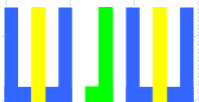


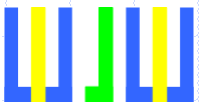
# 회로 이론/실습

## 10. 직렬 RC 회로



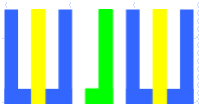
# 10. 직렬 RC 회로

- 10-1. 목적 및 배경
- 10-2. 소요 부품 및 장비
- 10-3. 유용한 공식
- 10-4. 주파수에 따른 임피던스
- 10-5. 위상의 변화
- 10-6. 전압과 전류의 위상



## 10-1. 목적 및 배경

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



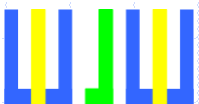
## 10-2. 소요 부품 및 장비

### ✓ 부품

- ✓ 저항 (1/4W) : 100Ω, 1kΩ, 6.8kΩ
- ✓ 캐패시터 : 0.01uF, 0.1uF

### ✓ 장비

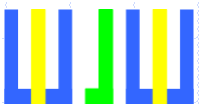
- ✓ 브레드 보드
- ✓ 디지털 멀티미터 (Digital Multi-Meter)
- ✓ 오실로스코프 (Oscilloscope)
- ✓ 신호발생기 (Function Generator)



## 10-3. 유용한 공식

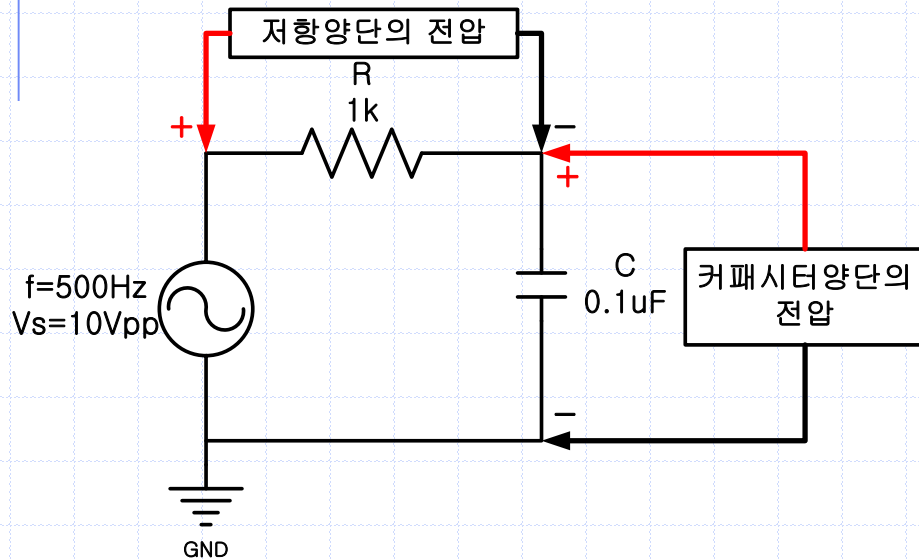
✓ 직렬 RC 회로의 임피던스

$$Z = R - j \frac{1}{2\pi f C} = R - jX_C = \sqrt{R^2 + X_C^2} \angle -\tan^{-1}\left(\frac{X_C}{R}\right)$$



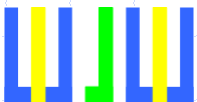
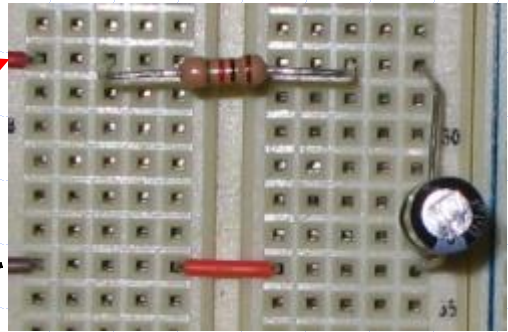
# 10-4. 주파수에 따른 임피던스

- 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 500Hz, 10Vpp의 정현파가 나오도록 한다.

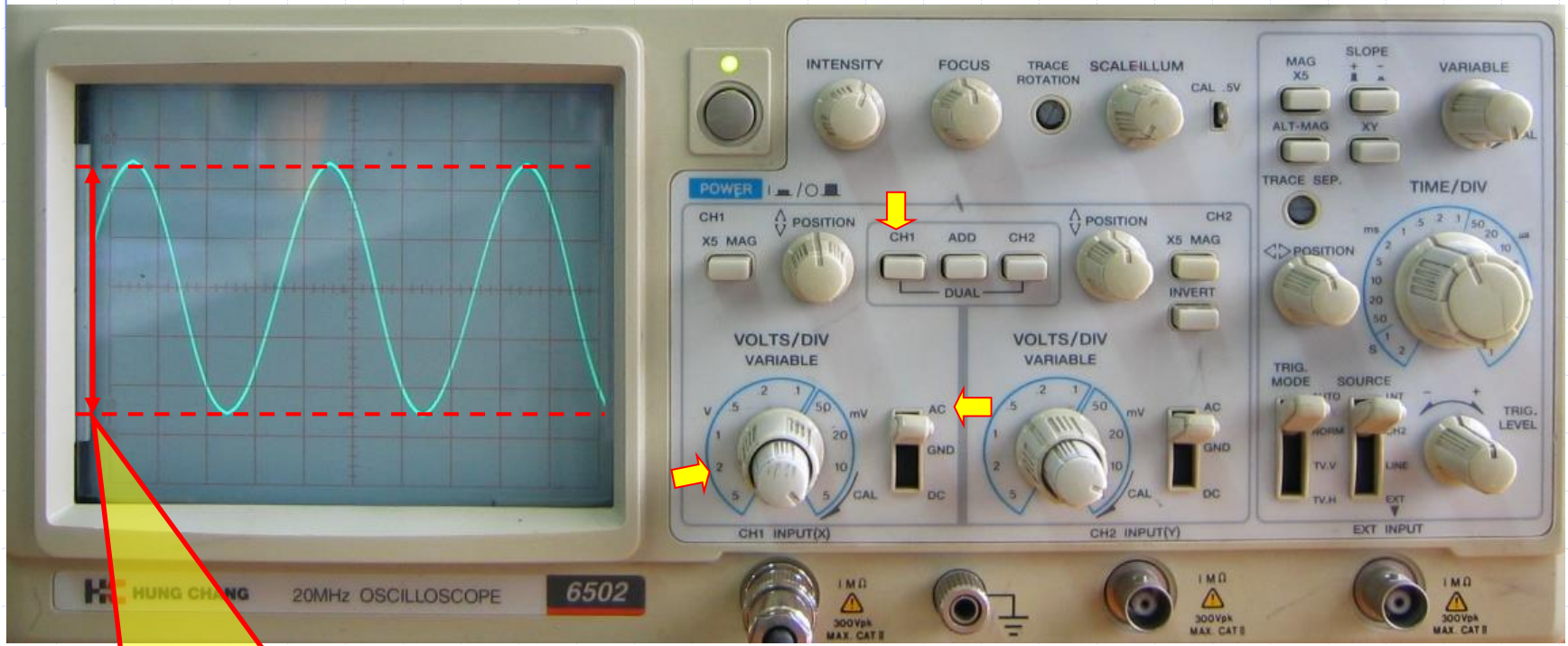
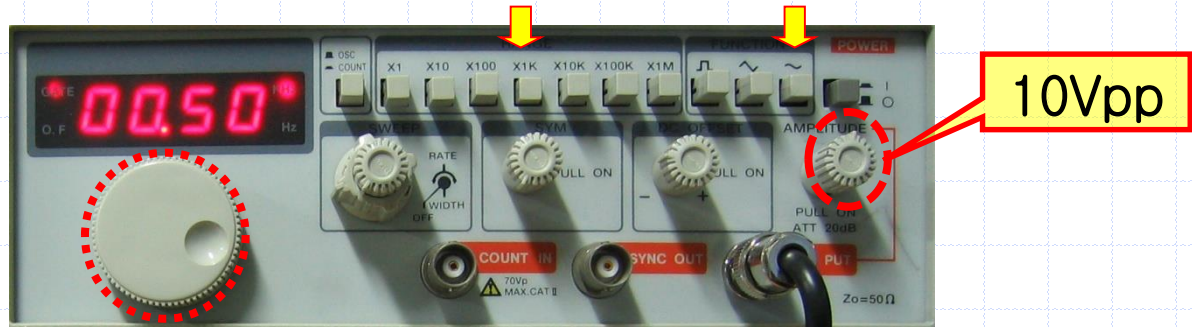


정현파  
500Hz  
10Vpp

GND



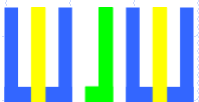
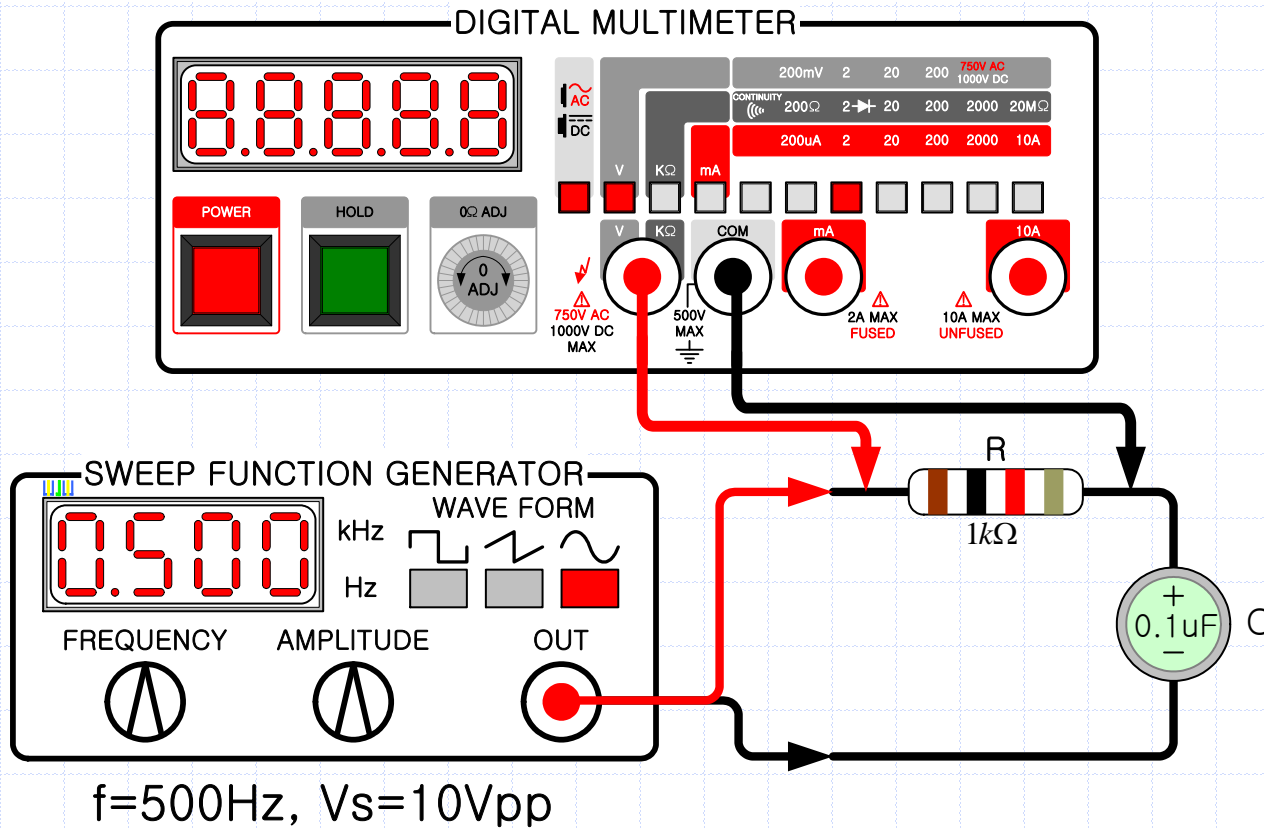
# 10-4. 주파수에 따른 임피던스



$$5\text{칸} \times 2\text{V/DIV} = 10\text{Vpp}$$

# 10-4. 주파수에 따른 임피던스

- ✓ 디지털 멀티미터를 이용하여 저항 양단의 실효 전압을 측정한다.





