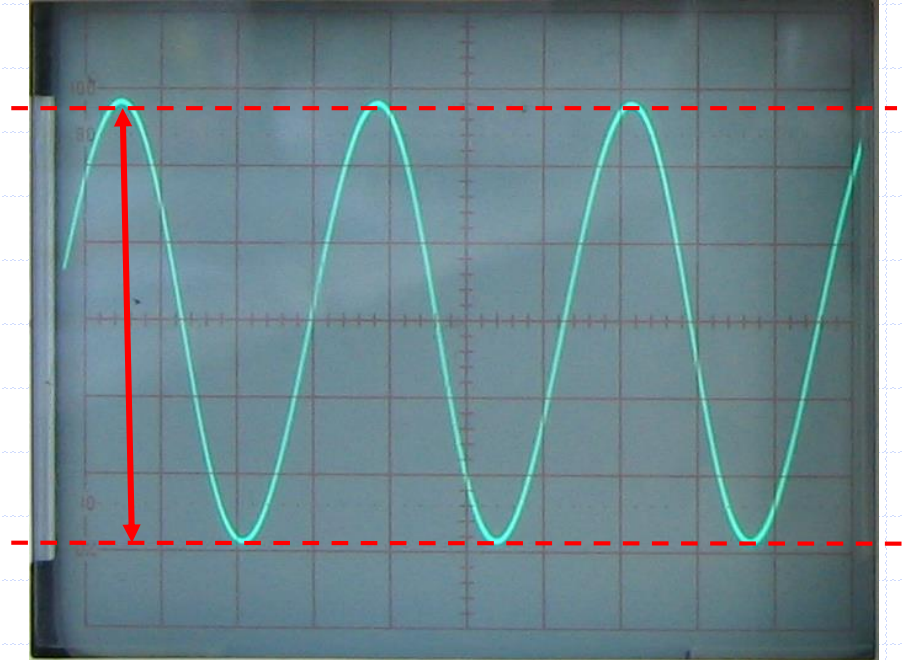
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10\text{V}_{PP}}{27.118\text{mA}_{PP}} = 368.76\Omega$$

$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{285\text{mV}_{PP}}{10\Omega} = 28.5\text{mA}_{PP}$$

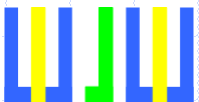
$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{10\text{V}_{PP}}{28.5\text{mA}_{PP}} = 350.9\Omega$$

✓ CH 2, V_{R2} 의 전압

$$V_{R2} : 5.7\text{칸} \times 50\text{mV/DIV} = 285\text{mVpp}$$



50mV/DIV, 50uS/DIV



13-4. 주파수에 따른 임피던스

✓ 주파수 : 7kHz

$$\begin{aligned} V_{R1(\text{rms})} &= 84.8\text{mV} \\ V_{R1(\text{p-p})} &= 84.8\text{mV} \times 2 \times 1.414 \\ &= 239.81\text{mVpp} \end{aligned}$$



$$I_T(\text{실험}) = \frac{V_{R1}}{R_1} = \frac{239.81\text{mV}_{PP}}{10\Omega} = 23.981\text{mA}_{PP}$$

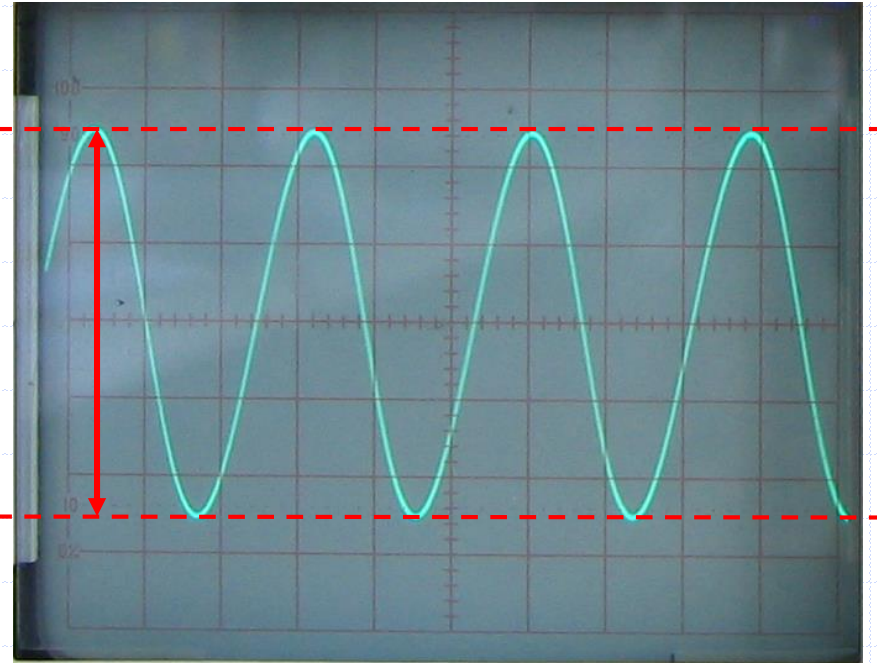
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10\text{V}_{PP}}{23.981\text{mA}_{PP}} = 417\Omega$$

$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{245\text{mV}_{PP}}{10\Omega} = 24.5\text{mA}_{PP}$$

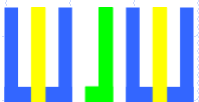
$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{10\text{V}_{PP}}{24.5\text{mA}_{PP}} = 408.16\Omega$$

✓ CH 2, V_{R2} 의 전압

$$V_{R2} : 4.9\text{칸} \times 50\text{mV/DIV} = 245\text{mVpp}$$



50mV/DIV, 50uS/DIV



13-4. 주파수에 따른 임피던스

✓ 주파수 : 8kHz

$$V_{R1(rms)} = 76.42mV$$

$$V_{R1(p-p)} = 76.42mV \times 2 \times 1.414$$

$$= 216.12mV_{pp}$$



$$I_T(\text{실험}) = \frac{V_{R1}}{R_1} = \frac{216.12mV_{PP}}{10\Omega} = 21.612mA_{PP}$$

