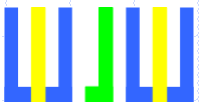


회로 이론/실습

15. 병렬 공진 회로



15. 병렬 공진 회로

15-1. 목적 및 배경

15-2. 소요 부품 및 장비

15-3. 유용한 공식

15-4. 주파수에 따른 전압

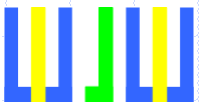
15-5. 공진 주파수

15-6. 주파수에 따른 전류, 임피던스

15-7. 대역폭 측정

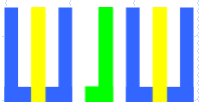
15-8. 주파수에 따른 위상 변화

15-9. 주파수에 따른 전류, 리액턴스



15-1. 목적 및 배경

- ✓ 병렬 공진 회로의 특성을 이해한다.
- ✓ 주파수에 따른 전압, 전류, 위상의 변화를 확인한다.
- ✓ 주파수에 따른 임피던스 변화를 확인한다.



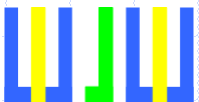
15-2. 소요 부품 및 장비

✓ 부품

- ✓ 저항 (1/4W) : 10Ω , $1k\Omega$
- ✓ 인덕터 : $10mH$
- ✓ 캐패시터 : $0.1\mu F$

✓ 장비

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

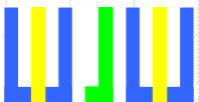


15-3. 유용한 공식

✓ 병렬 공진 회로의 공진 주파수

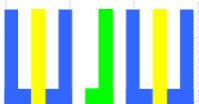
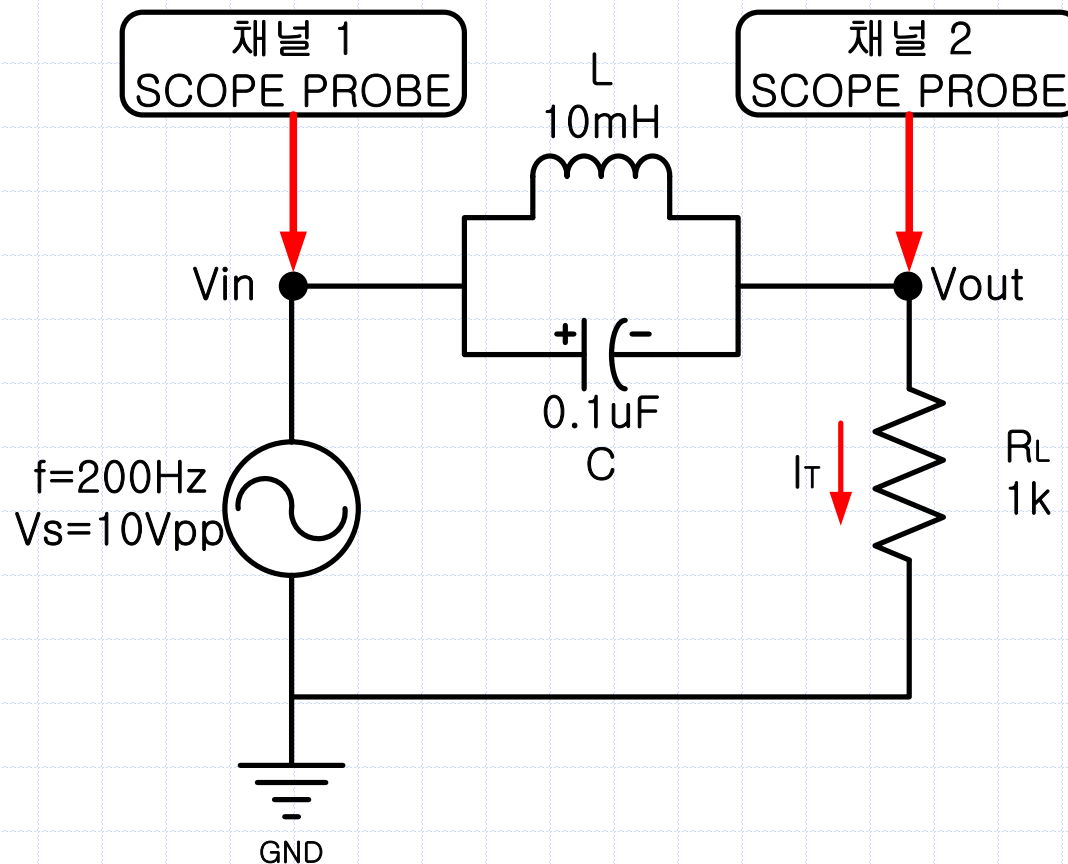
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$A_v(\text{전압이득}) = \frac{V_{out}}{V_{in}}$$



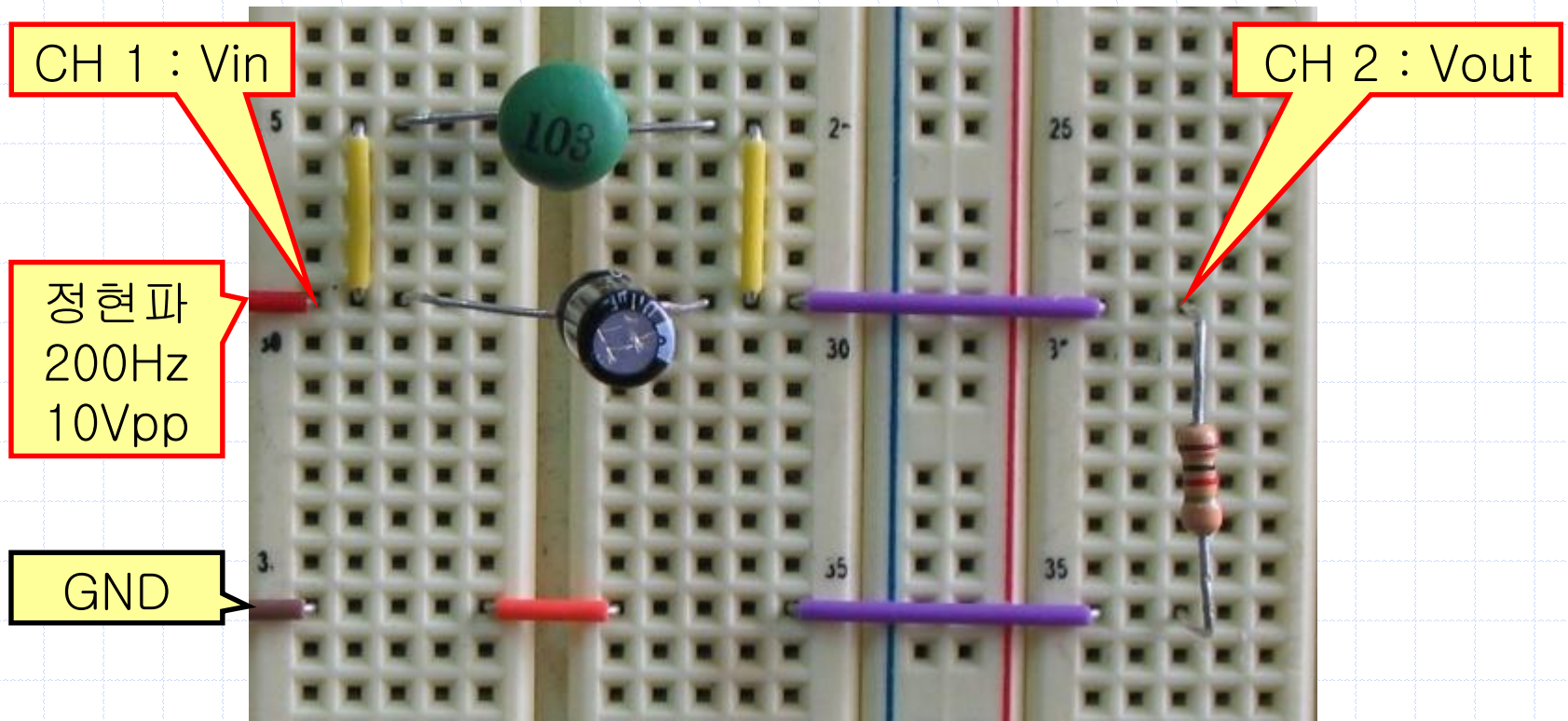
15-4. 주파수에 따른 전압

- 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.

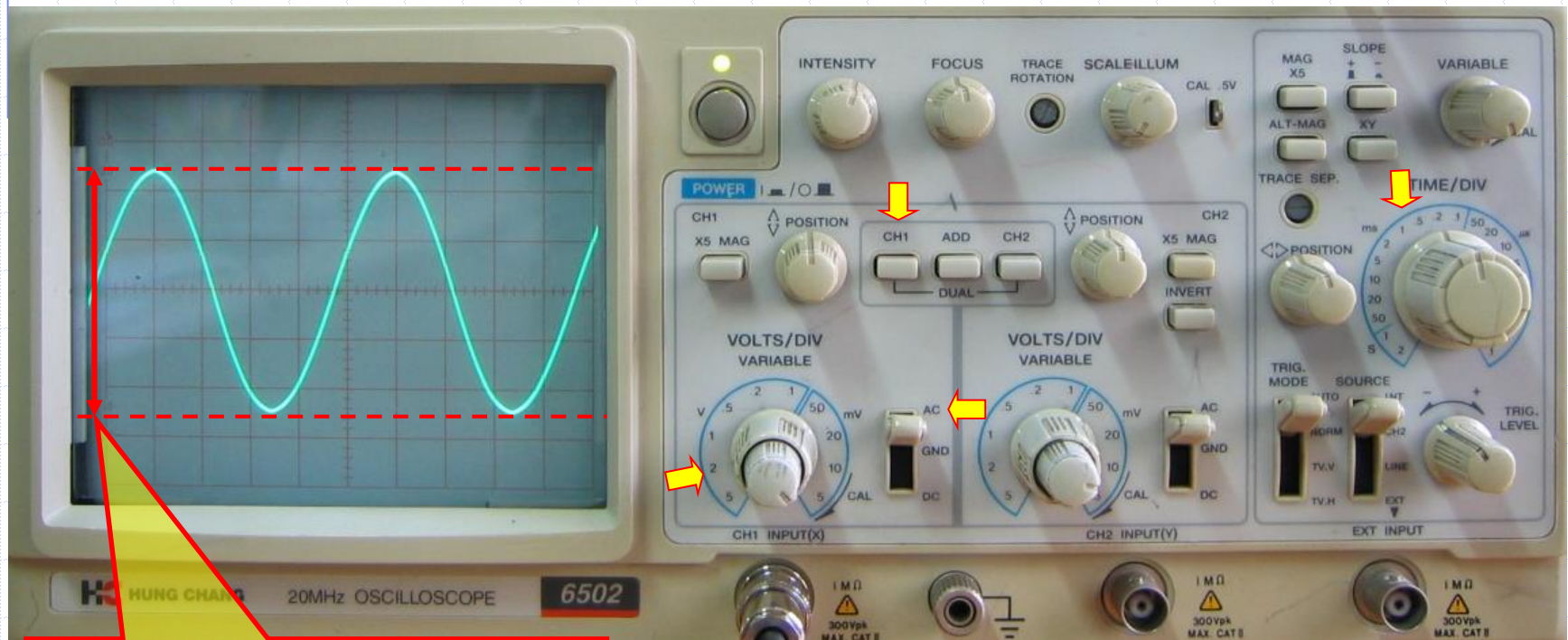
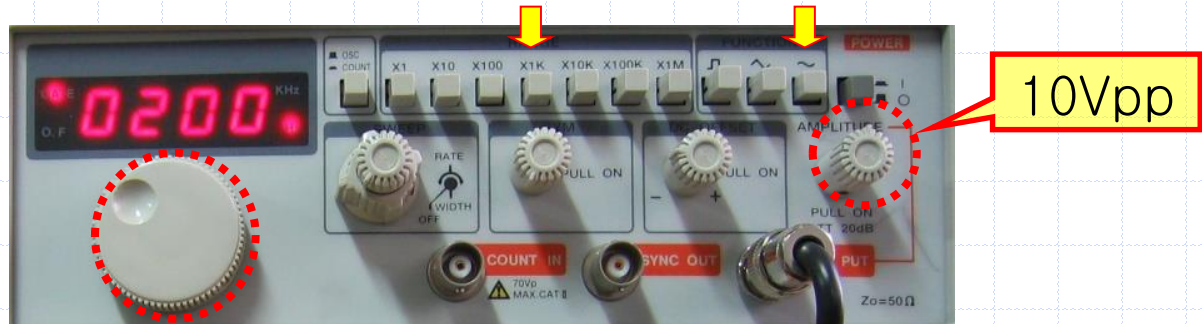