# 10-4. 주파수에 따른 임피던스

✓ 주파수 : 500Hz

$$V_{R(rms)} = 0.893V$$

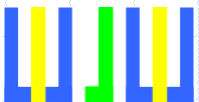
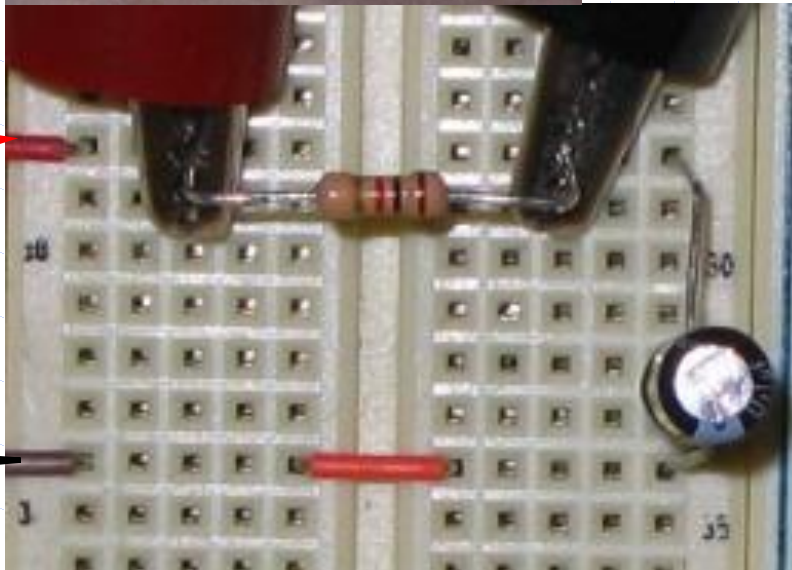
$$V_{R(p-p)} = 0.893V \times 2 \times 1.414 = 2.525V_{pp}$$



$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{2.525V}{1k\Omega} = 2.525mA$$

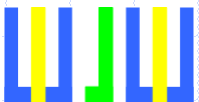
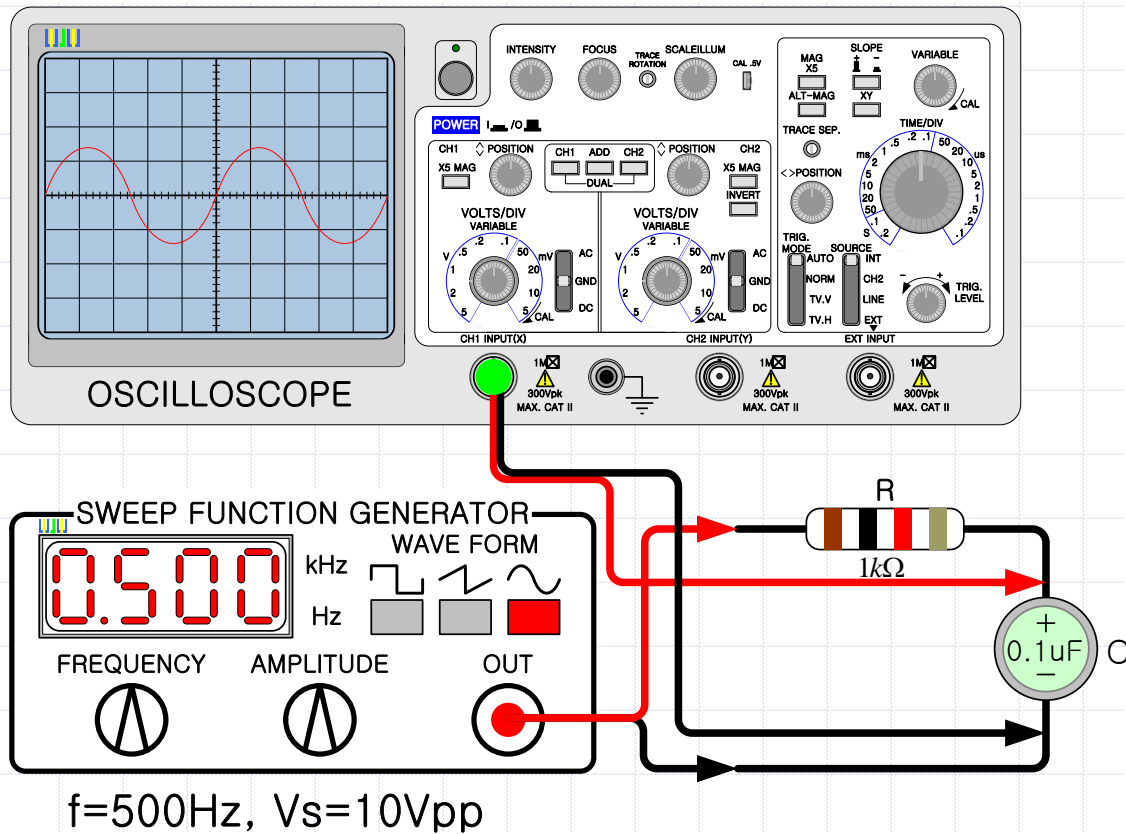
정현파  
500Hz  
10Vpp

GND



# 10-4. 주파수에 따른 임피던스

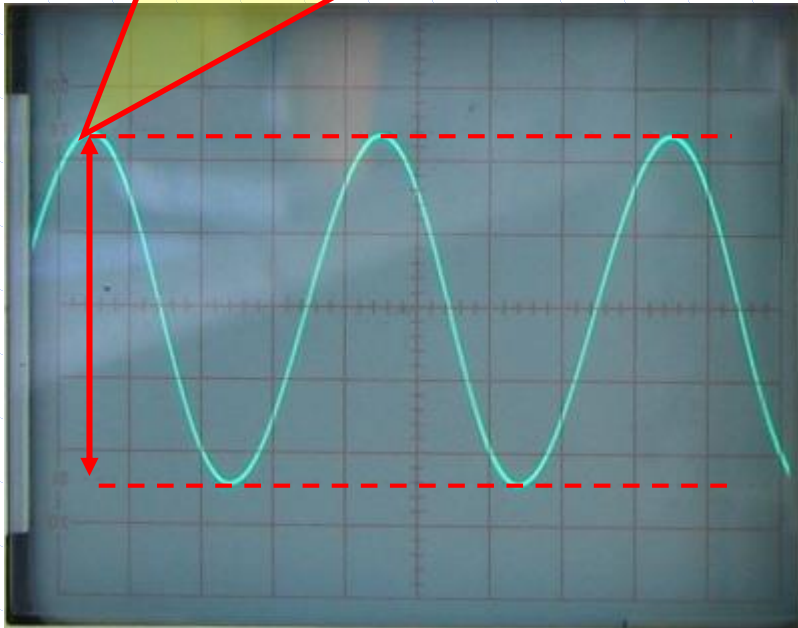
- ✓ 오실로스코프의 CH 1 을 이용하여 캐패시터 양단의 전압을 측정한다.



# 10-4. 주파수에 따른 임피던스

✓ 주파수 : 500Hz

$$V_c : 4.8\text{칸} \times 2\text{V/DIV} = 9.6\text{Vpp}$$



2V/DIV, 20uS/DIV

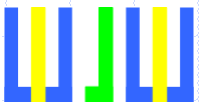
정현파  
500Hz  
10Vpp

GND



$$X_c(\text{실험}) = \frac{V_c}{I} = \frac{9.6\text{Vpp}}{2.525\text{mA}} = 3801.98\Omega$$

$$|Z|(\text{실험}) = \frac{V_s}{I} = \frac{10\text{Vpp}}{2.525\text{mA}} = 4060.40\Omega$$



# 10-4. 주파수에 따른 임피던스

✓ 주파수 : 1kHz, 10Vpp

$$V_{R(rms)} = 1.585V$$

$$V_{R(p-p)} = 1.585V \times 2 \times 1.414 \\ = 4.482V_{pp}$$



$$V_c : 4.2\text{칸} \times 2V/DIV = 8.4V_{pp}$$

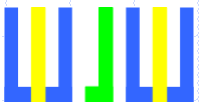


2V/DIV, 20uS/DIV

$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{4.482V}{1k\Omega} = 4.482mA$$

$$X_c(\text{실험}) = \frac{V_c}{I} = \frac{8.4V_{pp}}{4.482mA} = 1784.16\Omega$$

$$|Z|(\text{실험}) = \frac{V_s}{I} = \frac{10V_{pp}}{4.482mA} = 2231.15\Omega$$



# 10-4. 주파수에 따른 임피던스

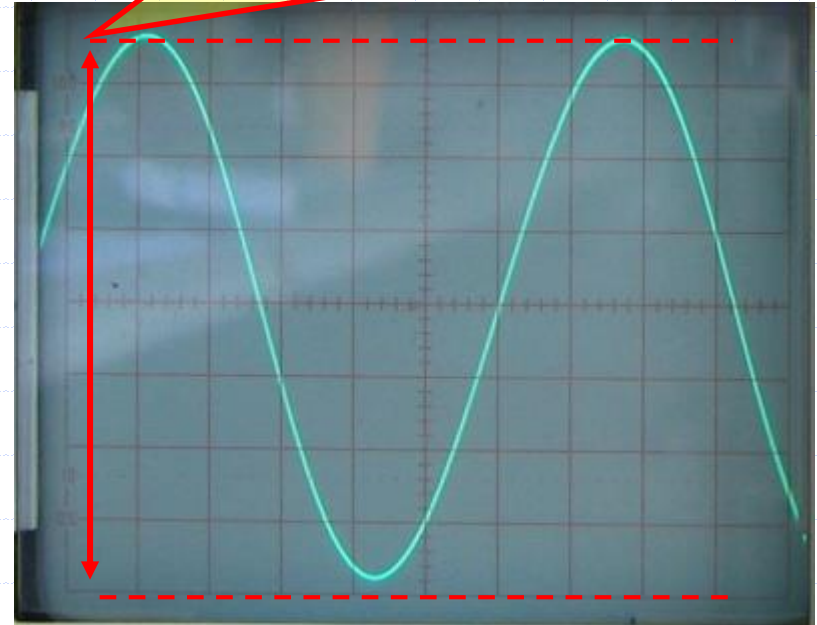
✓ 주파수 : 1.5kHz, 10Vpp

$$V_{R(rms)} = 2.061V$$

$$V_{R(p-p)} = 2.061V \times 2 \times 1.414 \\ = 5.829V_{pp}$$



$$V_c : 7.2\text{칸} \times 1V/DIV = 7.2V_{pp}$$

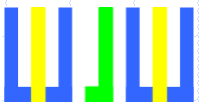


1V/DIV, 20uS/DIV

$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{5.829V}{1k\Omega} = 5.829mA$$

$$X_c(\text{실험}) = \frac{V_c}{I} = \frac{7.2V_{pp}}{5.829mA} = 1235.2\Omega$$

$$|Z|(\text{실험}) = \frac{V_s}{I} = \frac{10V_{pp}}{5.829mA} = 1715.56\Omega$$



# 10-4. 주파수에 따른 임피던스

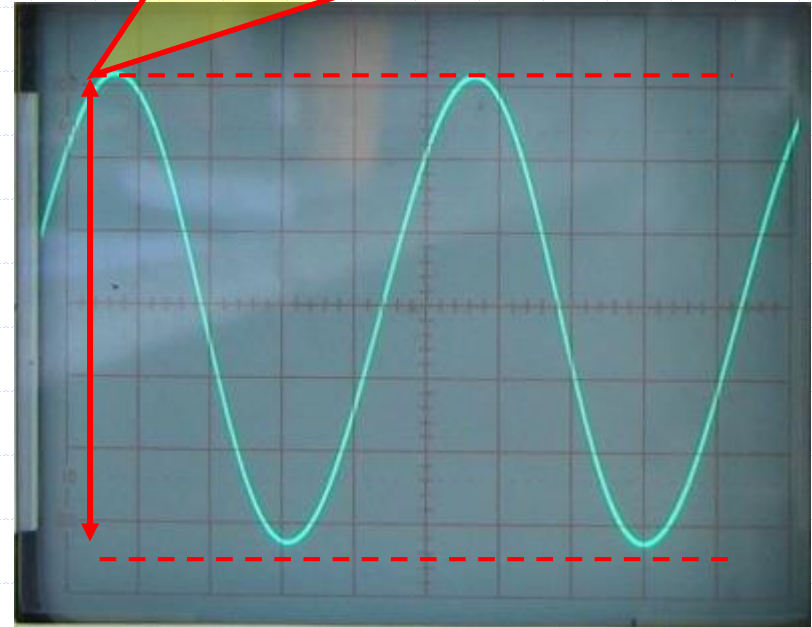
✓ 주파수 : 2kHz, 10Vpp

$$V_{R(rms)} = 2.393V$$

$$V_{R(p-p)} = 2.393V \times 2 \times 1.414 = 6.767V_{pp}$$



$$V_c : 6.4칸 \times 1V/DIV = 6.4V_{pp}$$

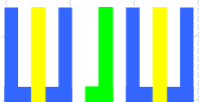


1V/DIV, 20uS/DIV

$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{6.767V}{1k\Omega} = 6.767mA$$