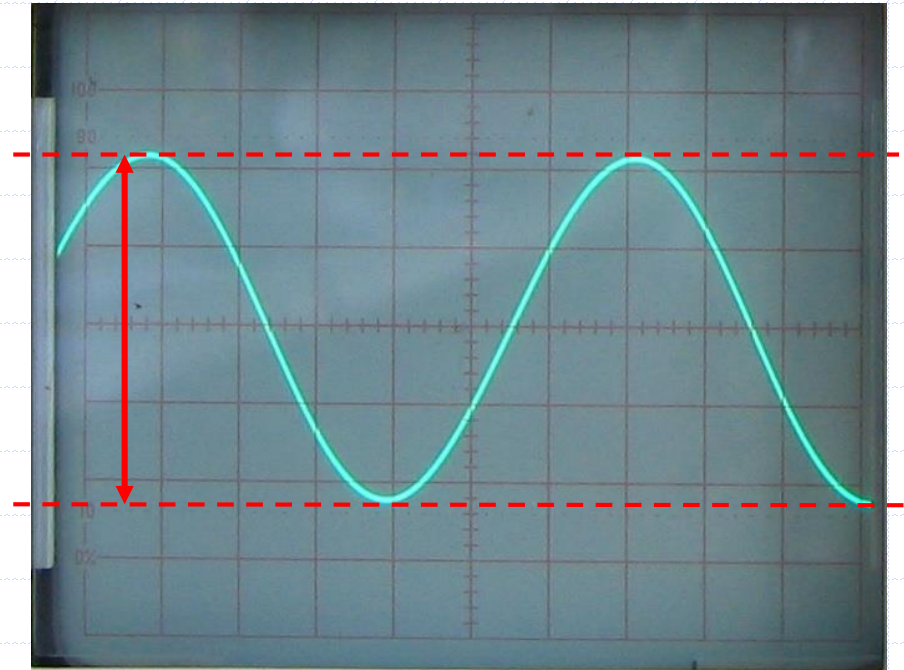
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10V_{PP}}{21.612mA_{PP}} = 462.71\Omega$$

$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{215mV_{PP}}{10\Omega} = 21.5mA_{PP}$$

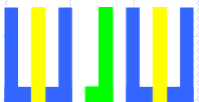
$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{10V_{PP}}{21.5mA_{PP}} = 465.12\Omega$$

✓ CH 2, V_{R2} 의 전압

$$V_{R2} : 4.3\text{칸} \times 50mV/DIV = 215mV_{pp}$$



50mV/DIV, 50uS/DIV



13-4. 주파수에 따른 임피던스

✓ 주파수 : 9kHz

$$V_{R1(rms)} = 69.77mV$$

$$V_{R1(p-p)} = 69.77mV \times 2 \times 1.414$$

$$= 197.31mV_{pp}$$



$$I_T(\text{실험}) = \frac{V_{R1}}{R_1} = \frac{197.31mV_{PP}}{10\Omega} = 19.731mA_{PP}$$

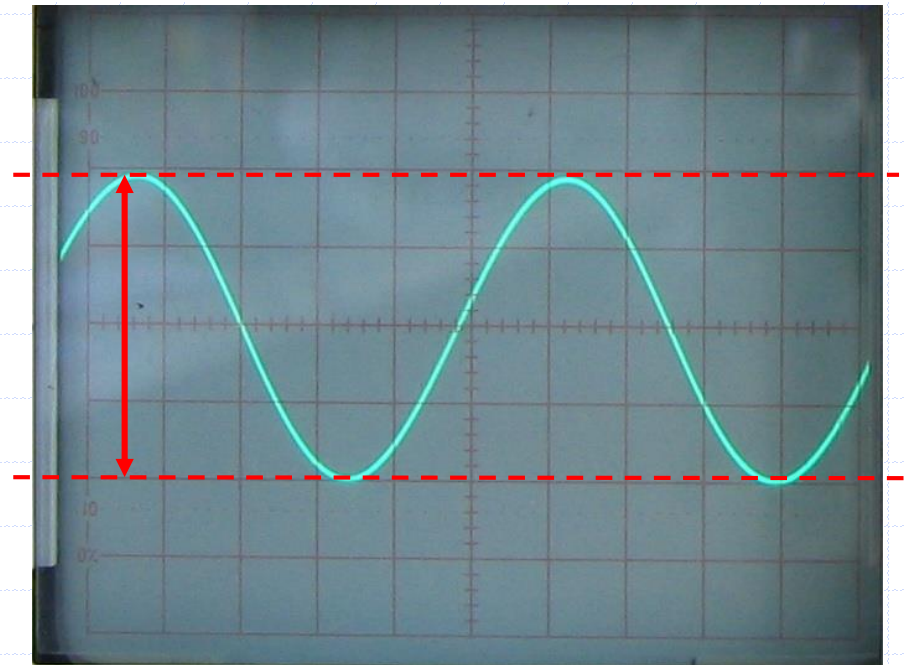
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10V_{PP}}{19.731mA_{PP}} = 506.82\Omega$$

$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{195mV_{PP}}{10\Omega} = 19.5mA_{PP}$$

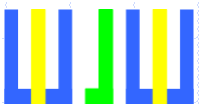
$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{10V_{PP}}{19.5mA_{PP}} = 512.82\Omega$$

✓ CH 2, V_{R2} 의 전압

$$V_{R2} : 3.9\text{칸} \times 50mV/DIV = 195mV_{pp}$$



50mV/DIV, 50uS/DIV



13-4. 주파수에 따른 임피던스

✓ 주파수 : 10kHz

$$V_{R1(rms)} = 64.40mV$$

$$V_{R1(p-p)} = 64.40mV \times 2 \times 1.414$$

$$= 182.12mV_{pp}$$



$$I_T(\text{실험}) = \frac{V_{R1}}{R_1} = \frac{182.12mV_{PP}}{10\Omega} = 18.212mA_{PP}$$

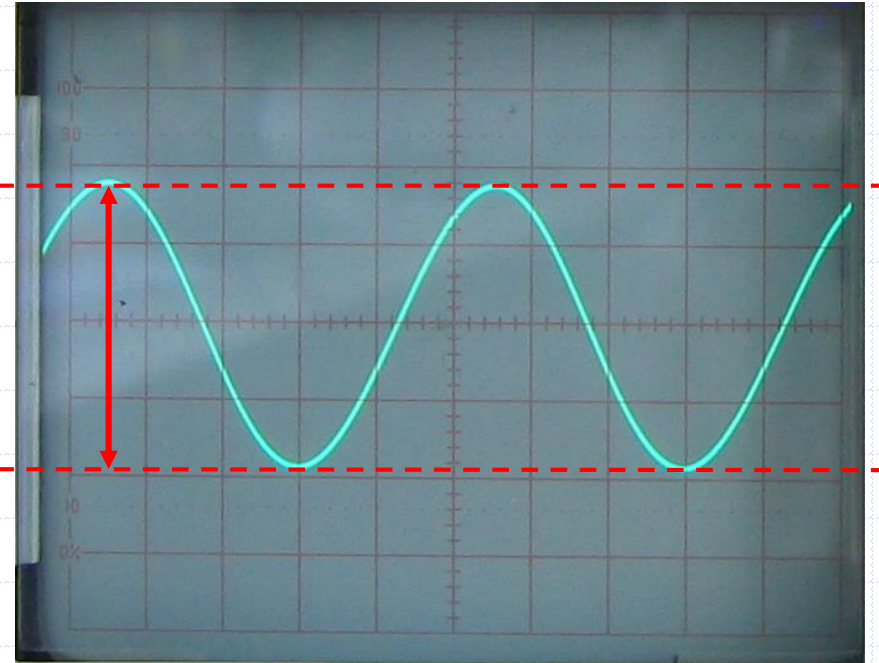
$$|Z|(\text{실험}) = \frac{V_S}{I_T} = \frac{10V_{PP}}{18.212mA_{PP}} = 549.1\Omega$$

$$I_L(\text{실험}) = \frac{V_{R2}}{R_2} = \frac{180mV_{PP}}{10\Omega} = 18mA_{PP}$$