15-4. 주파수에 따른 전압

- ✓ 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.

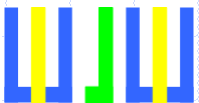
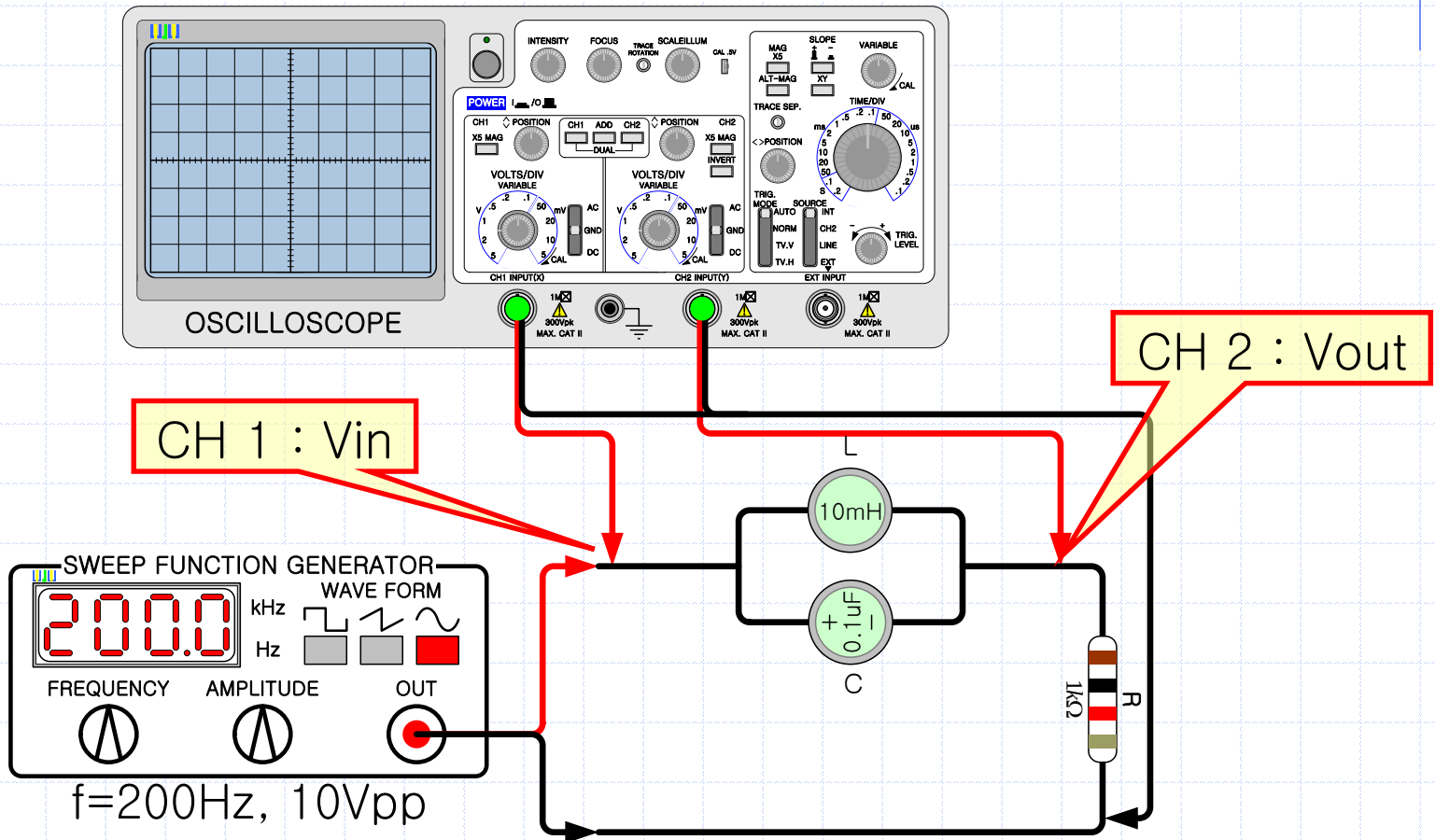


15-4. 주파수에 따른 전압



15-4. 주파수에 따른 전압

- ✓ 오실로스코프의 CH 1 을 이용하여 입력 전압 (V_{in}) 을 측정하고, CH 2 는 출력 전압 (V_{out}) 을 측정한다.



15-4. 주파수에 따른 전압

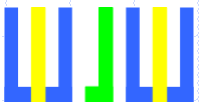
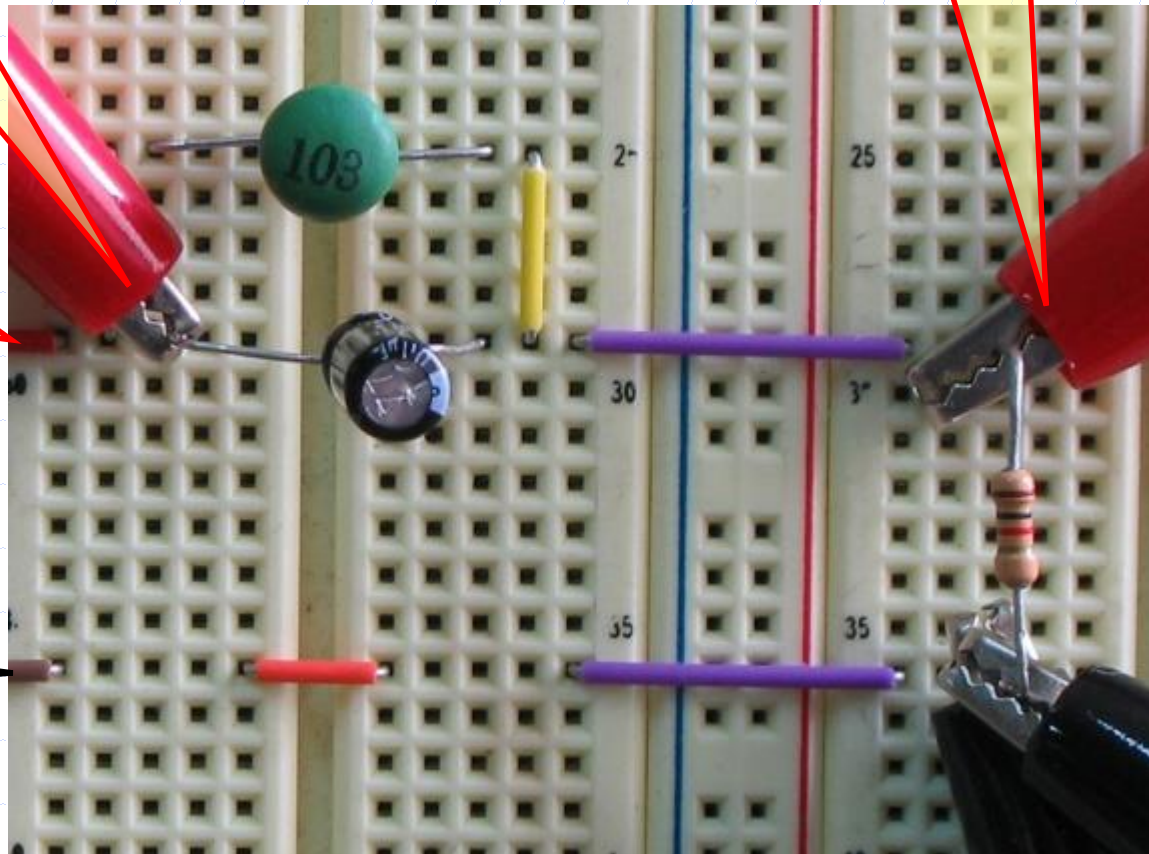
✓ 주파수 : 200Hz