$$X_c(\text{실험}) = \frac{V_c}{I} = \frac{6.4V_{pp}}{6.767mA} = 945.77\Omega$$

$$|Z|(\text{실험}) = \frac{V_s}{I} = \frac{10V_{pp}}{6.767mA} = 1477.76\Omega$$





# 10-4. 주파수에 따른 임피던스

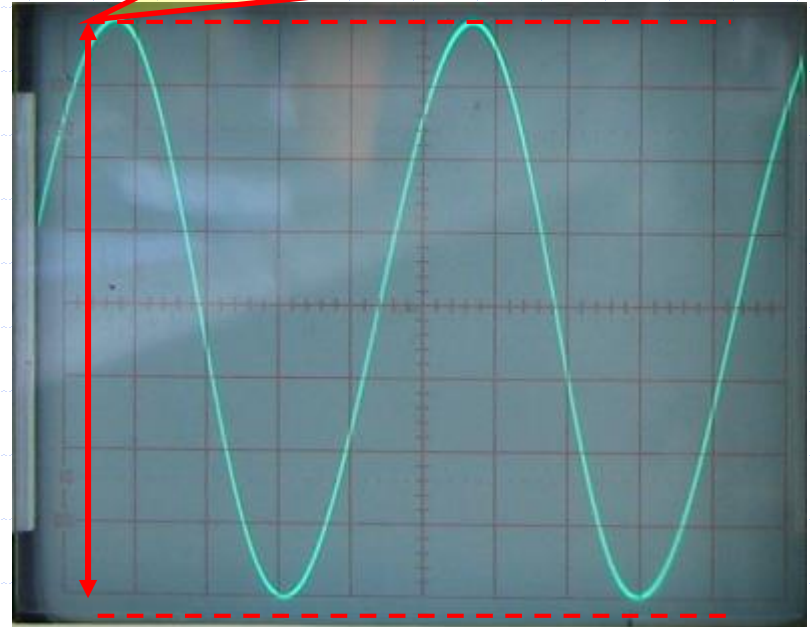
✓ 주파수 : 4kHz, 10Vpp

$$V_{R(rms)} = 2.855V$$

$$V_{R(p-p)} = 2.855V \times 2 \times 1.414 \\ = 8.074V_{pp}$$



$$V_c : 7.9\text{칸} \times 0.5V/DIV = 3.95V_{pp}$$

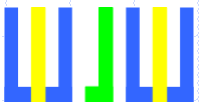


1V/DIV, 20uS/DIV

$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{8.074V}{1k\Omega} = 8.074mA$$

$$X_c(\text{실험}) = \frac{V_c}{I} = \frac{3.95V_{pp}}{8.074mA} = 489.22\Omega$$

$$|Z|(\text{실험}) = \frac{V_s}{I} = \frac{10V_{pp}}{8.074mA} = 1238.54\Omega$$



# 10-4. 주파수에 따른 임피던스

✓ 주파수 : 8kHz, 10Vpp

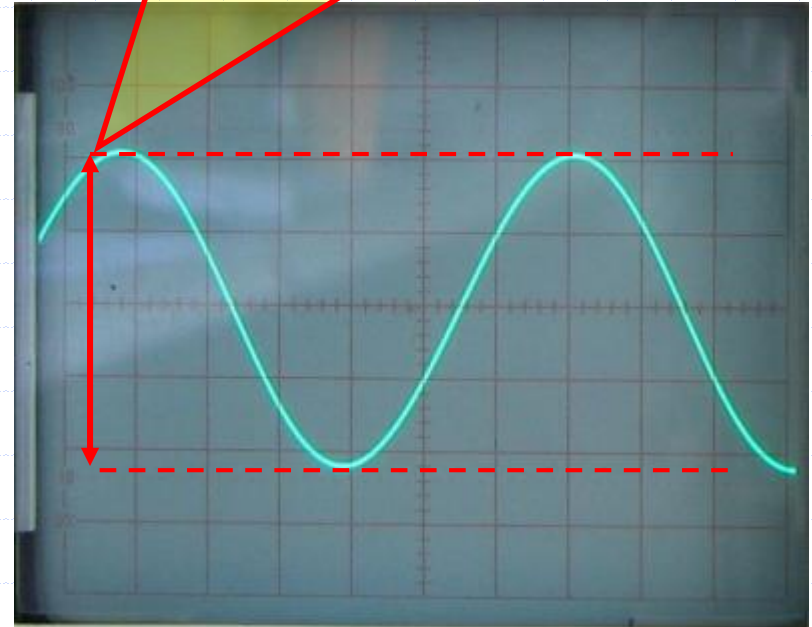
$$V_{R(rms)} = 2.925V$$

$$V_{R(p-p)} = 2.925V \times 2 \times 1.414$$

$$= 8.272V_{pp}$$



$$V_C : 4.2\text{칸} \times 0.5V/DIV = 2.1V_{pp}$$

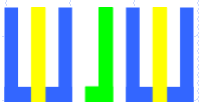


0.5V/DIV, 20uS/DIV

$$I_T(\text{실험}) = \frac{V_R}{R} = \frac{8.272V}{1k\Omega} = 8.272mA$$

$$X_C(\text{실험}) = \frac{V_C}{I} = \frac{2.1V_{pp}}{8.272mA} = 253.87\Omega$$

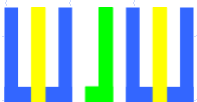
$$|Z|(\text{실험}) = \frac{V_S}{I} = \frac{10V_{pp}}{8.272mA} = 1208.90\Omega$$





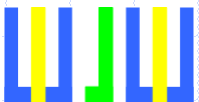
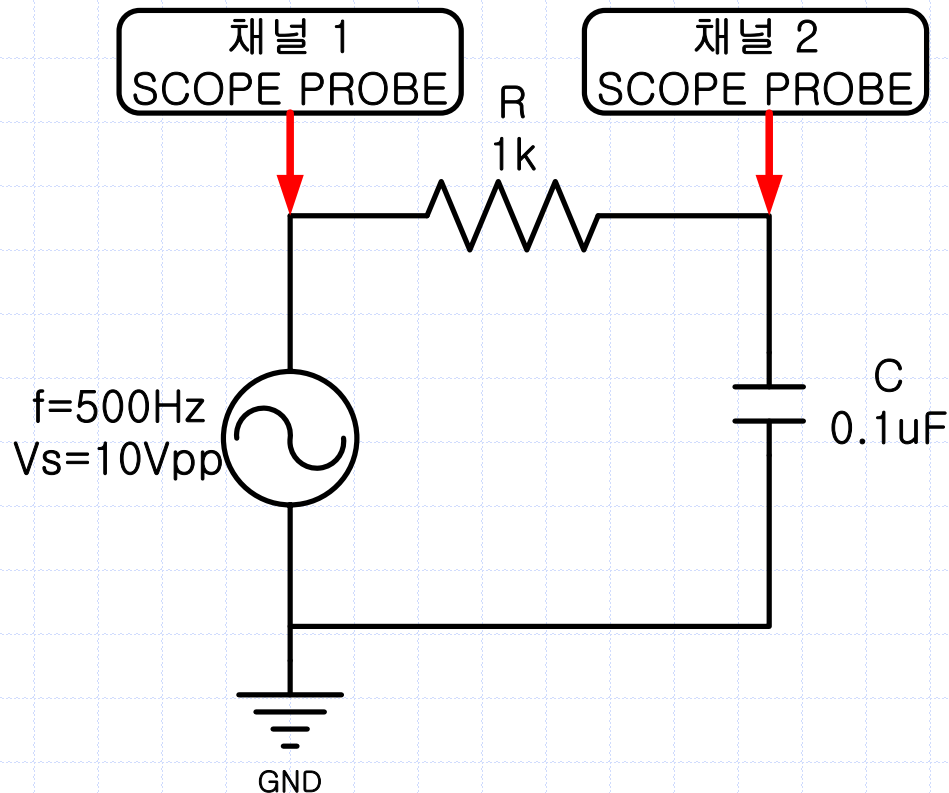
# 10-4. 주파수에 따른 임피던스

주파수	VR (Vpp)		Vc (Vpp)		I (mA)		Xc (Ω)		Z  (Ω)	
	이론	실험	이론	실험	이론	실험	이론	실험	이론	실험
500	3.00	2.525	9.54	9.60	3.00	2.525	3183.10	3801.98	3336.00	4060.40
1,000	5.32	4.482	8.47	8.40	5.32	4.482	1591.55	1784.16	1880.00	2231.15
1,500	6.86	5.829	7.28	7.20	6.86	5.829	1061.03	1235.20	1458.00	1715.56
2,000	7.83	6.767	6.23	6.40	7.83	6.767	795.77	945.77	1278.00	1477.76
4,000	9.29	8.074	3.70	3.95	9.29	8.074	397.89	489.22	1076.00	1238.54
8,000	9.80	8.272	1.95	2.10	9.80	8.272	198.94	253.87	1020.00	1208.90

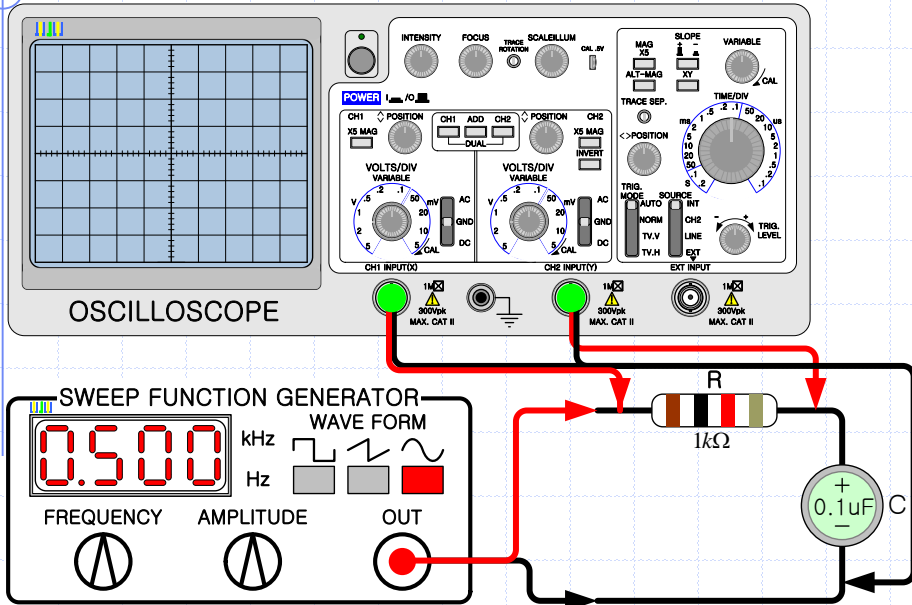


## 10-5. 위상의 변화

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



# 10-5. 위상의 변화



$f=500\text{Hz}$ ,  $V_s=10\text{Vpp}$

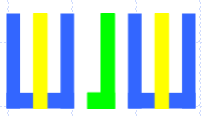
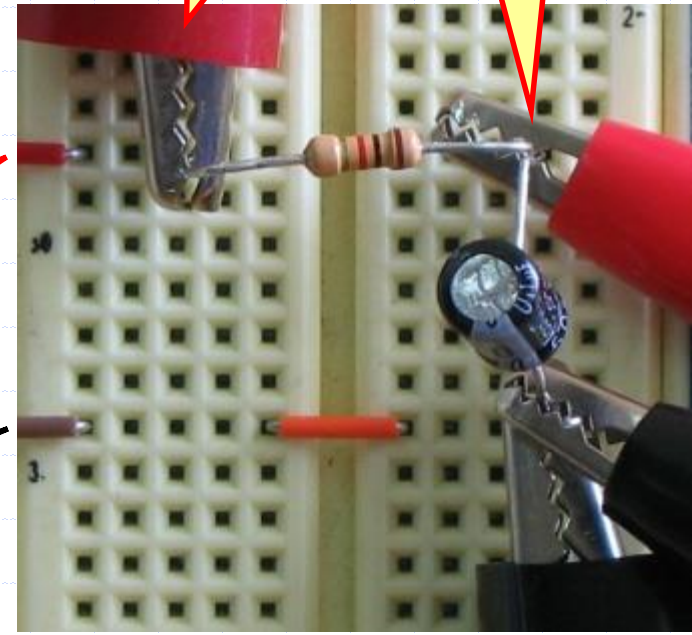
신호발생기  
Function Generator