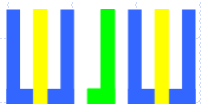
$$X_L(\text{실험}) = \frac{V_S}{I_L} = \frac{10V_{PP}}{18mA_{PP}} = 555.56\Omega$$

✓ CH 2, V_{R2} 의 전압

$$V_{R2} : 3.6\text{칸} \times 50mV/DIV = 180mV_{pp}$$



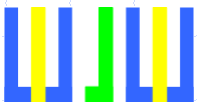
50mV/DIV, 50uS/DIV



13-4. 주파수에 따른 임피던스

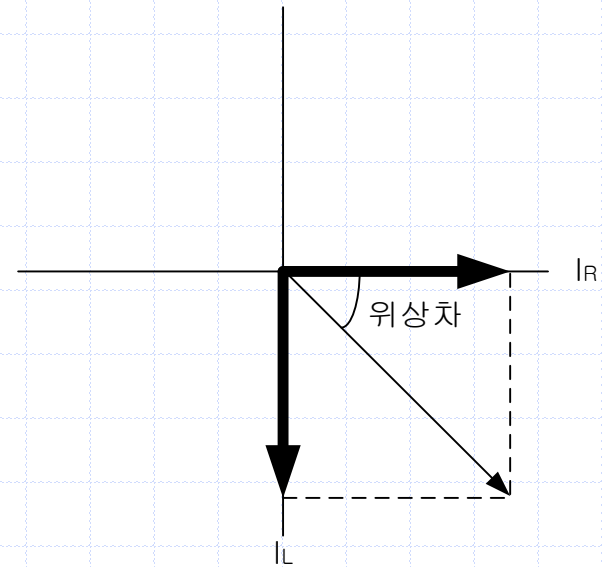
✓ 측정값의 비교

주파수	V_{R1} (mVpp)		I_T (mApp)		V_{R2} (mVpp)		I_L (mApp)		V_R (Vpp)		I_R (mApp)		X_L (Ω)		$ Z $ (Ω)	
	실험	이론	실험	이론	실험	이론	실험	이론	실험	이론	실험	이론	실험	이론	실험	이론
5 kHz	314.05	333.6	31.405	33.36	335	318.3	33.5	31.83	10	10	10	10	298.5	314.2	318.42	299.7
6 kHz	271.18	283.4	27.118	28.34	285	265.3	28.5	26.53	10	10	10	10	350.9	377	368.76	352.8
7 kHz	239.81	248.3	23.981	24.83	245	227.4	24.5	22.74	10	10	10	10	408.16	439.8	417	402.6
8 kHz	216.12	222.7	21.612	22.27	215	198.9	21.5	19.89	10	10	10	10	465.12	502.7	462.71	449.1
9 kHz	197.31	203.2	19.731	20.32	195	176.8	19.5	17.68	10	10	10	10	512.82	565.5	506.82	492.2
10 kHz	182.12	188	18.212	18.8	180	159.2	18.0	15.92	10	10	10	10	555.56	628.3	549.1	532



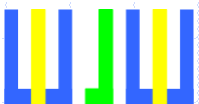
11-5. 주파수에 따른 위상의 변화

주파수	I _C 와 I _R 의 위상차 (도)	
	실험 8.	계산값
5 kHz	73.38	72.56
6 kHz	70.67	69.34
7 kHz	67.8	66.26
8 kHz	65.06	63.31
9 kHz	62.85	60.51
10 kHz	60.95	57.86



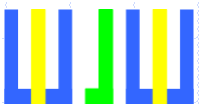
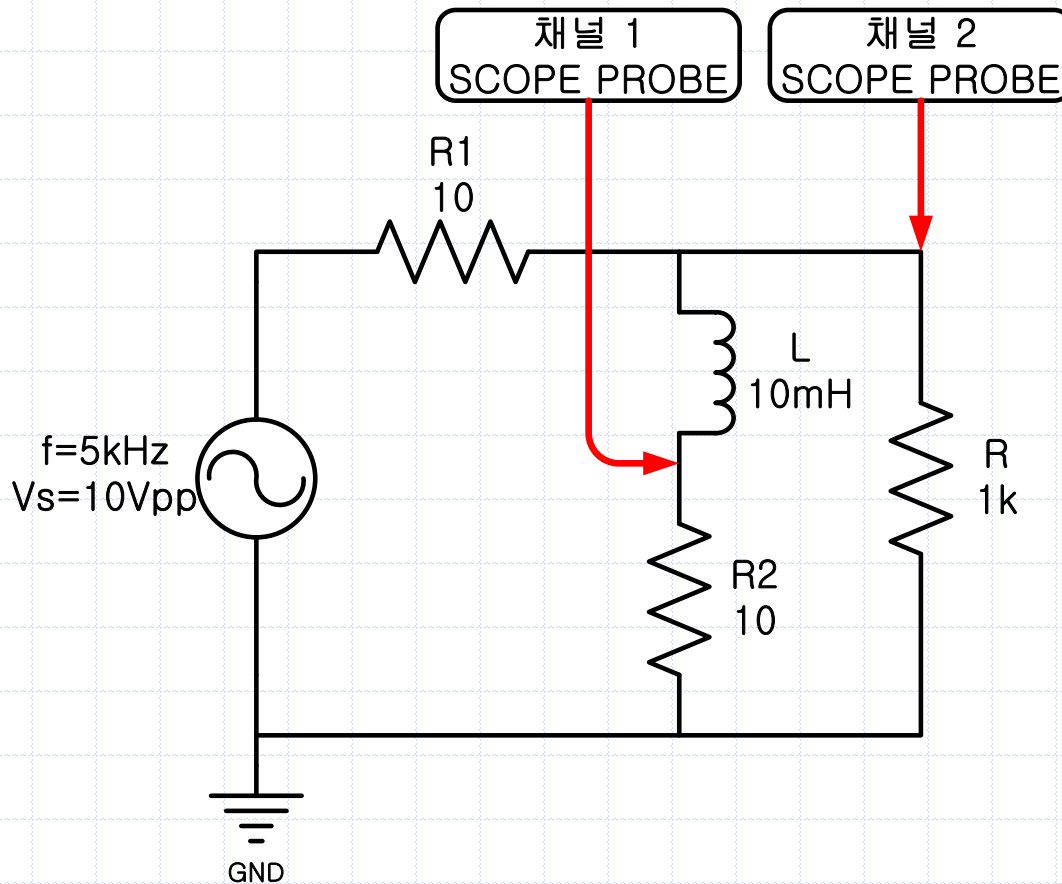
$$\text{위상차(실험 8.)} = \tan^{-1}\left(\frac{I_L}{I_R}\right)$$