CH 1 : V_{in}

CH 2 : V_{out}

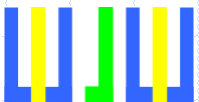
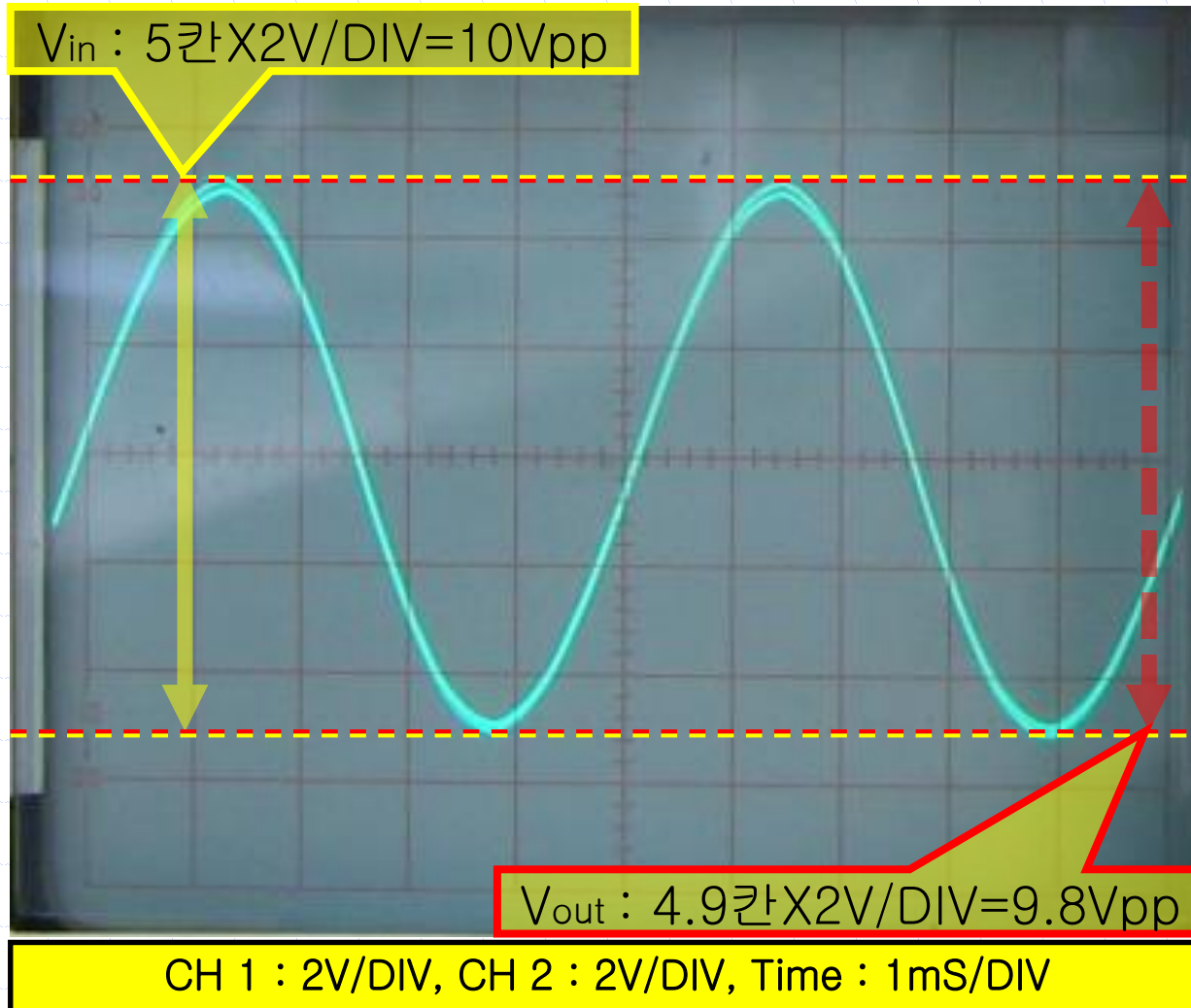
정현파
200Hz
10Vpp

GND



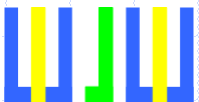
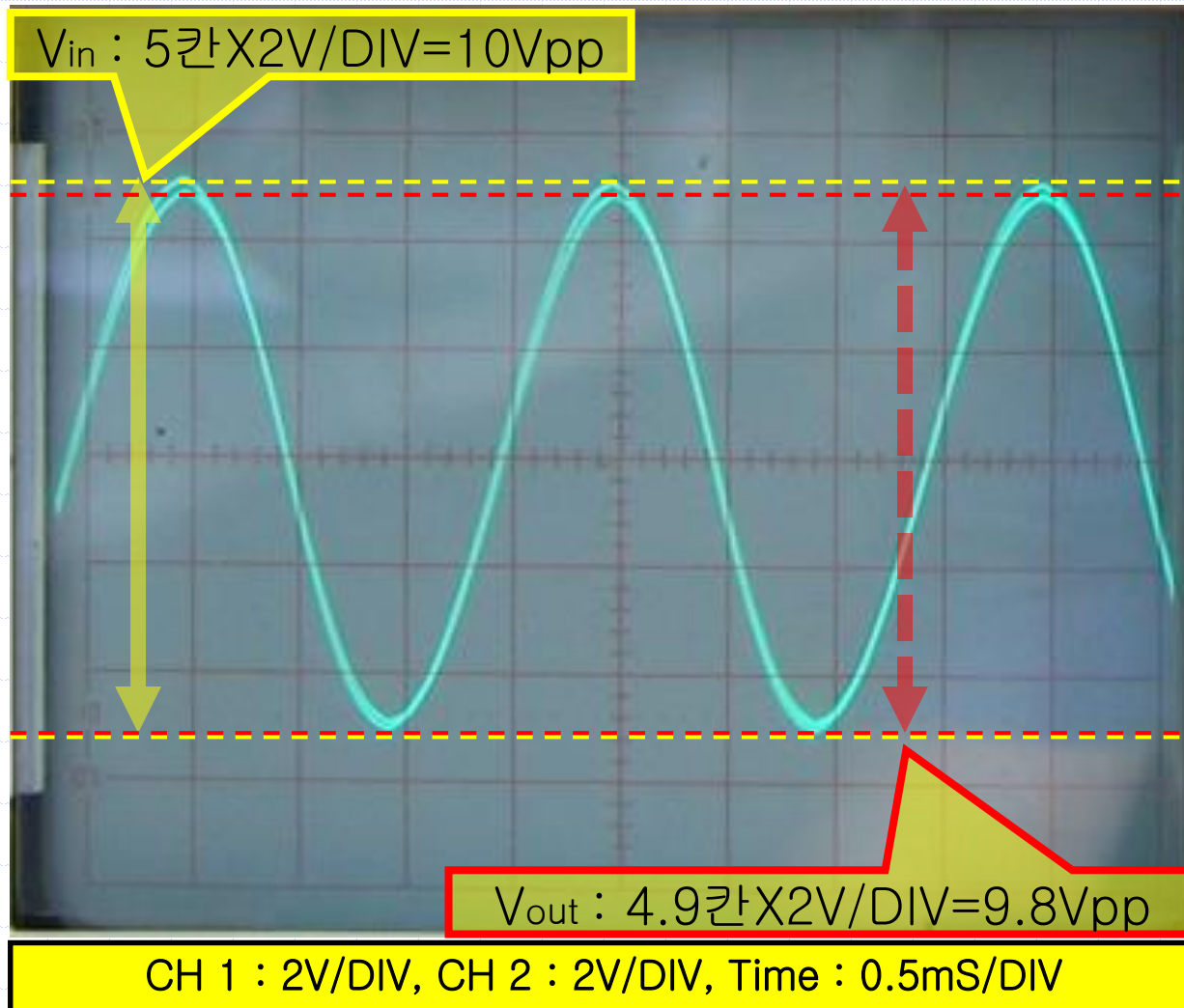
15-4. 주파수에 따른 전압

✓ 주파수 : 200Hz



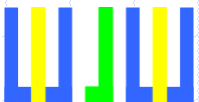
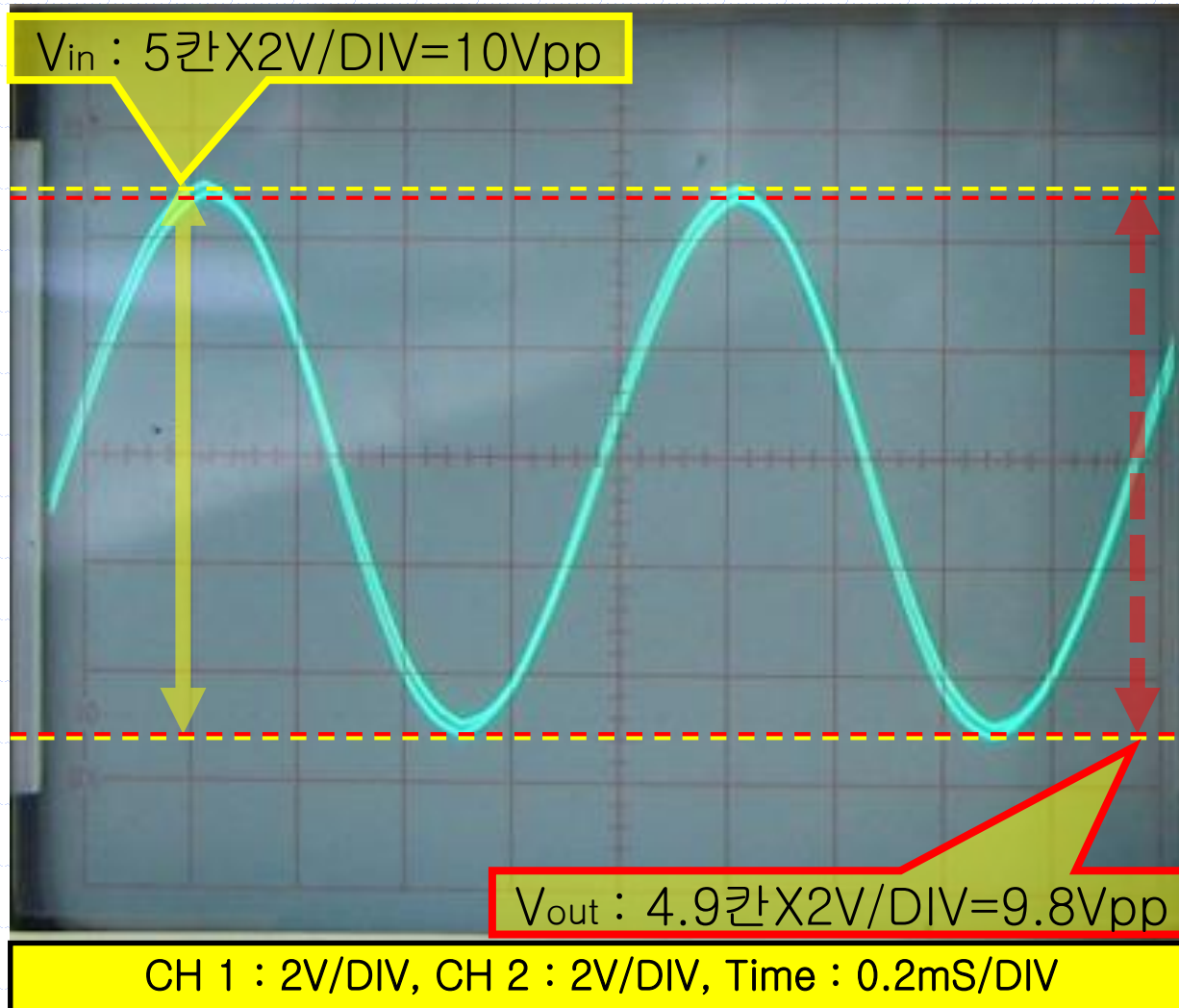
15-4. 주파수에 따른 전압