정현파  
500Hz  
10Vpp

GND

CH 1

CH 2



# 10-5. 위상의 변화

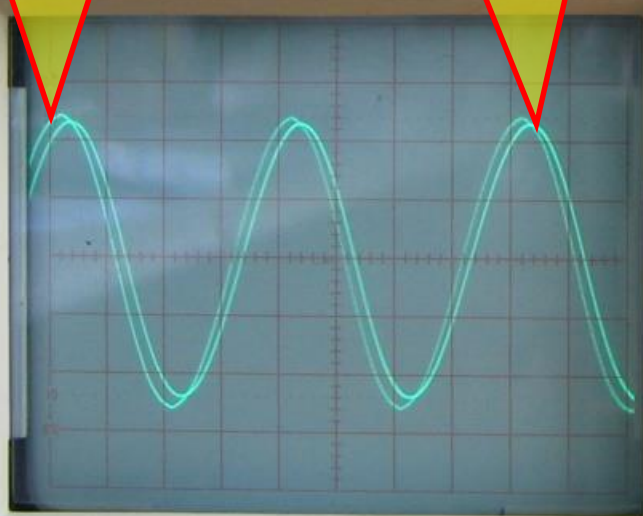
500Hz



10Vpp

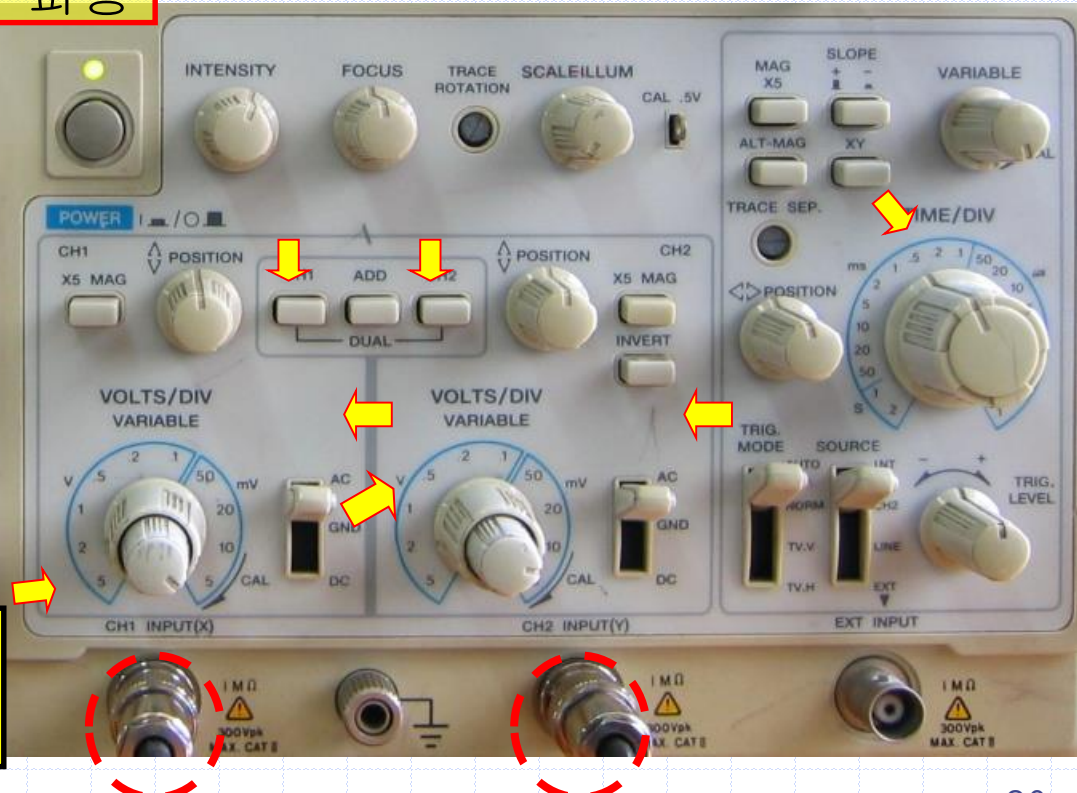
CH 1 : 전압 파형

CH 2 : 전압 파형



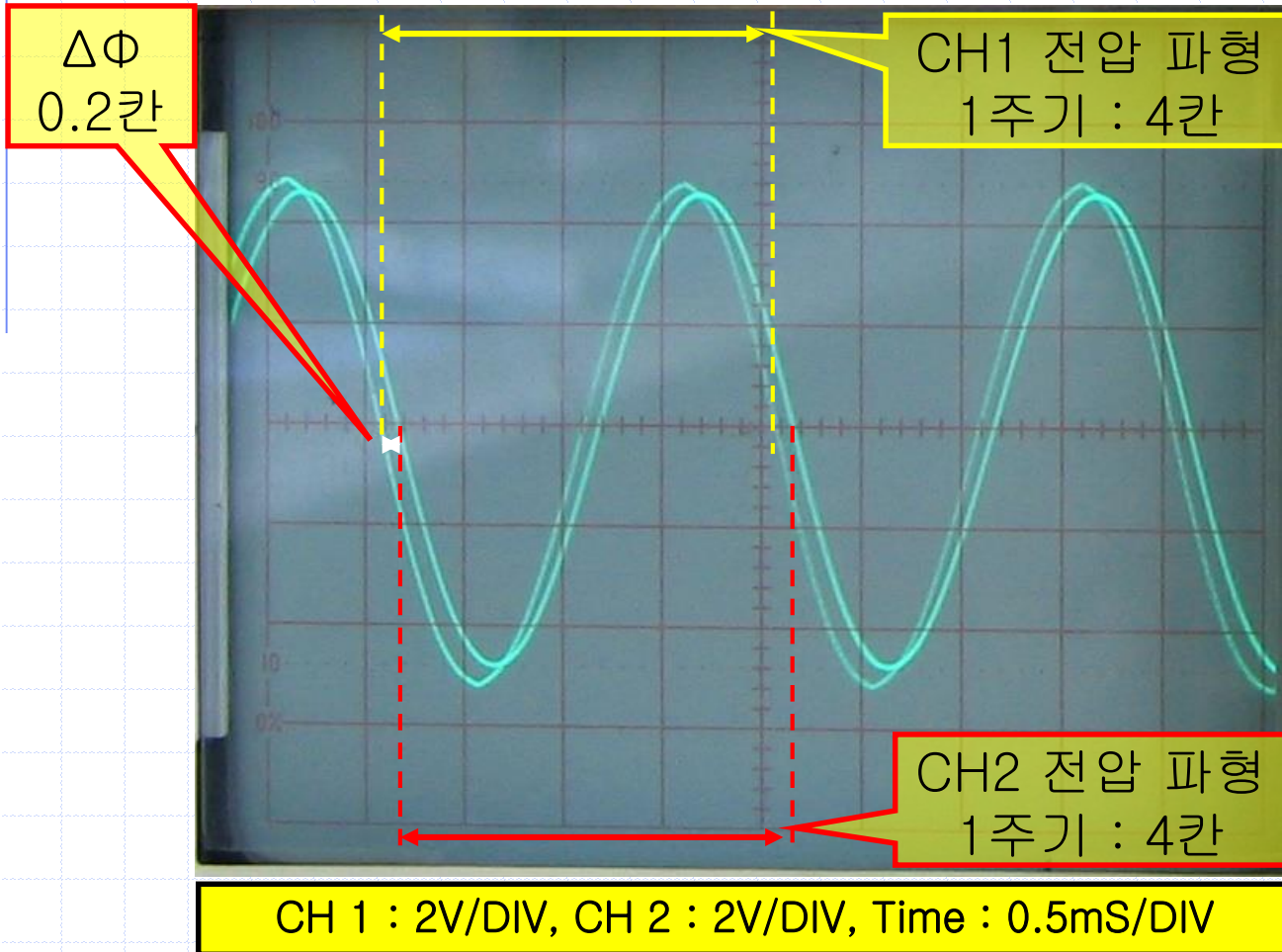
CH 1 : 2V/DIV, CH 2 : 2V/DIV

Time : 0.5mS/DIV



# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 500Hz)

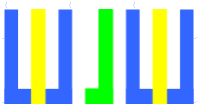


$$1T = 4\text{칸} \times 0.5\text{mSec} = 2\text{mSec}$$

$$\Delta t = 0.2\text{칸} \times 0.5\text{mSec} = 0.1\text{mSec}$$

$$2\text{mSec} : 0.1\text{mSec} = 360^\circ : \Delta\theta$$

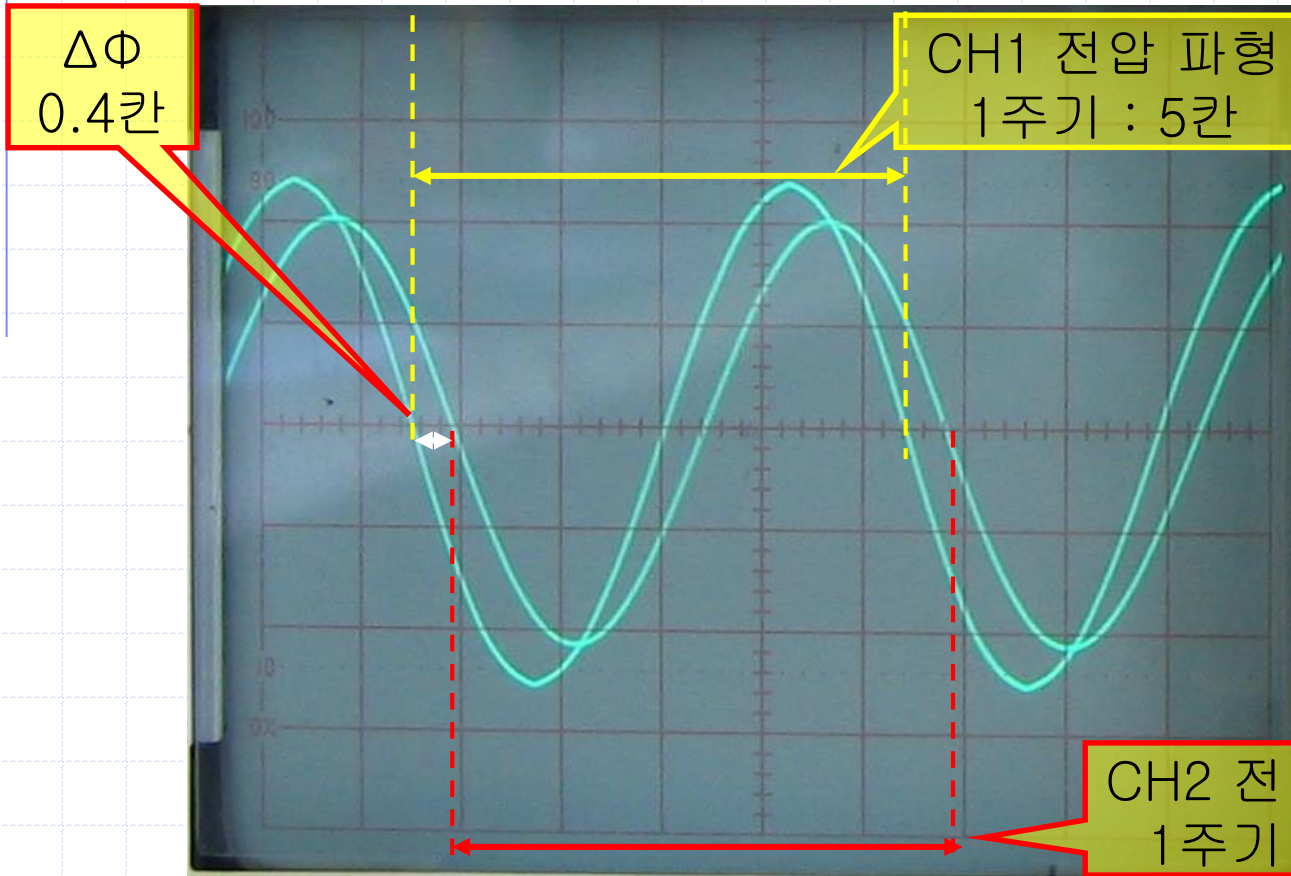
$$\Delta\theta = 18^\circ$$





# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 1kHz)