$$\text{위상차(계산값)} = \tan^{-1}\left(\frac{R}{X_L}\right)$$

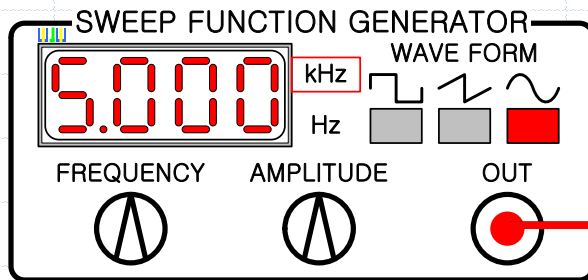
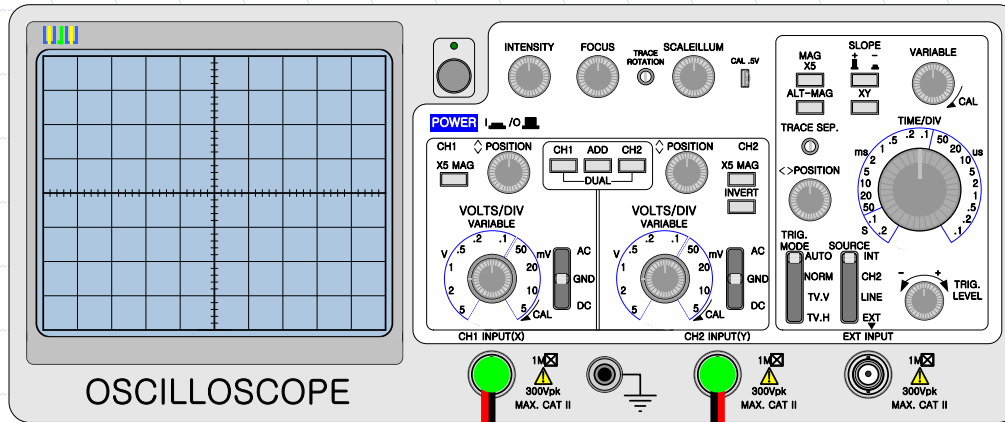


13-6. 전압과 전류의 위상

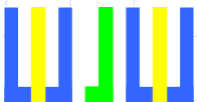
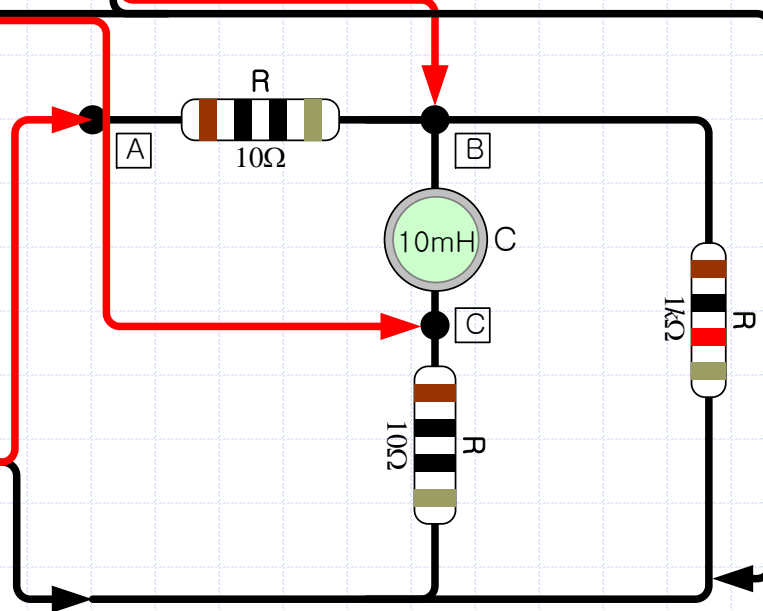
- 다음과 같이 회로를 연결하고, 신호 발생기를 조절하여 주파수 500Hz, 10Vpp 의 정현파가 나오도록 한다.



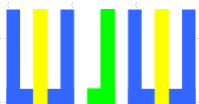
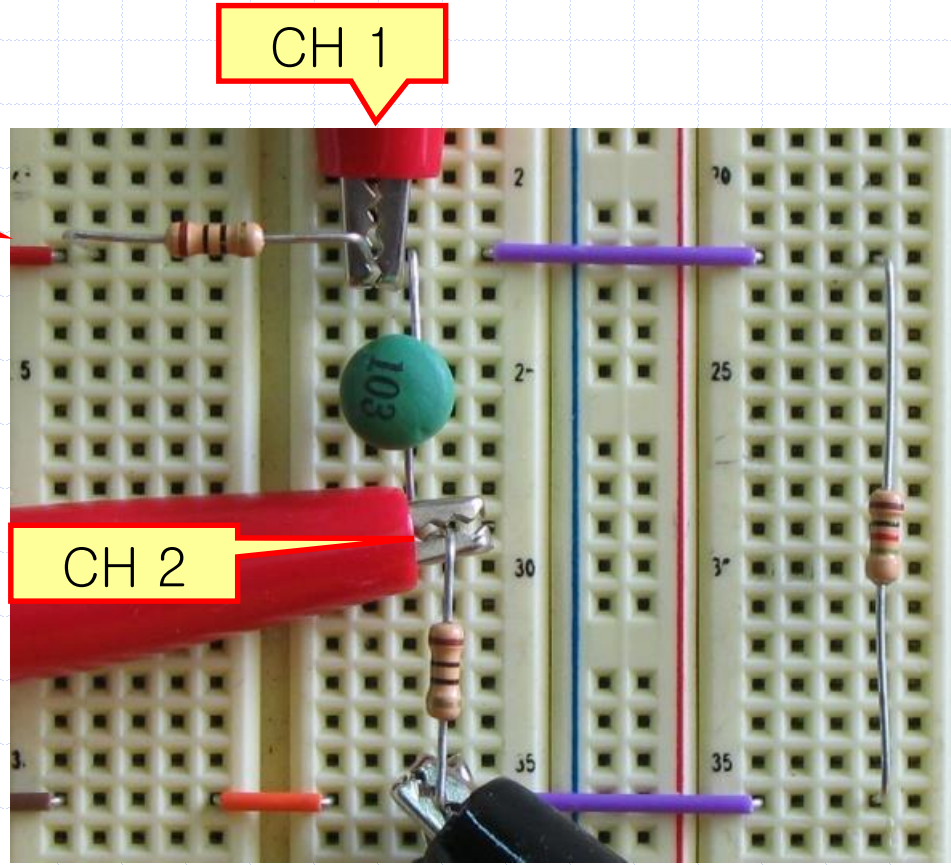
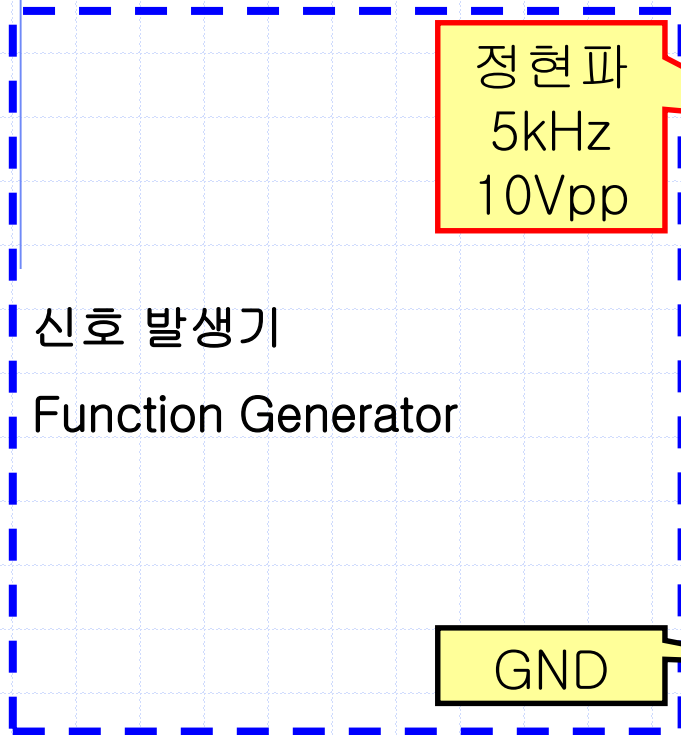
13-6. 전압과 전류의 위상