✓ 주파수 : 500Hz



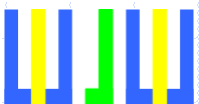
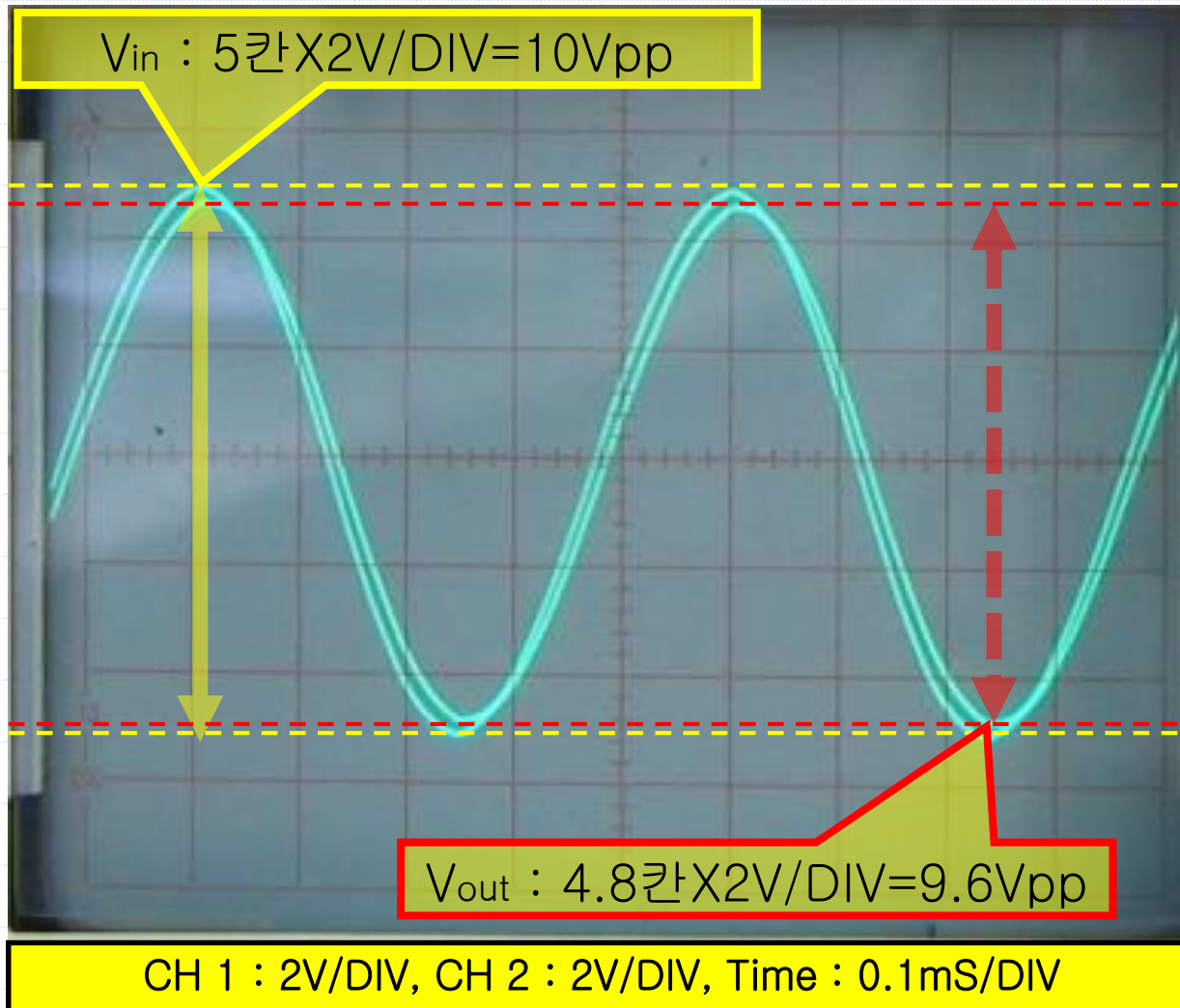
15-4. 주파수에 따른 전압

✓ 주파수 : 1kHz



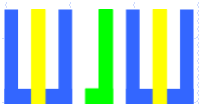
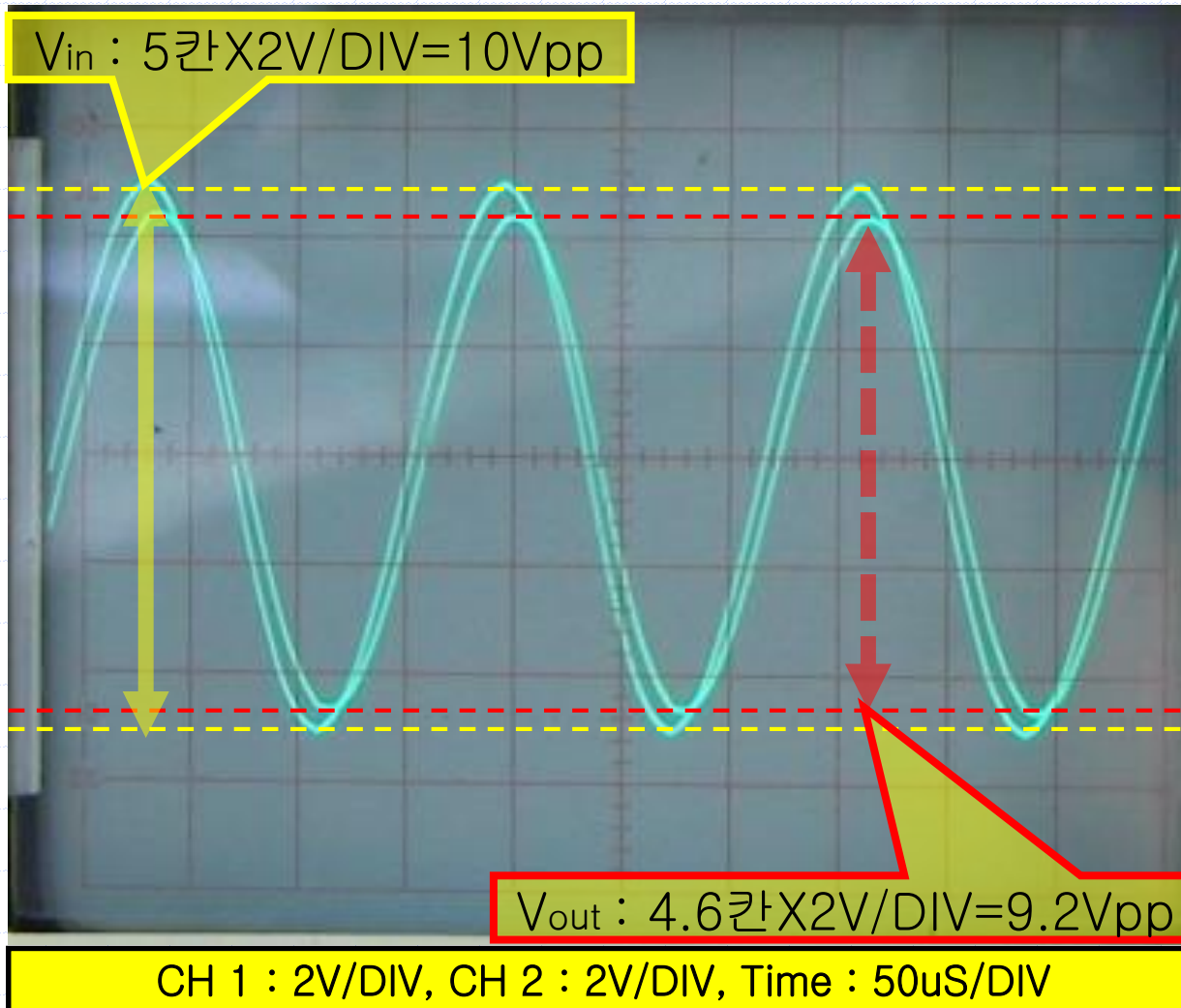
15-4. 주파수에 따른 전압

✓ 주파수 : 2kHz



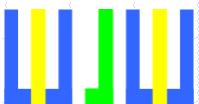
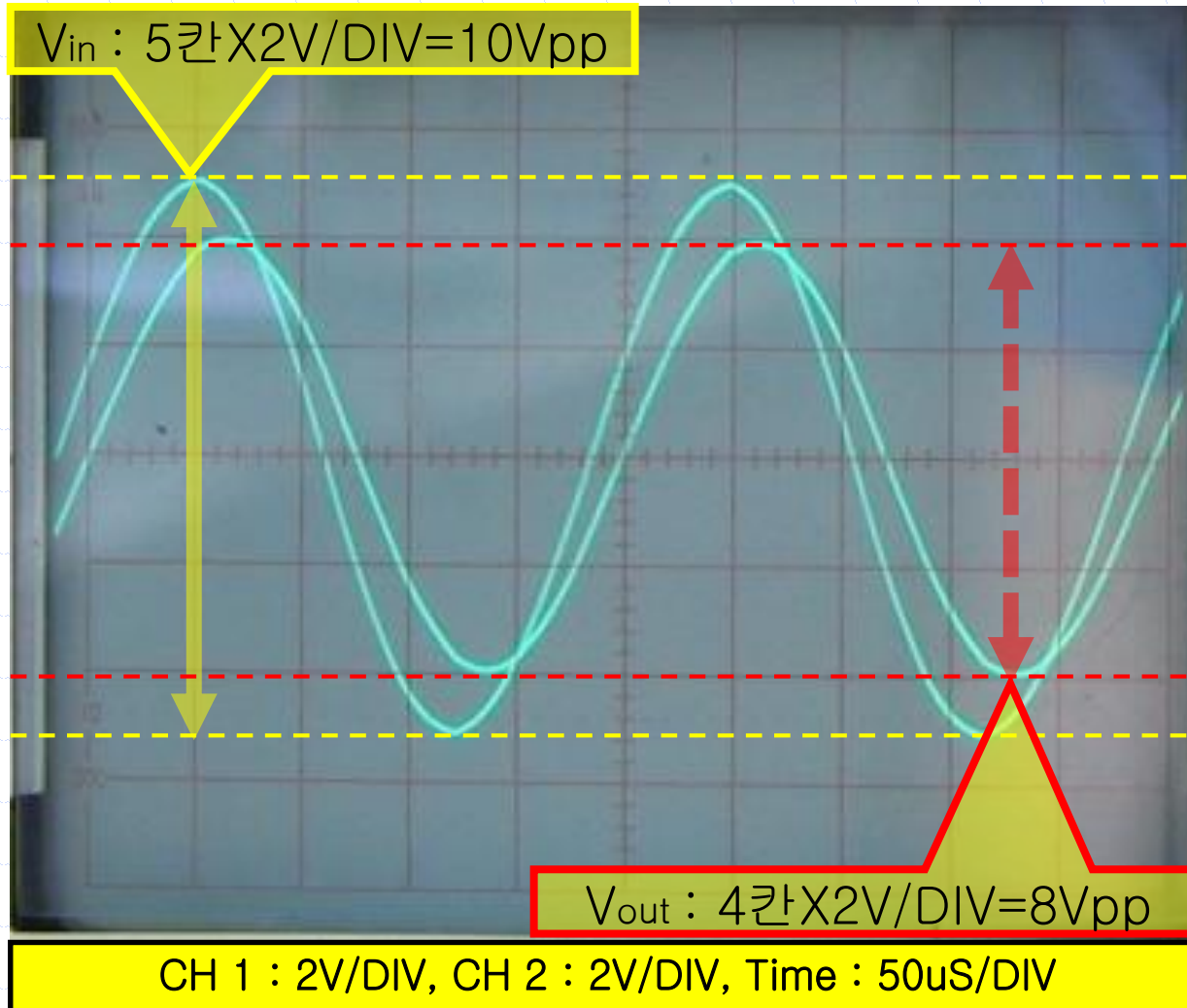
15-4. 주파수에 따른 전압