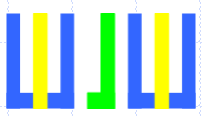
$$1T = 5\text{칸} \times 0.2\text{mSec} = 1\text{mSec}$$

$$\Delta t = 0.4\text{칸} \times 0.2\text{mSec} = 0.08\text{mSec}$$

$$1\text{mSec} : 0.08\text{mSec} = 360^\circ : \Delta\theta$$

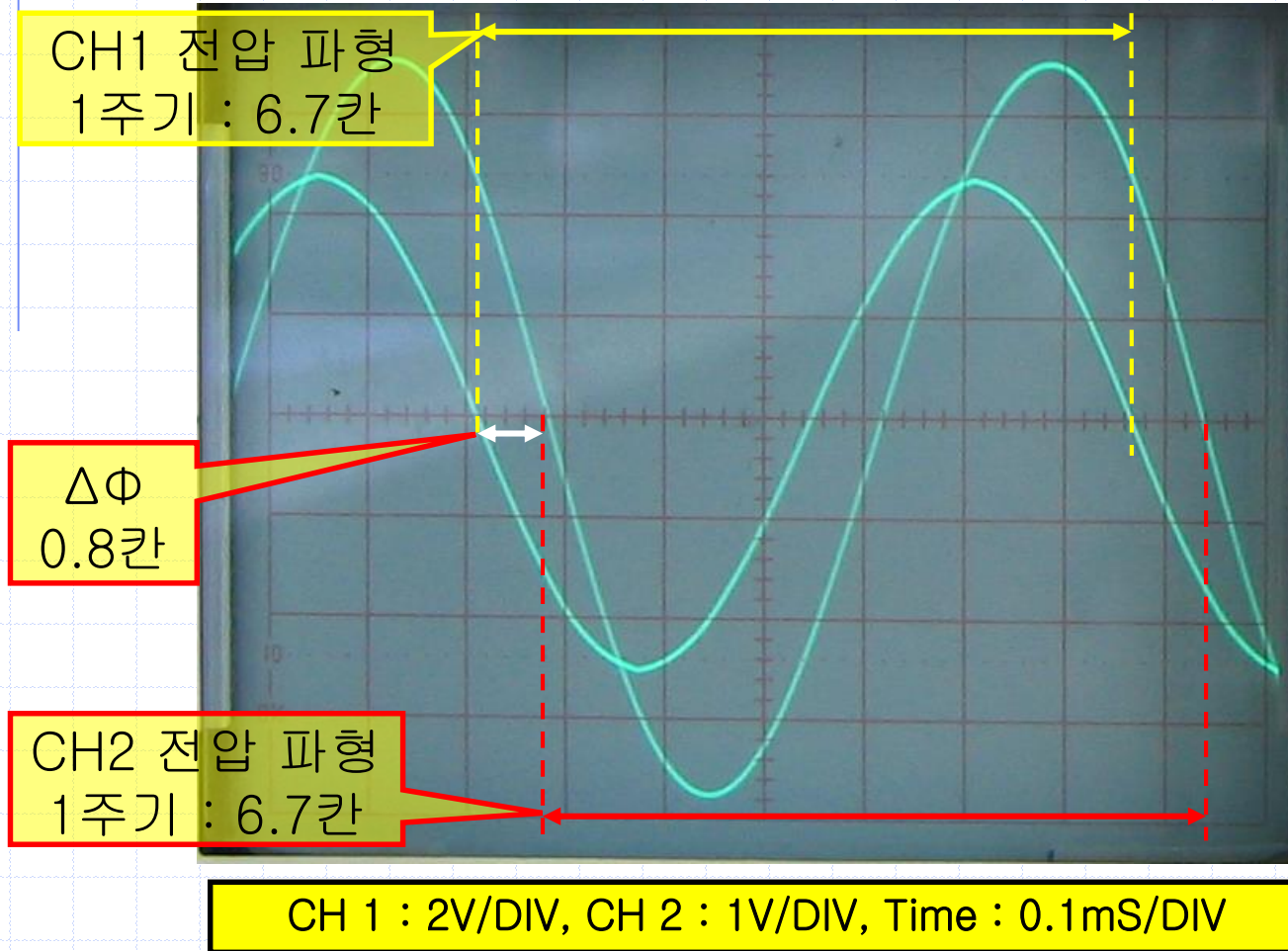
$$\Delta\theta = 28.8^\circ$$

CH 1 : 2V/DIV, CH 2 : 2V/DIV, Time : 0.2mS/DIV



# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 1.5kHz)

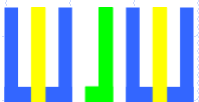


$$1T = 6.7\text{칸} \times 0.1\text{mSec} \\ = 0.67\text{mSec}$$

$$\Delta t = 0.8\text{칸} \times 0.1\text{mSec} \\ = 0.08\text{mSec}$$

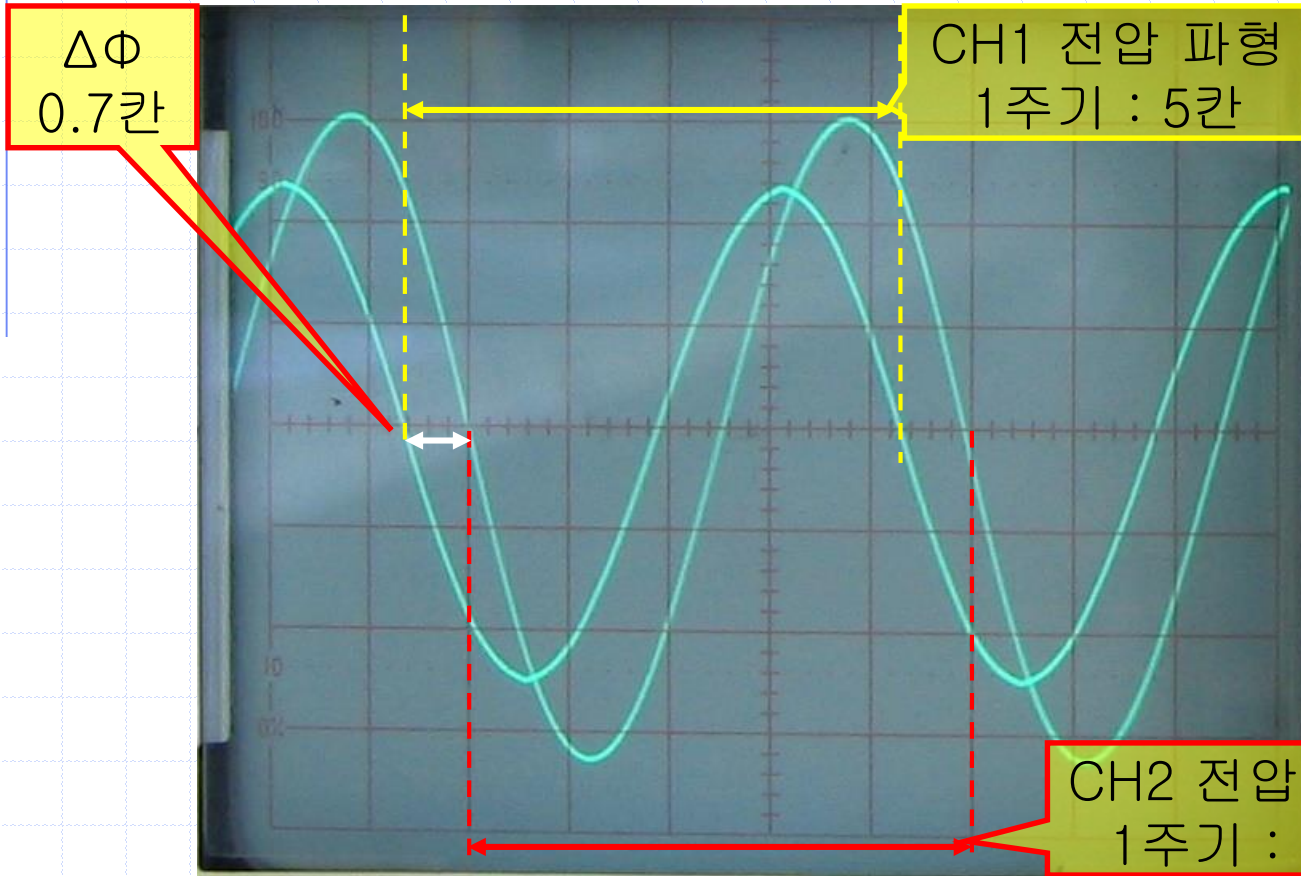
$$0.67\text{mSec} : 0.08\text{mSec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 42.99^\circ$$



# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 2kHz)



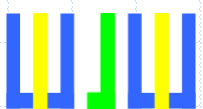
$$1T = 5\text{칸} \times 0.1\text{mSec} = 0.5\text{mSec}$$

$$\Delta t = 0.7\text{칸} \times 0.1\text{mSec} = 0.07\text{mSec}$$

$$0.5\text{mSec} : 0.07\text{mSec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 50.4^\circ$$

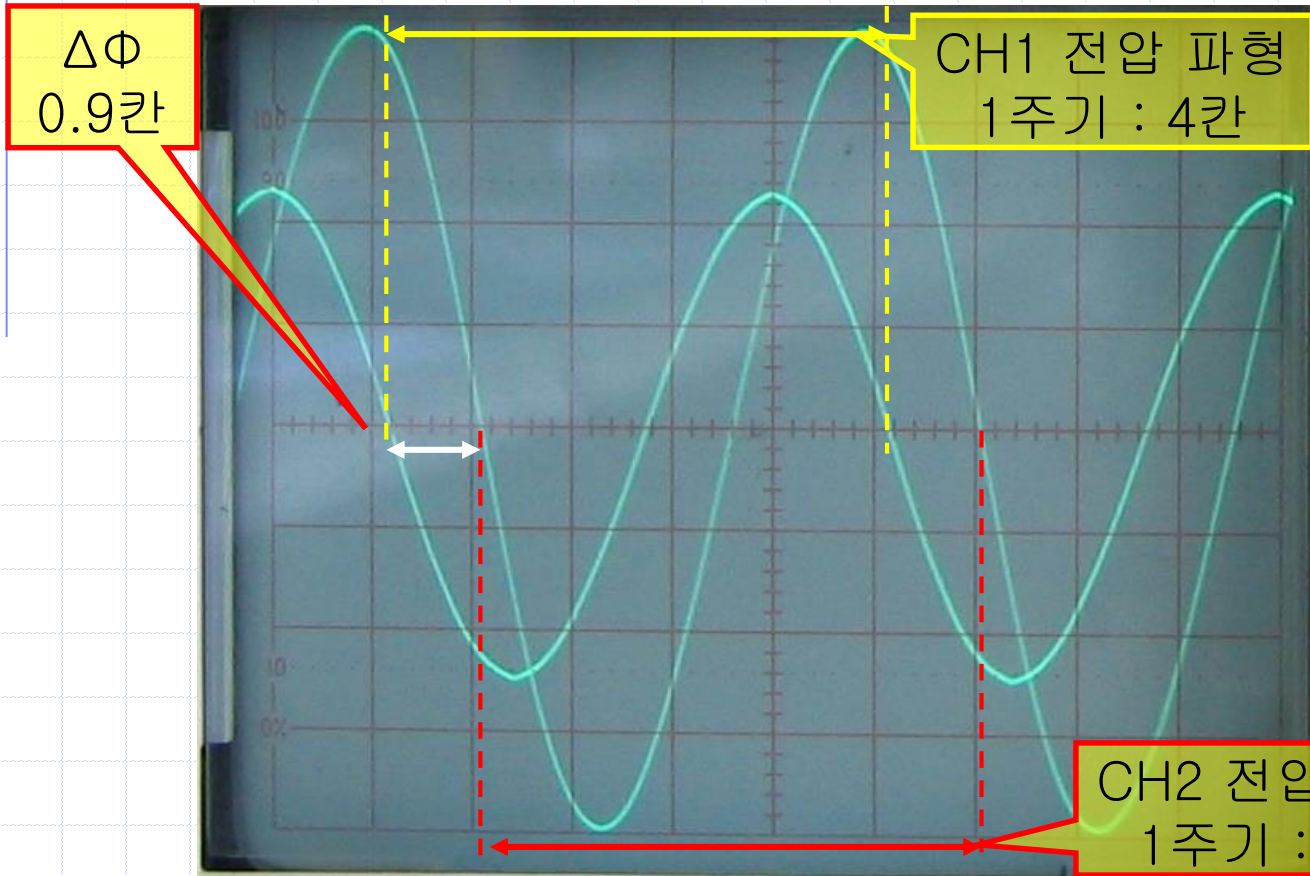
CH 1 : 2V/DIV, CH 2 : 1V/DIV, Time : 0.1mS/DIV





# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 4kHz)



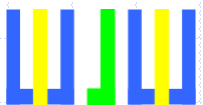
$$1T = 5\text{칸} \times 50\mu\text{Sec} = 250\mu\text{Sec}$$

$$\Delta t = 0.9\text{칸} \times 50\mu\text{Sec} = 45\mu\text{Sec}$$

$$250\mu\text{Sec} : 45\mu\text{Sec} = 360^\circ : \Delta\theta$$

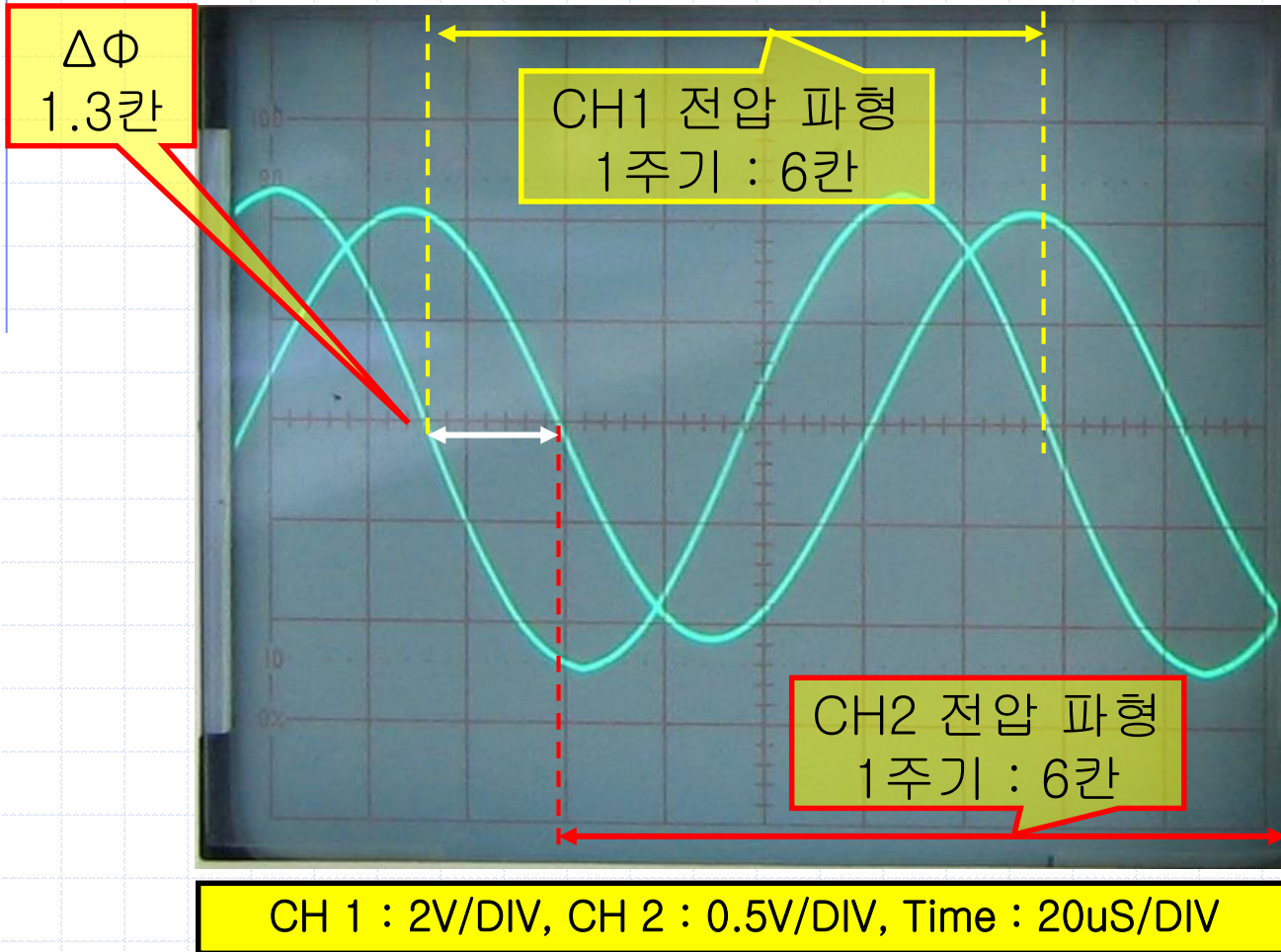
$$\Delta\theta = 64.8^\circ$$

CH 1 : 2V/DIV, CH 2 : 0.5V/DIV, Time : 50uS/DIV



# 10-5. 위상의 변화

✓ 위상차를 측정하라. (주파수 : 8kHz)

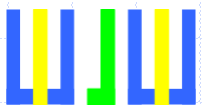


$$1T = 6\text{칸} \times 20\mu\text{Sec} = 120\mu\text{Sec}$$

$$\Delta t = 1.3\text{칸} \times 20\mu\text{Sec} = 26\mu\text{Sec}$$

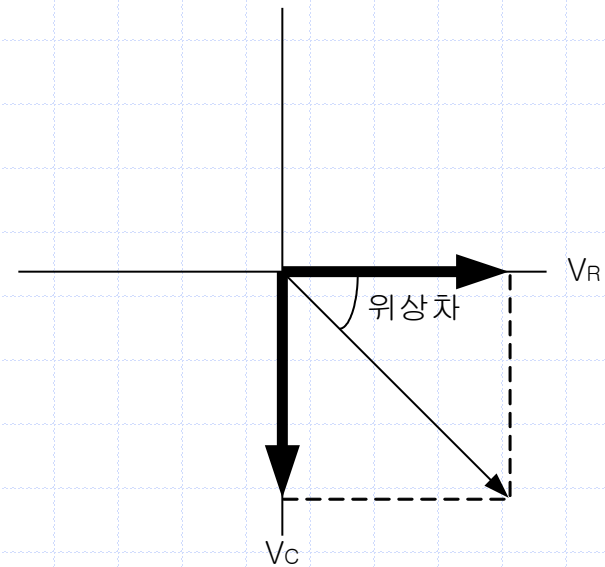
$$120\mu\text{Sec} : 26\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 77.9^\circ$$



# 10-5. 위상의 변화

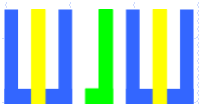
주파수	위상차 (도)		
	실험 9.	실험 10.	계산값
500 Hz	-72.0	-72.9	-72.6
1 kHz	-61.2	-59.2	-57.9
1.5 kHz	-47.0	-48.4	-46.7
2 kHz	-39.6	-41.6	-38.5
4 kHz	-25.2	-24.7	-21.7
8 kHz	-12.1	-13.1	-11.3



$$\text{위상차(실험10.)} = -\tan^{-1}\left(\frac{V_C}{V_R}\right)$$

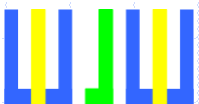
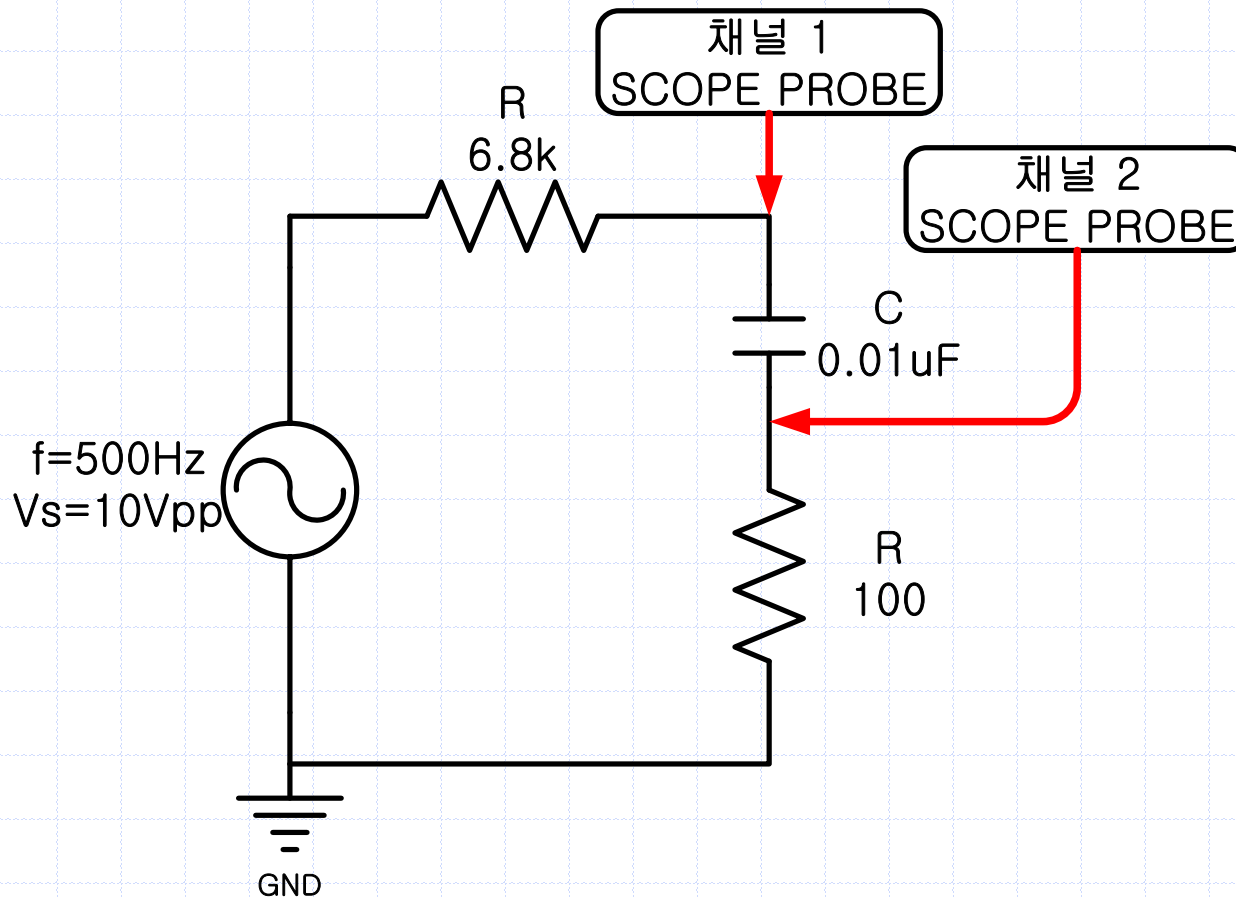
$$\text{위상차(계산값)} = -\tan^{-1}\left(\frac{X_C}{R}\right)$$

$$X_C = \frac{1}{2\pi fC}$$

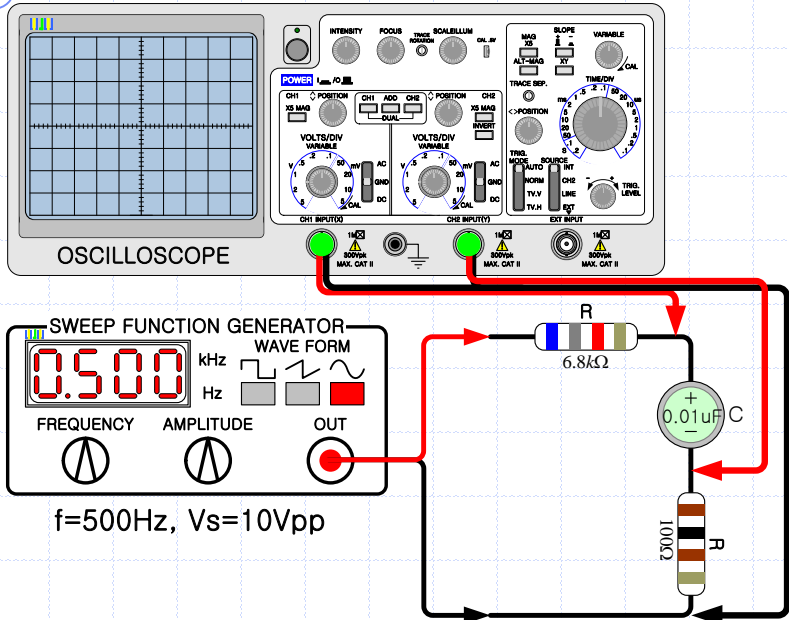


## 10-6. 전압과 전류의 위상

- 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 500Hz, 10Vpp의 정현파가 나오도록 한다.