$f=5\text{kHz}$, $V_s=10\text{Vpp}$

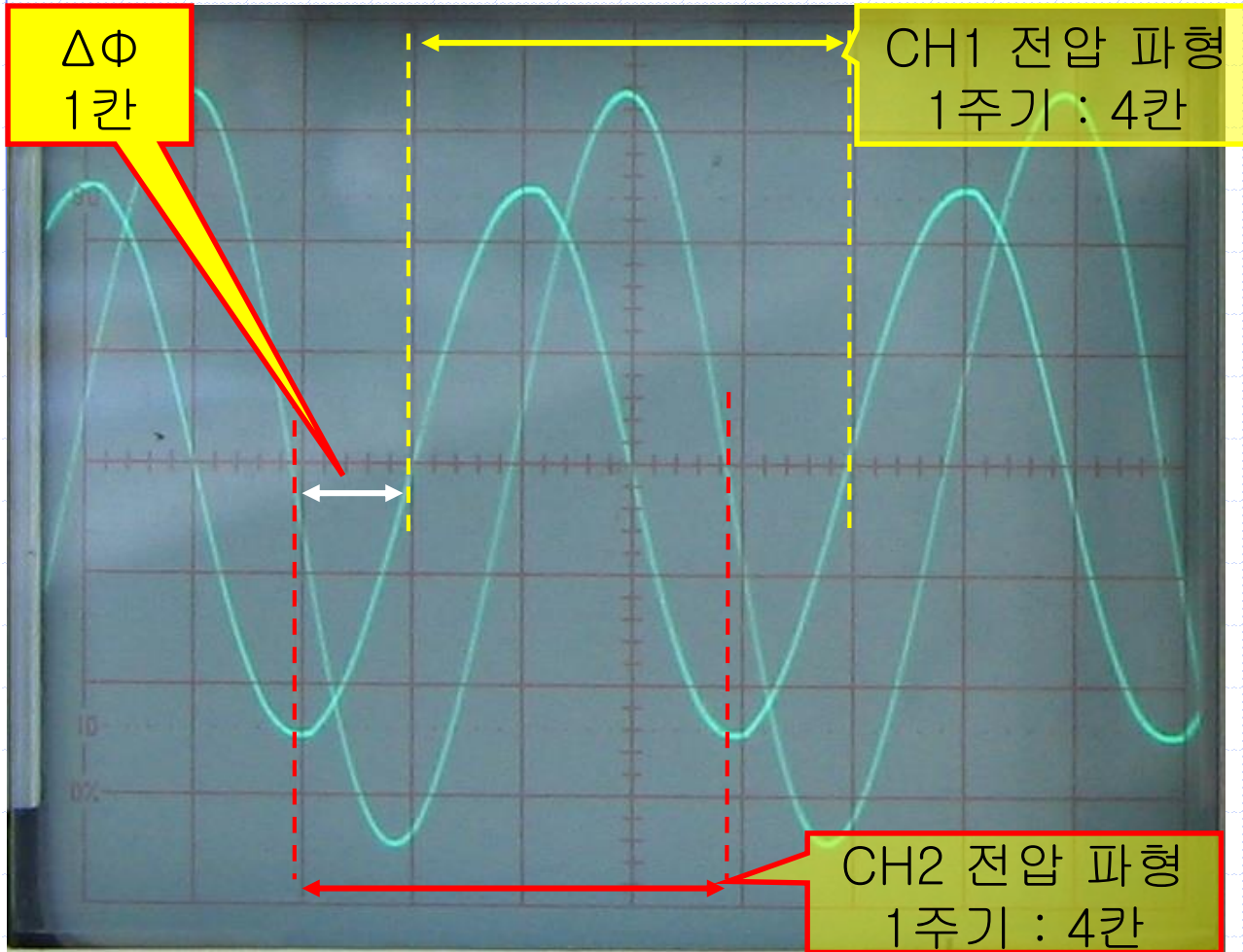


13-6. 전압과 전류의 위상



13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 5kHz)