✓ 주파수 : 3kHz



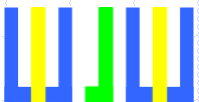
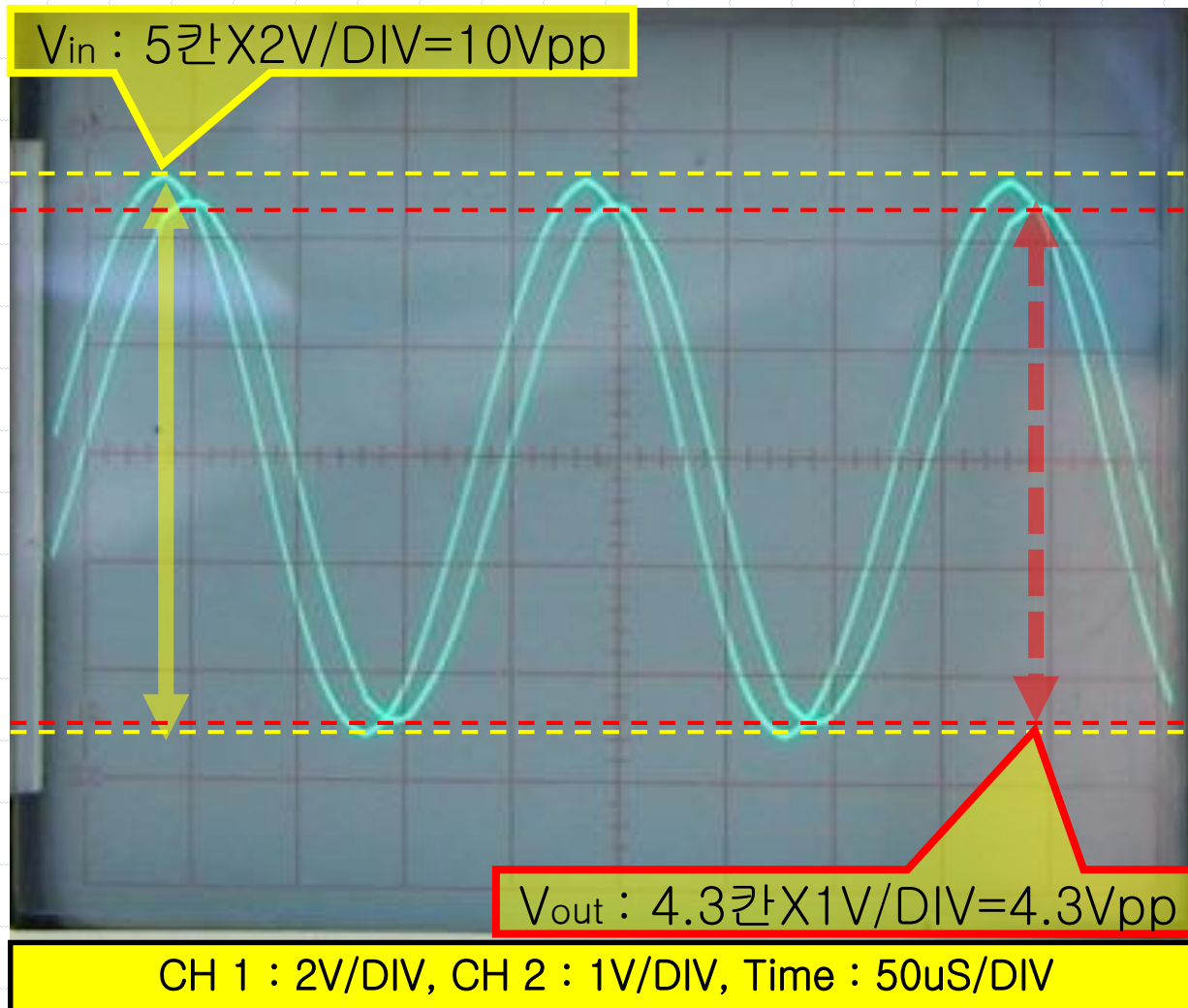
15-4. 주파수에 따른 전압

✓ 주파수 : 4kHz



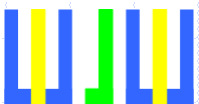
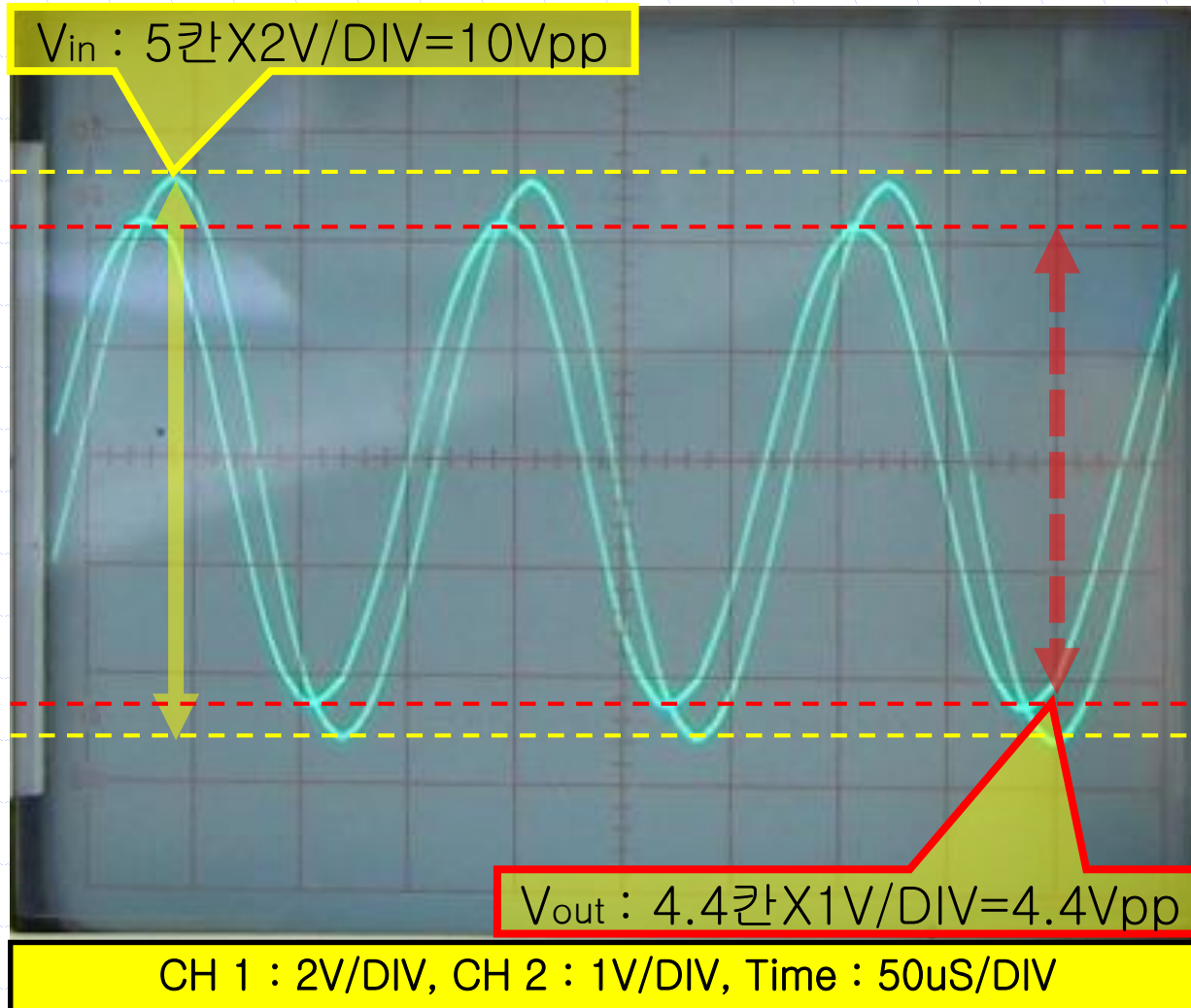
15-4. 주파수에 따른 전압

✓ 주파수 : 5kHz



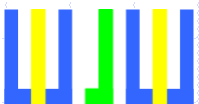
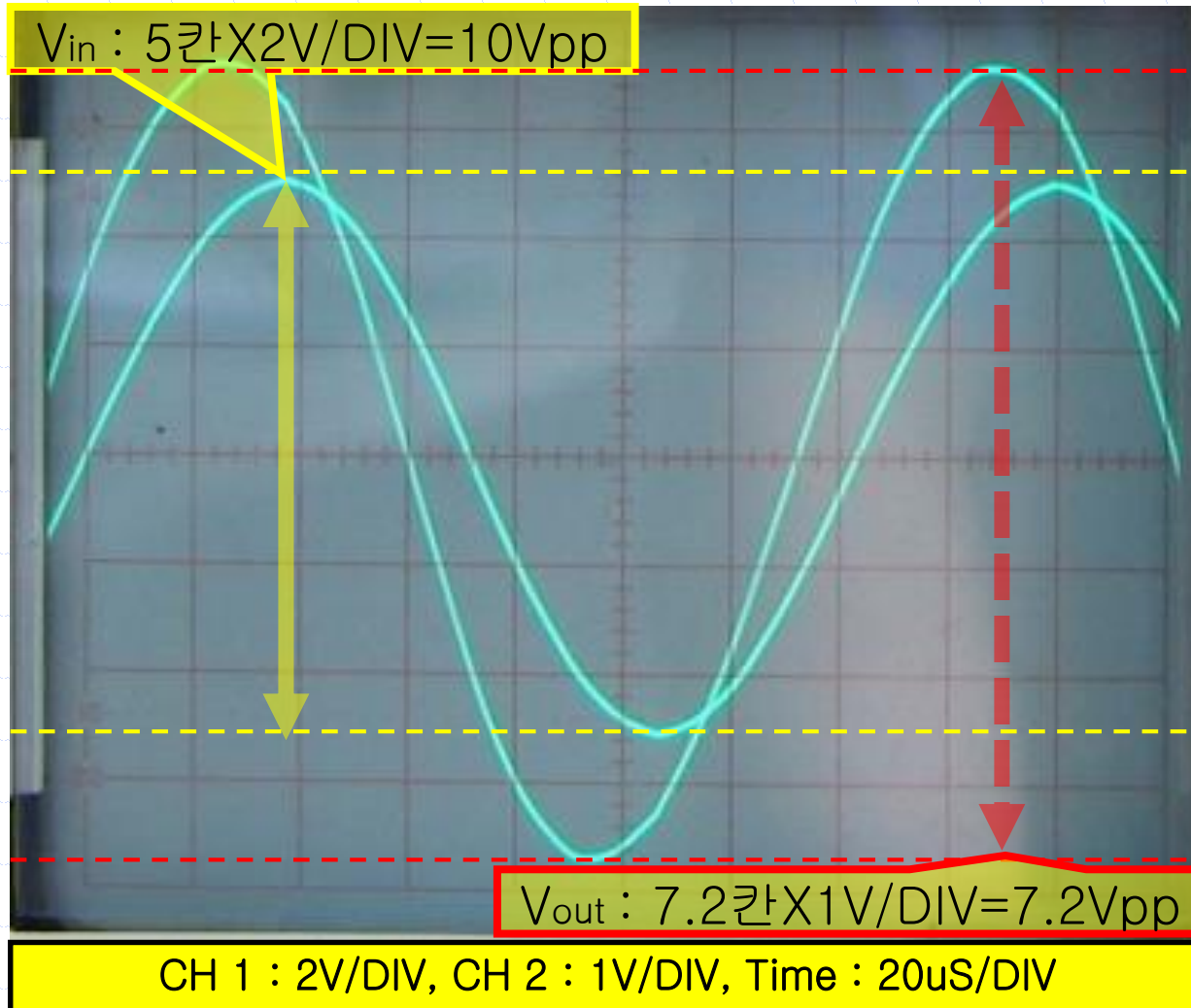
15-4. 주파수에 따른 전압