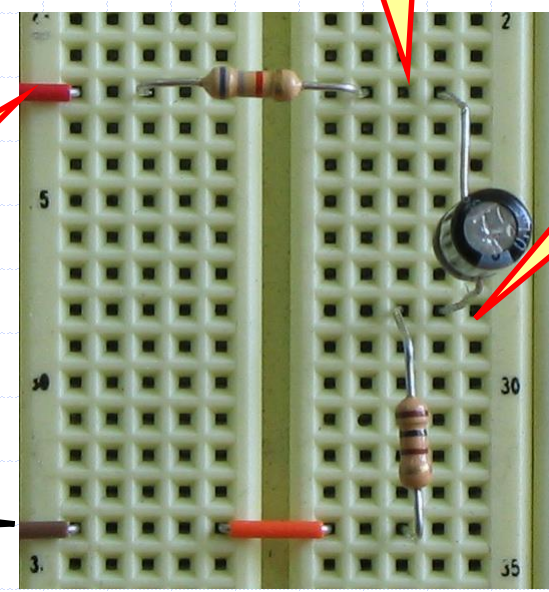
# 10-6. 전압과 전류의 위상



신호발생기  
Function Generator

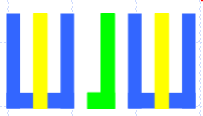
정현파  
500Hz  
10Vpp

GND



CH 1

CH 2





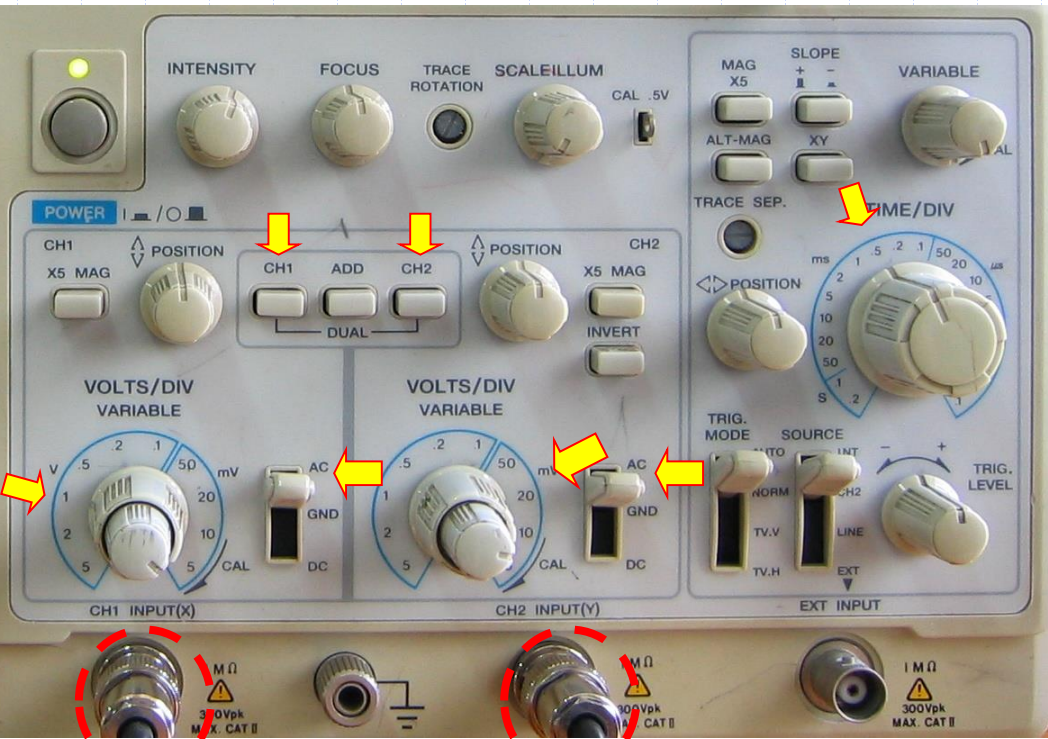
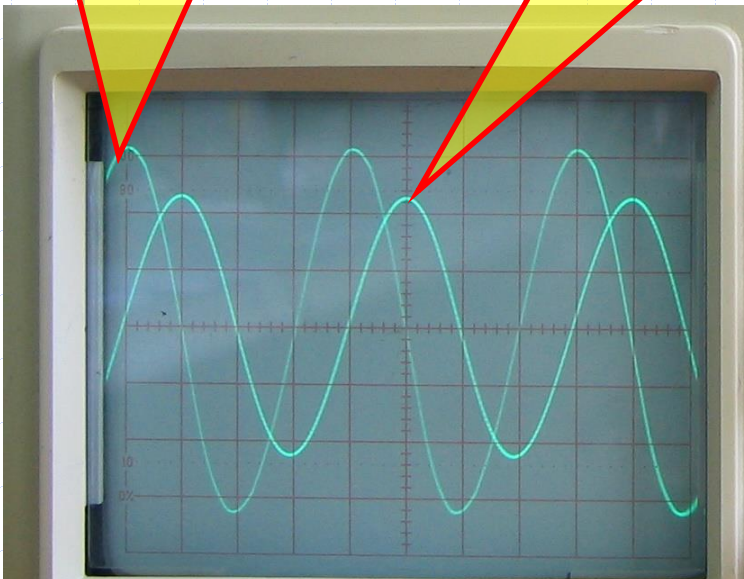
# 10-6. 전압과 전류의 위상