$$1T = 4\text{칸} \times 50\mu\text{Sec} = 200\mu\text{Sec}$$

$$\Delta t = 1\text{칸} \times 50\mu\text{Sec} = 50\mu\text{Sec}$$

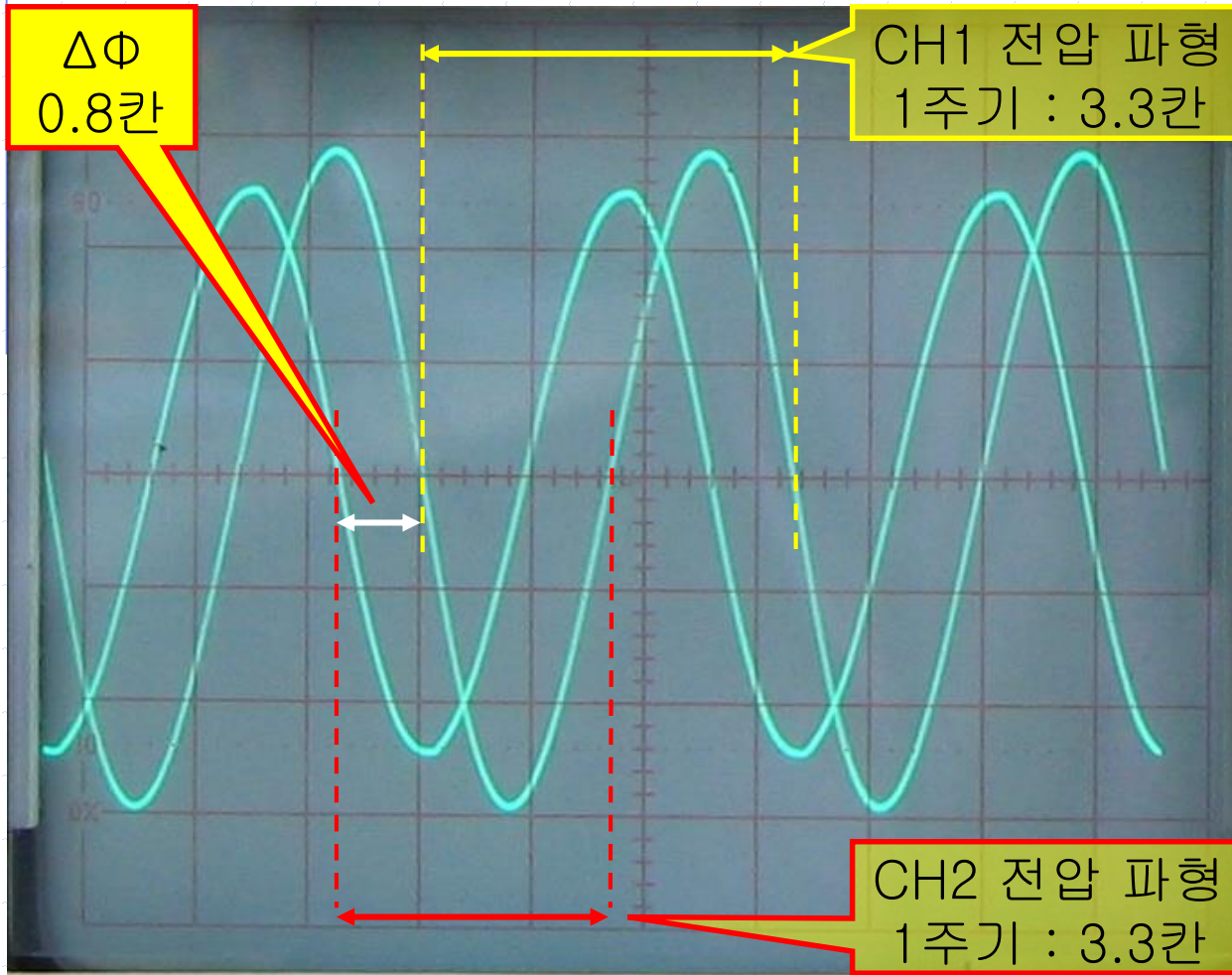
$$200\mu\text{Sec} : 50\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 90^\circ$$

CH 1 : 2V/DIV, CH 2 : 50mV/DIV, Time : 50uS/DIV

13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 6kHz)



$$1T = 3.3\text{칸} \times 50\mu\text{Sec} = 165\mu\text{Sec}$$

$$\Delta t = 0.8\text{칸} \times 50\mu\text{Sec} = 40\mu\text{Sec}$$

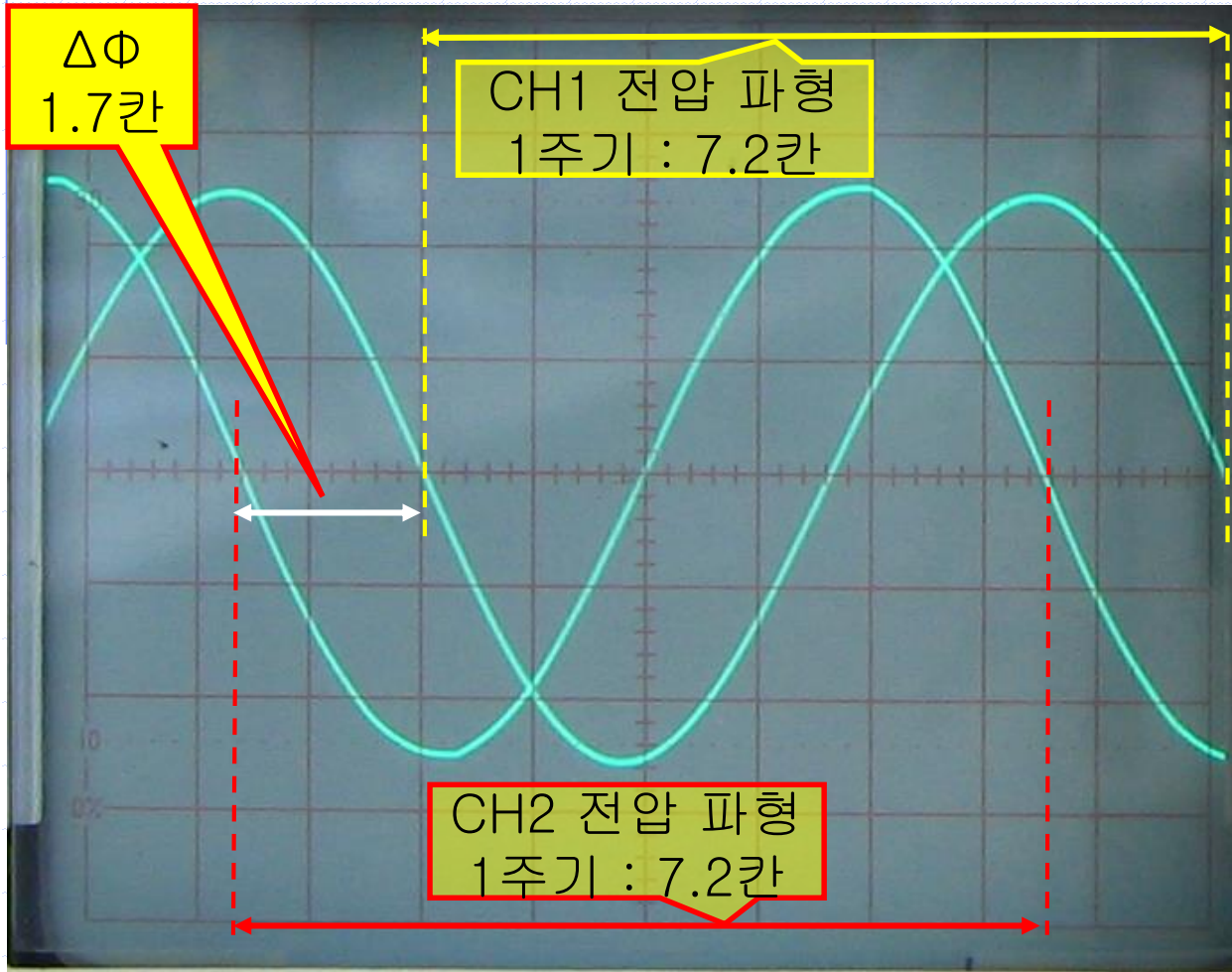
$$165\mu\text{Sec} : 40\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 87.27^\circ$$