✓ 주파수 : 6kHz



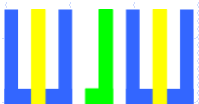
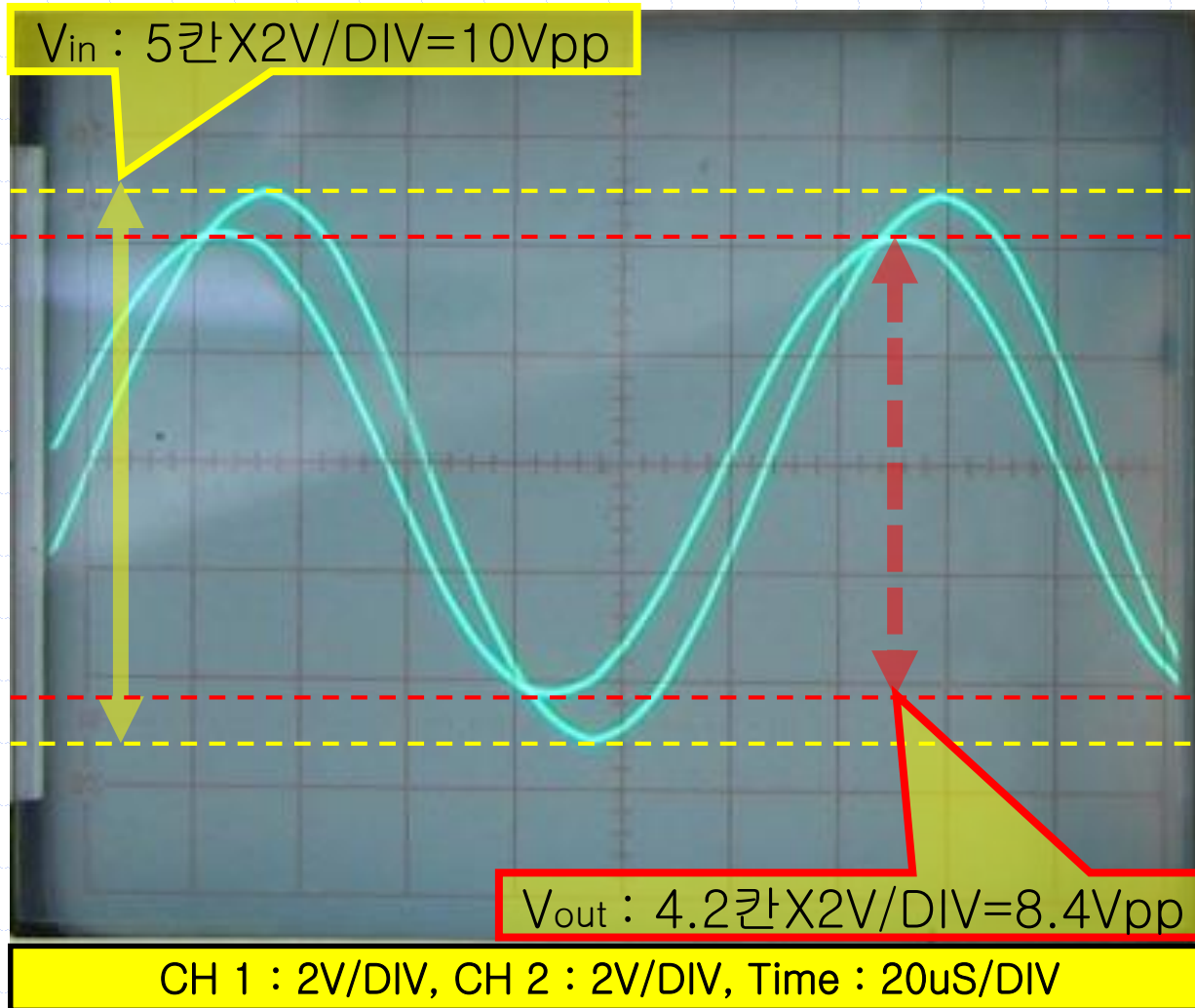
15-4. 주파수에 따른 전압

✓ 주파수 : 7kHz



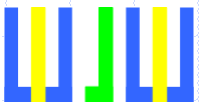
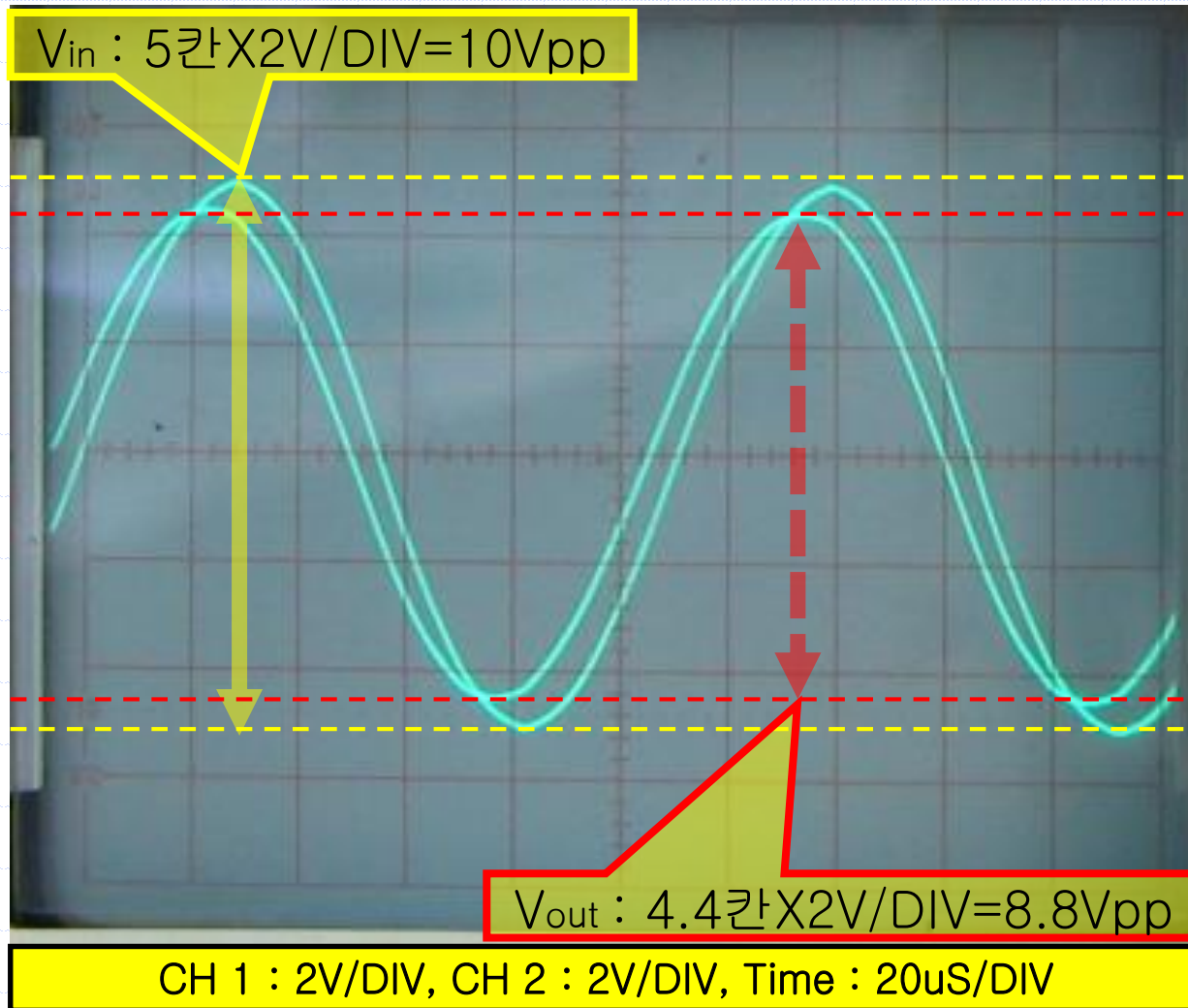
15-4. 주파수에 따른 전압