500Hz



10Vpp

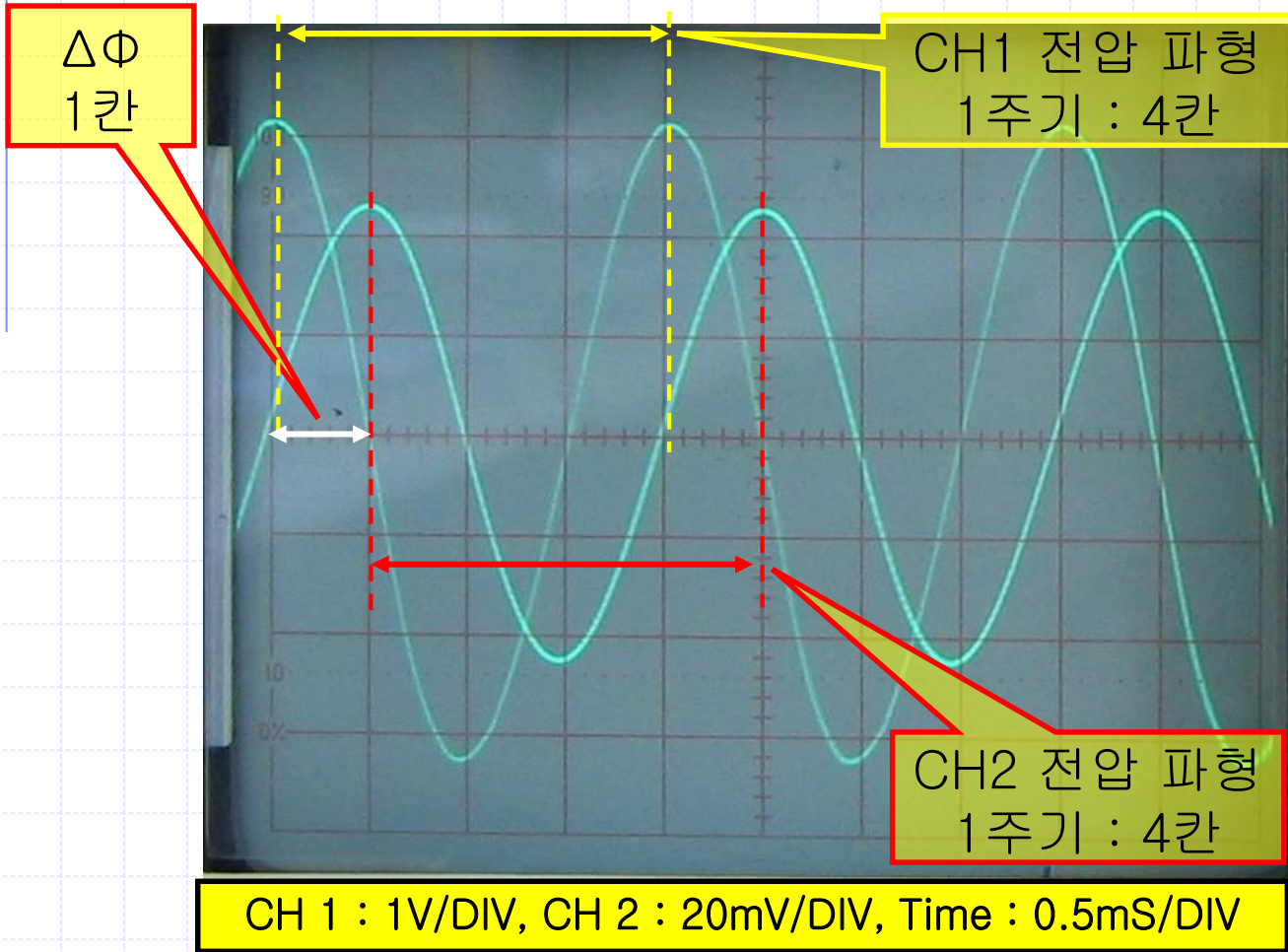
CH 1 : 전압 파형    CH 2 : 전압 파형



CH 1 : 1V/DIV, CH 2 : 20mV/DIV  
Time : 0.5mS/DIV

# 10-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 500Hz)

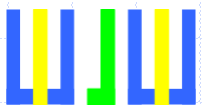


$$1T = 4\text{칸} \times 0.5\text{mSec} = 2\text{mSec}$$

$$\Delta t = 1\text{칸} \times 0.5\text{mSec} = 0.5\text{mSec}$$

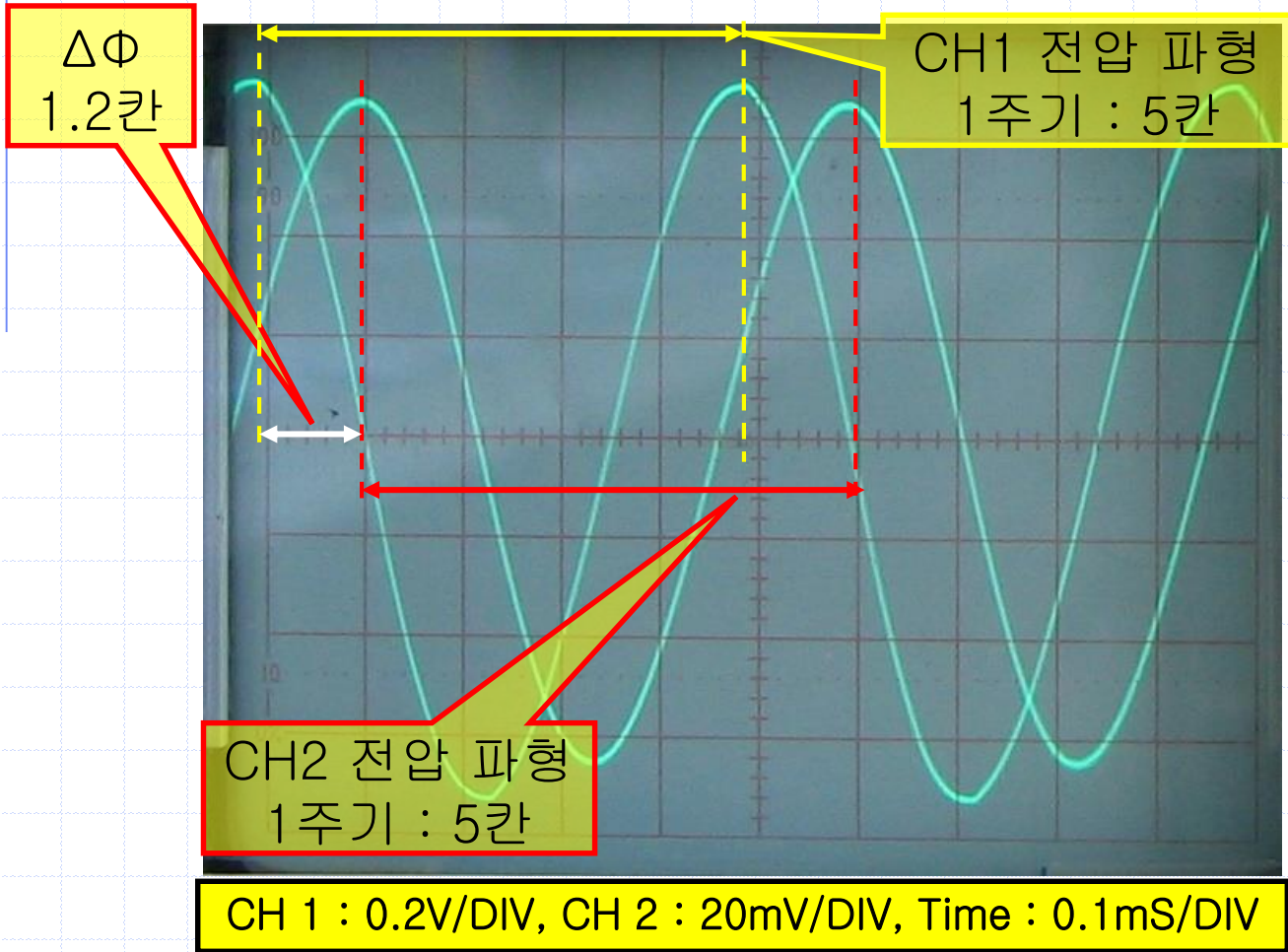
$$2\text{mSec} : 0.5\text{mSec} = 360^\circ : \Delta\theta$$

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



# 10-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 2kHz)

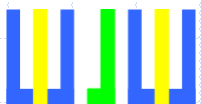


$$1T = 5\text{칸} \times 0.1\text{mSec} = 0.5\text{mSec}$$

$$\Delta t = 1.2\text{칸} \times 0.1\text{mSec} = 0.12\text{mSec}$$

$$0.5\text{mSec} : 0.12\text{mSec} = 360^\circ : \Delta\theta$$

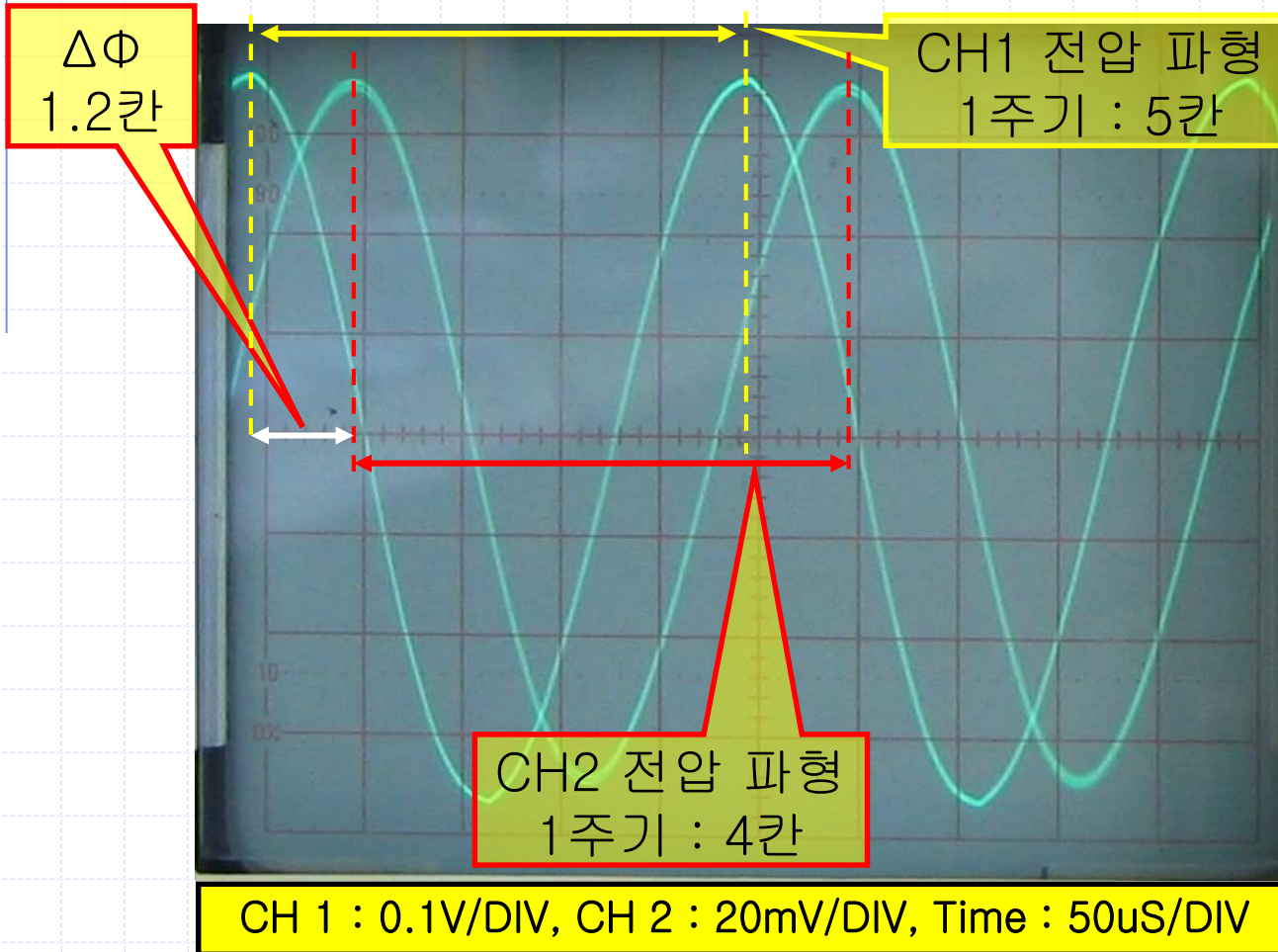
$$\Delta\theta = 86.4^\circ$$





# 10-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 4kHz)

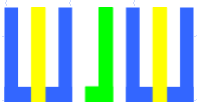


$$1T = 5\text{칸} \times 50\mu\text{Sec} = 250\mu\text{Sec}$$

$$\Delta t = 1.2\text{칸} \times 50\mu\text{Sec} = 60\mu\text{Sec}$$

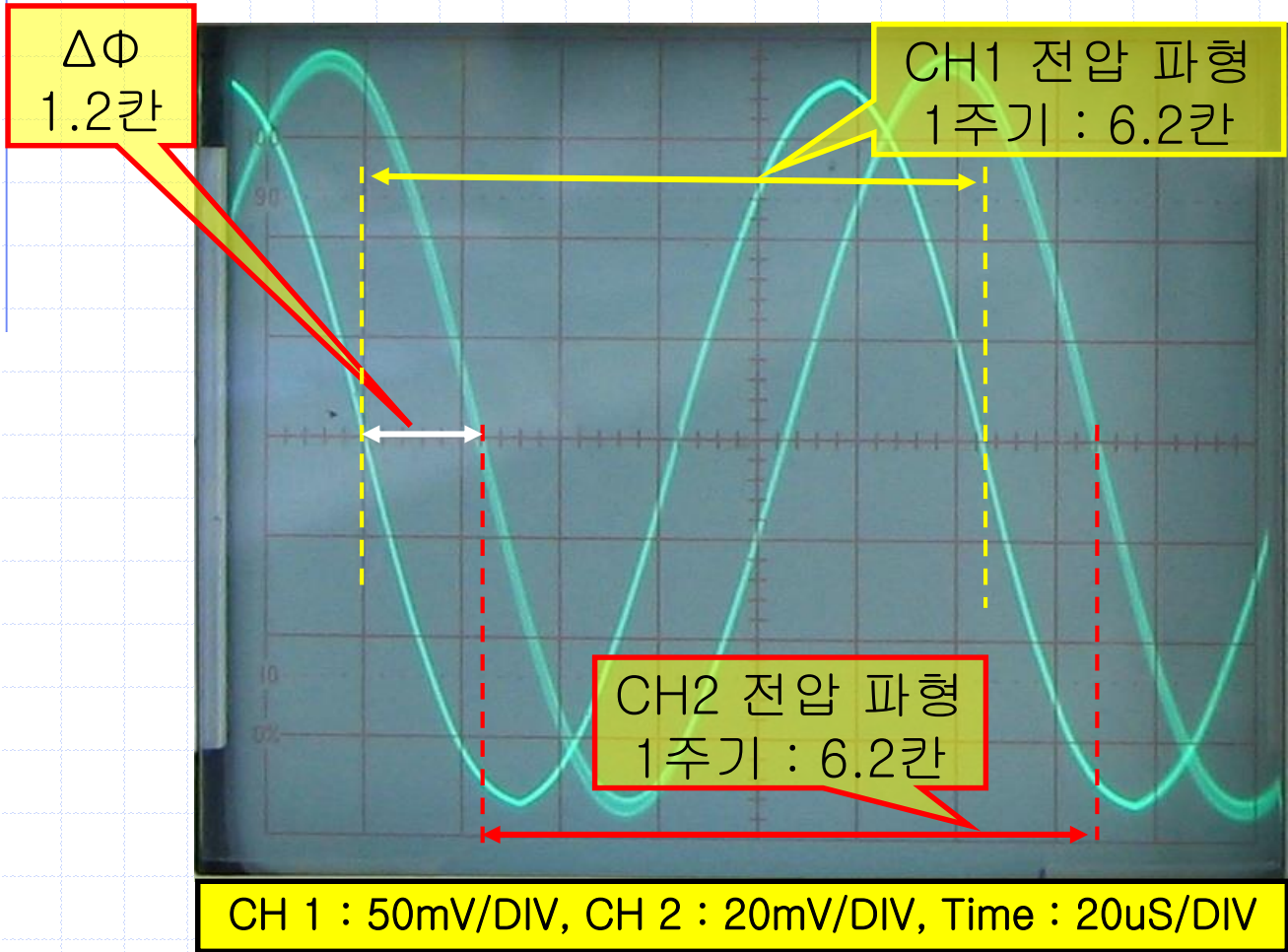
$$250\mu\text{Sec} : 60\mu\text{Sec} = 360^\circ : \Delta\theta$$

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



# 10-6. 전압과 전류의 위상

✓ 위상차를 측정하라. (주파수 : 8kHz)

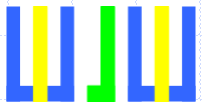


$$1T = 6.2\text{칸} \times 20\mu\text{Sec} = 124\mu\text{Sec}$$

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

$$124\mu\text{Sec} : 24\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 69.7^\circ$$



# 10-6. 전압과 전류의 위상

주파수	실험 9.	계산값
500 Hz	90.0 도	90 도
2 kHz	86.4 도	90 도
4 kHz	86.4 도	90 도
8 kHz	69.7도	90 도