CH 1 : 2V/DIV, CH 2 : 50mV/DIV, Time : 50uS/DIV

13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 7kHz)



$$1T = 7.2\text{칸} \times 20\mu\text{Sec} = 144\mu\text{Sec}$$

$$\Delta t = 1.7\text{칸} \times 20\mu\text{Sec} = 34\mu\text{Sec}$$

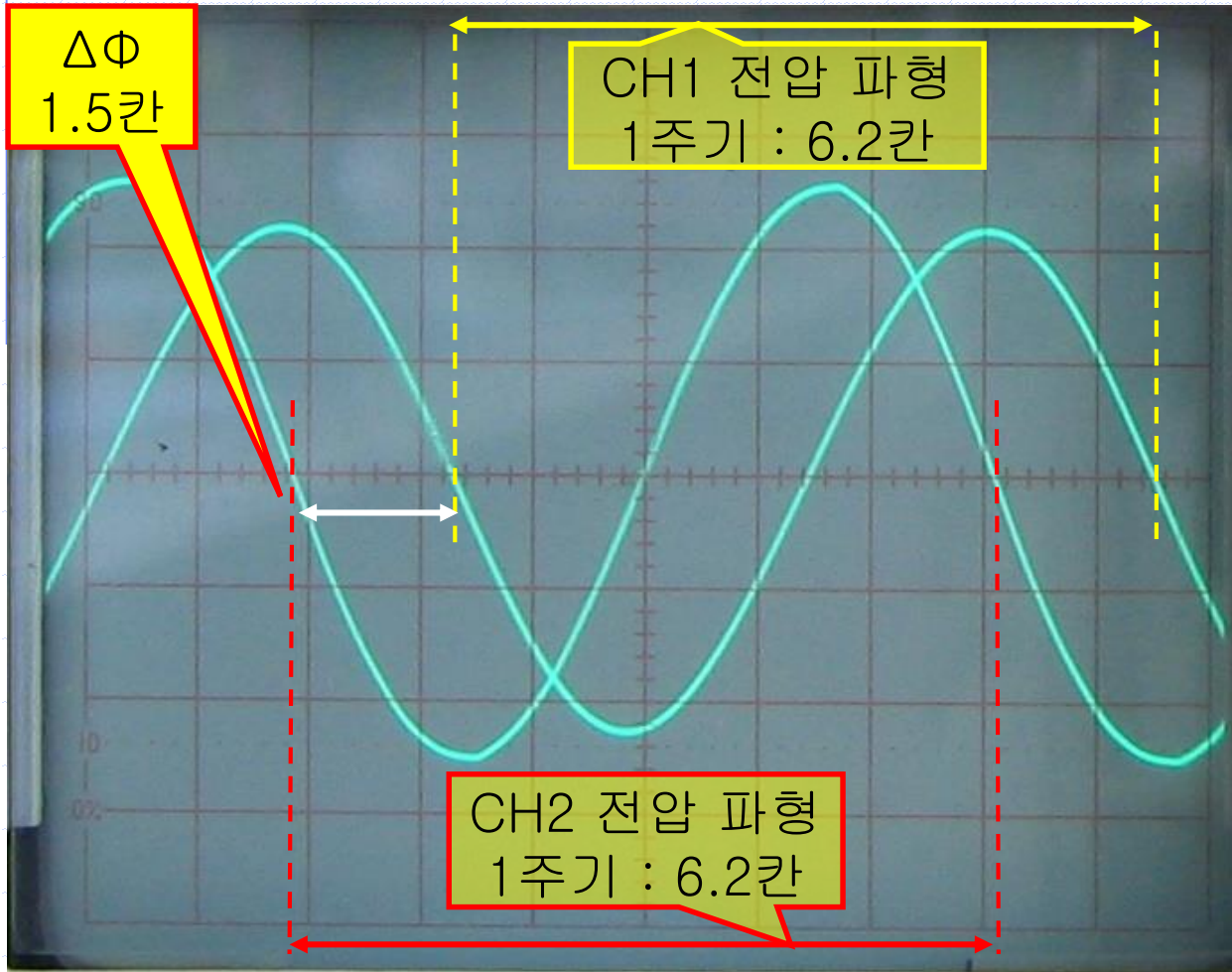
$$144\mu\text{Sec} : 34\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 85^\circ$$

CH 1 : 2V/DIV, CH 2 : 50mV/DIV, Time : 20uS/DIV

13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 8kHz)