✓ 주파수 : 8kHz



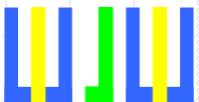
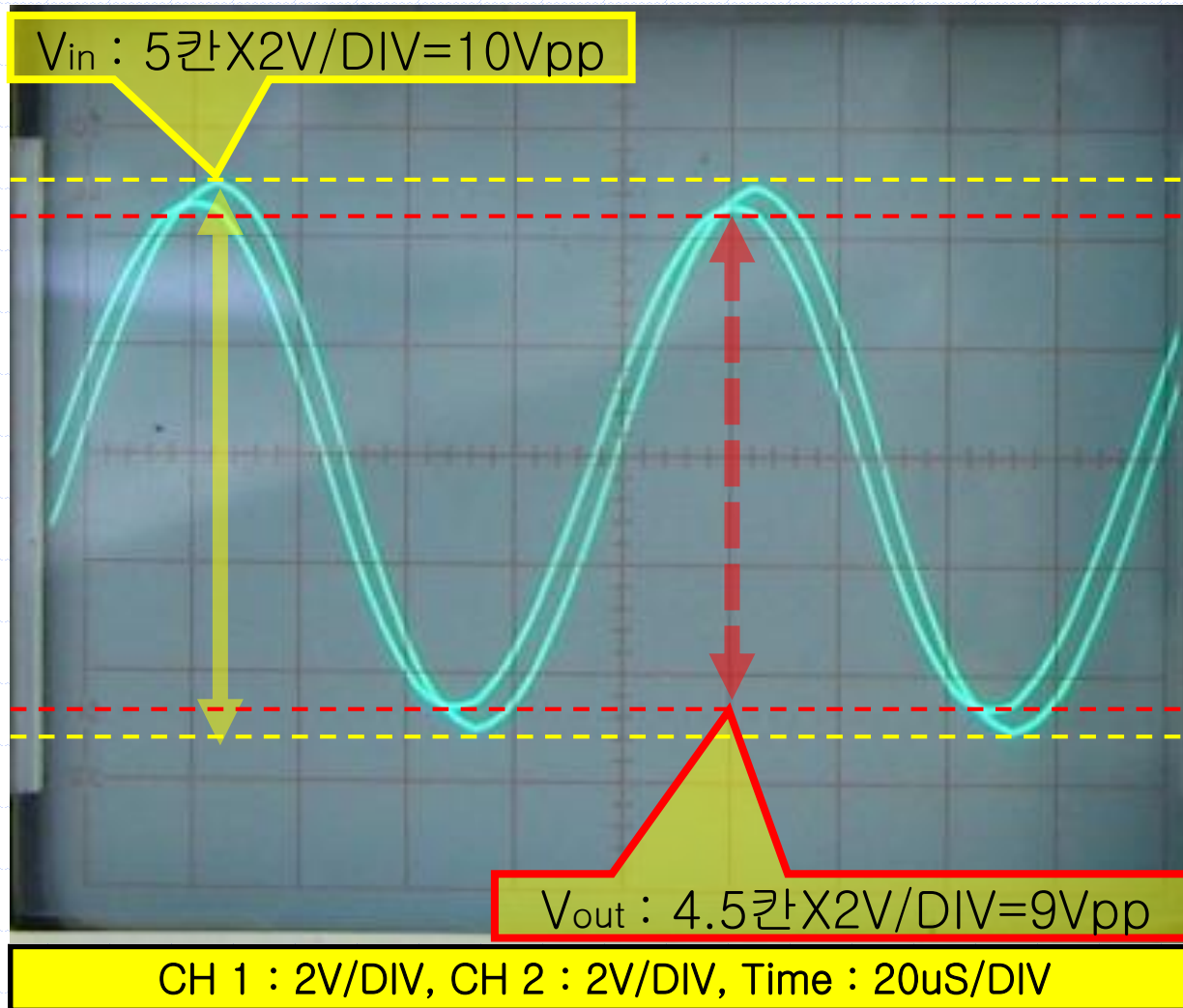
15-4. 주파수에 따른 전압

✓ 주파수 : 9kHz



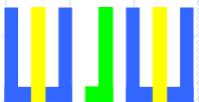
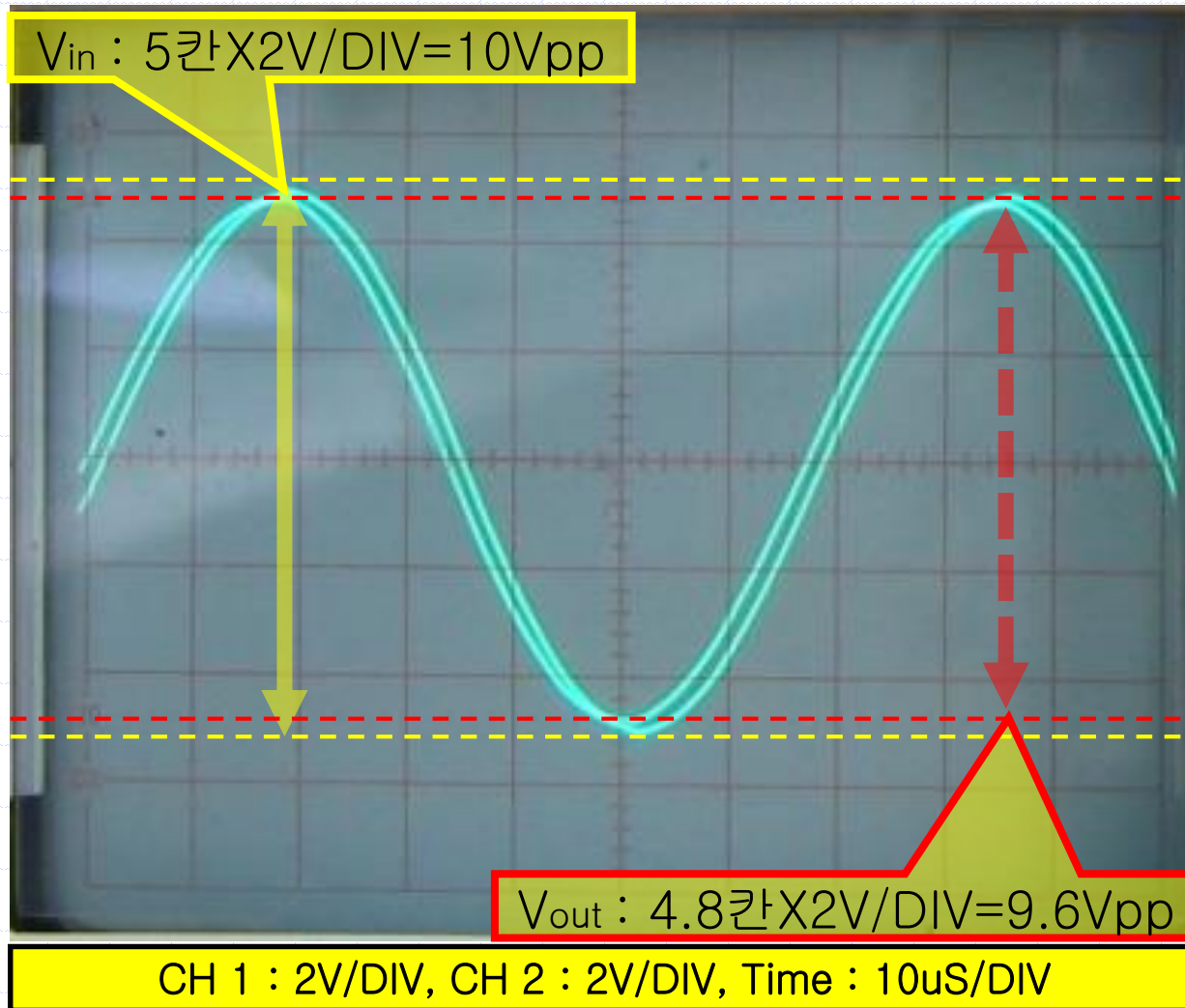
15-4. 주파수에 따른 전압

✓ 주파수 : 10kHz



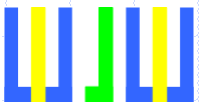
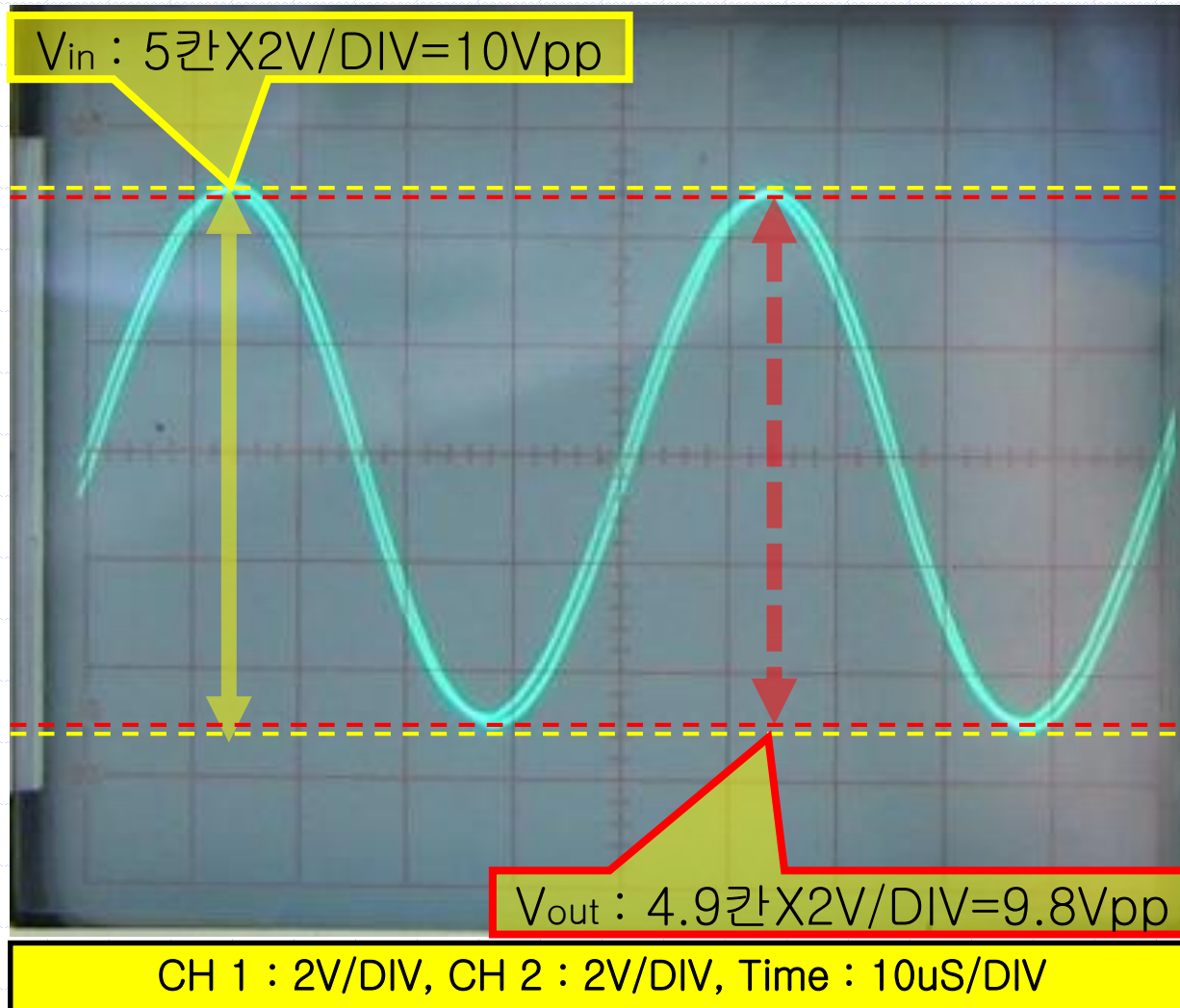
15-4. 주파수에 따른 전압