$$1T = 6.2\text{칸} \times 20\mu\text{Sec} = 124\mu\text{Sec}$$

$$\Delta t = 1.5\text{칸} \times 20\mu\text{Sec} = 30\mu\text{Sec}$$

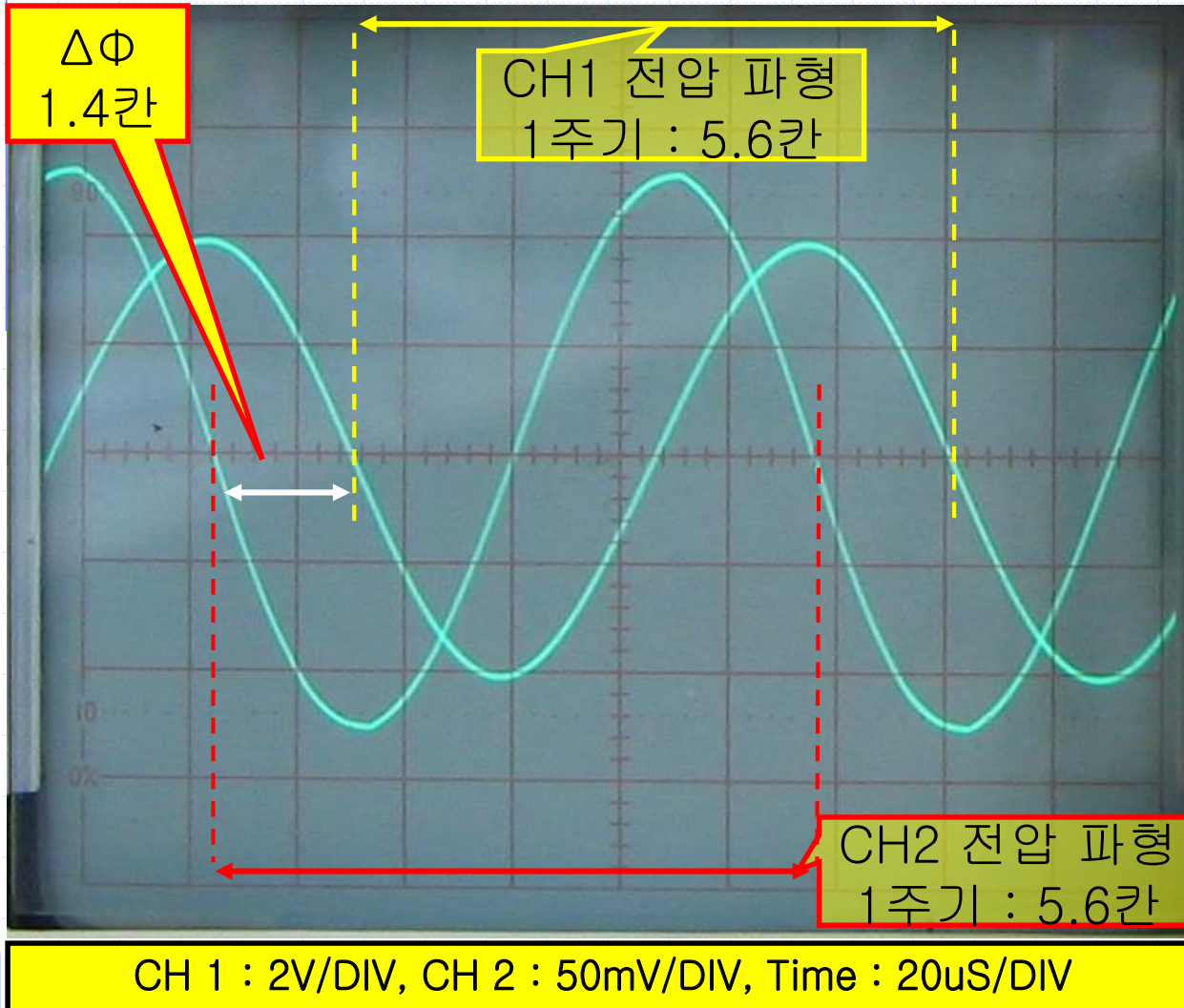
$$124\mu\text{Sec} : 30\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 87.1^\circ$$

CH 1 : 2V/DIV, CH 2 : 50mV/DIV, Time : 20uS/DIV

13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 9kHz)



$$1T = 5.6\text{칸} \times 20\mu\text{Sec} = 112\mu\text{Sec}$$

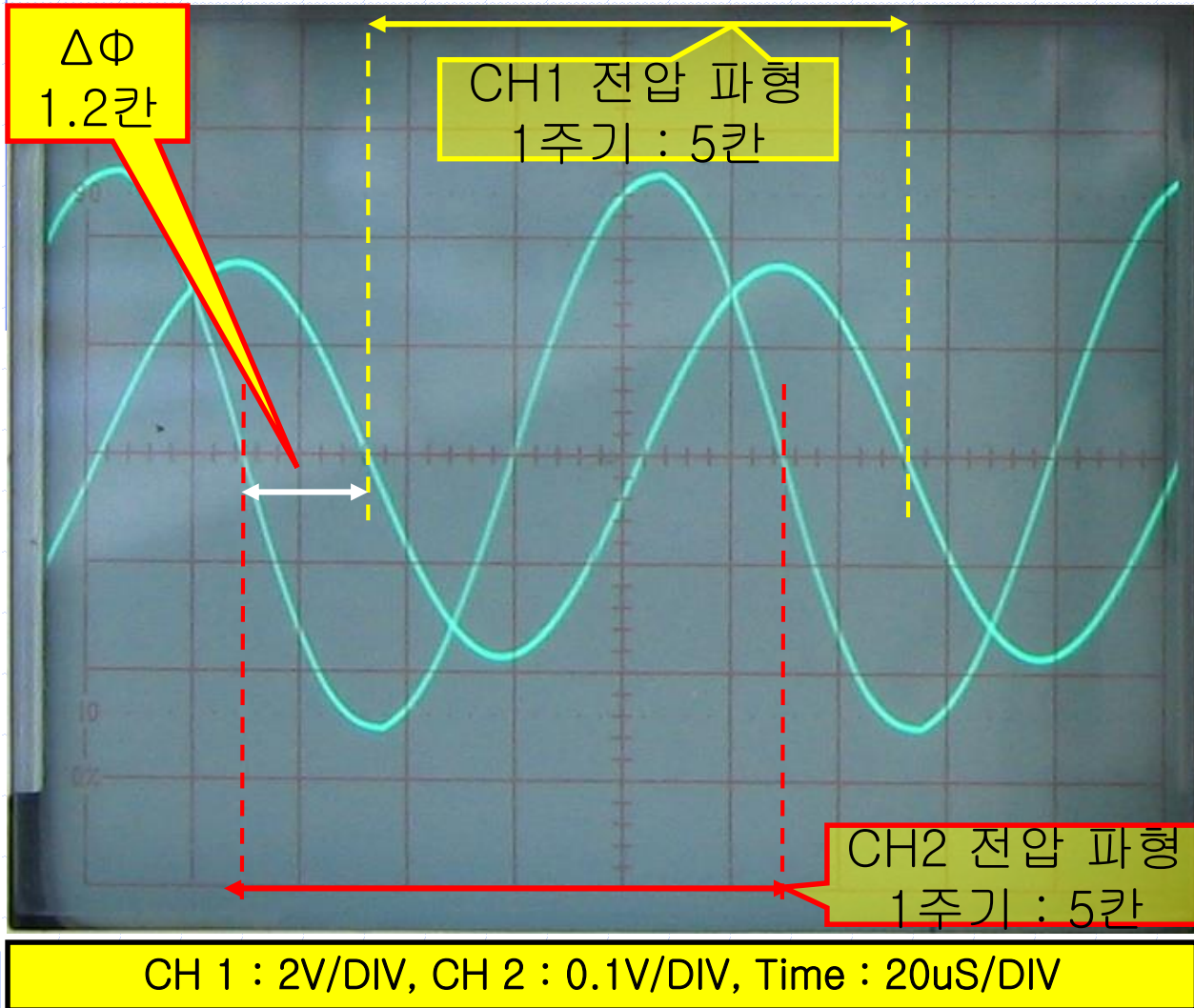
$$\Delta t = 1.4\text{칸} \times 20\mu\text{Sec} = 28\mu\text{Sec}$$

$$112\mu\text{Sec} : 28\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 90^\circ$$

13-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 10kHz)



$$1T = 5\text{칸} \times 20\mu\text{Sec} = 100\mu\text{Sec}$$

$$\Delta t = 1.2\text{칸} \times 20\mu\text{Sec} = 24\mu\text{Sec}$$

$$100\mu\text{Sec} : 24\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 86.4^\circ$$

13-6. 전압과 전류의 위상

주파수	실험 9.	계산값
5 kHz	90 도	90 도
6 kHz	87.27 도	90 도
7 kHz	85 도	90 도
8 kHz	87.1 도	90 도
9 kHz	90 도	90 도
10 kHz	86.4 도	90 도