✓ 주파수 : 15kHz



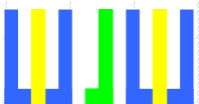
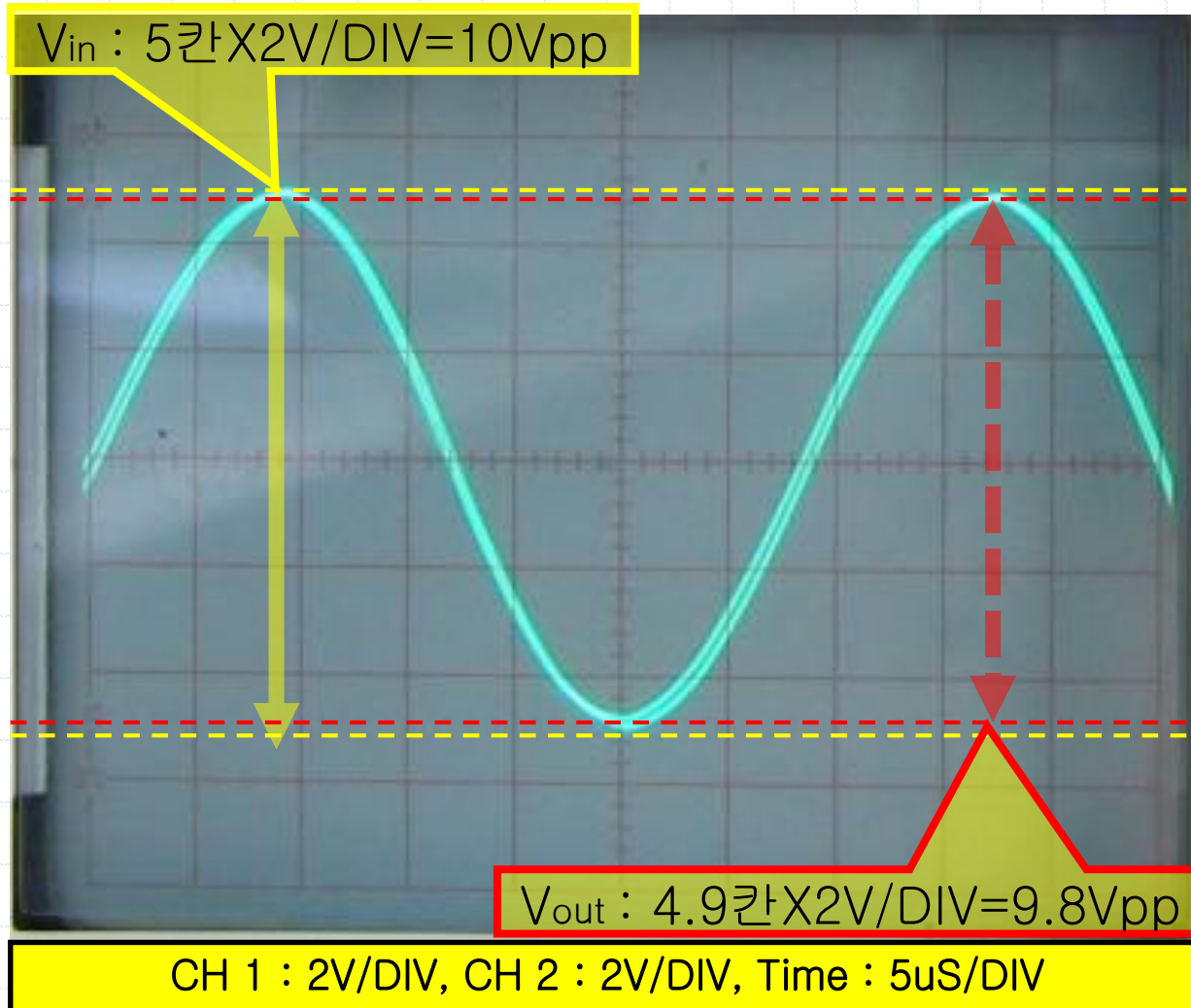
15-4. 주파수에 따른 전압

✓ 주파수 : 20kHz



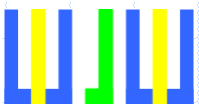
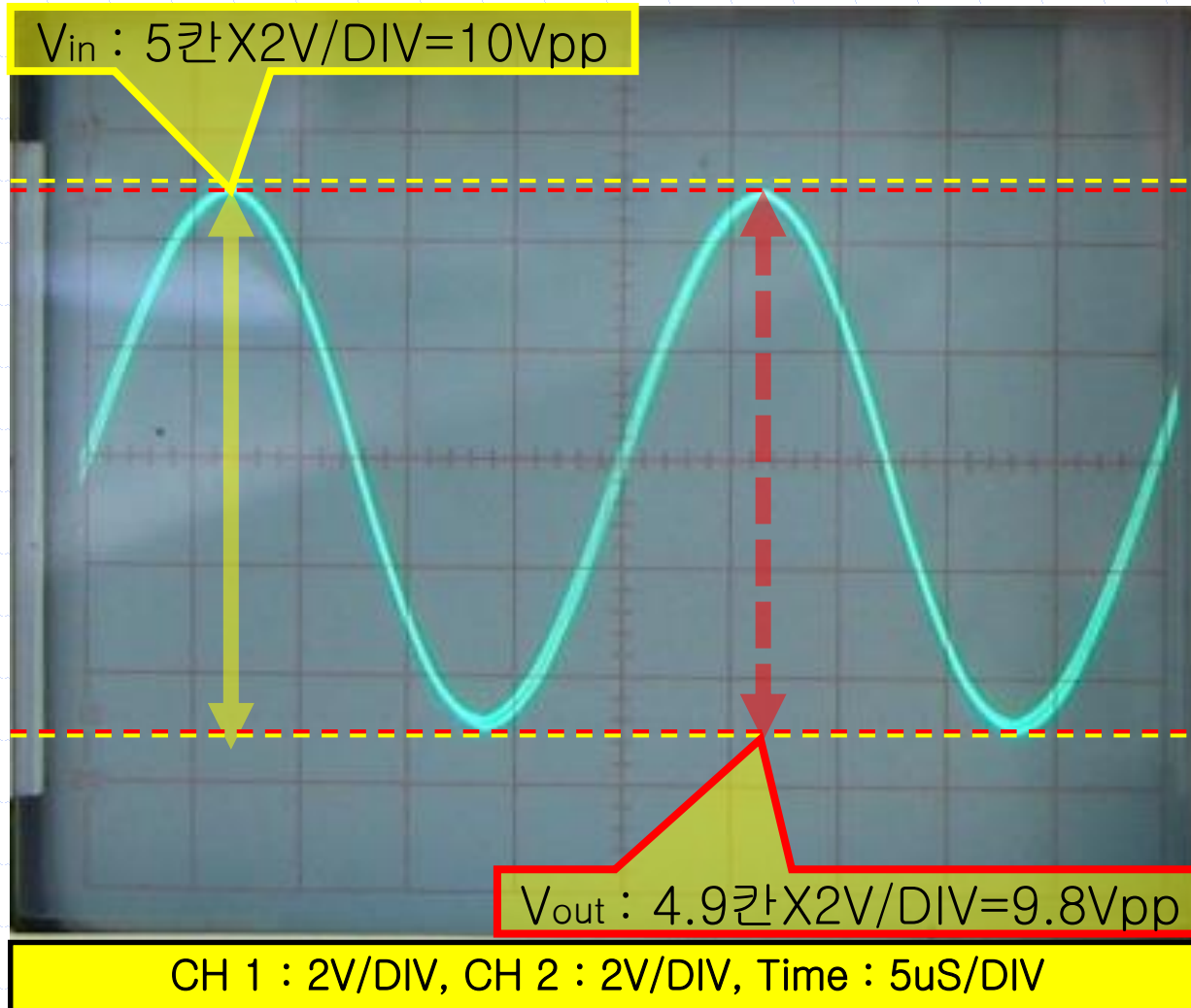
15-4. 주파수에 따른 전압

✓ 주파수 : 30kHz



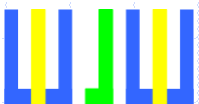
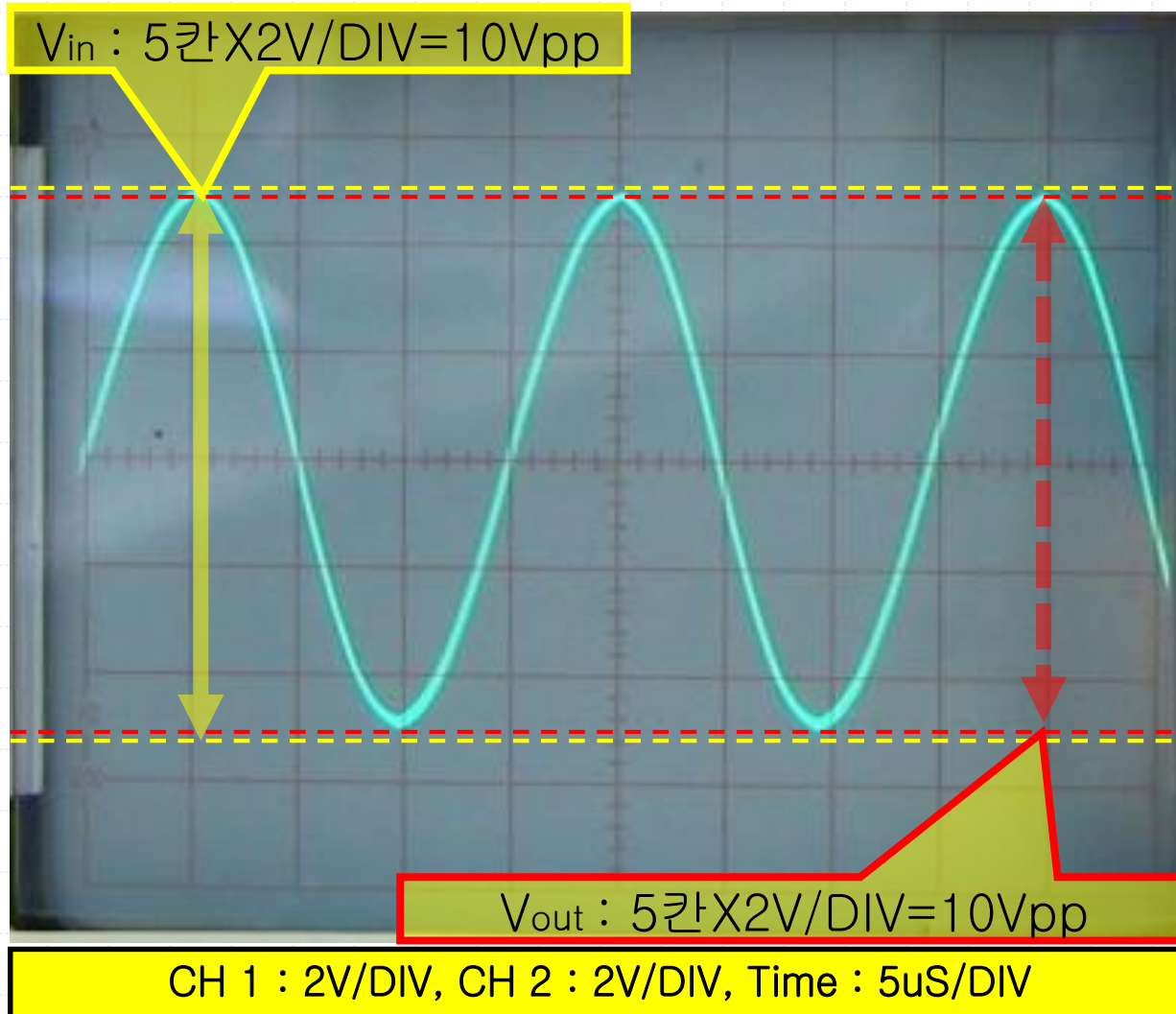
15-4. 주파수에 따른 전압

✓ 주파수 : 40kHz



15-4. 주파수에 따른 전압

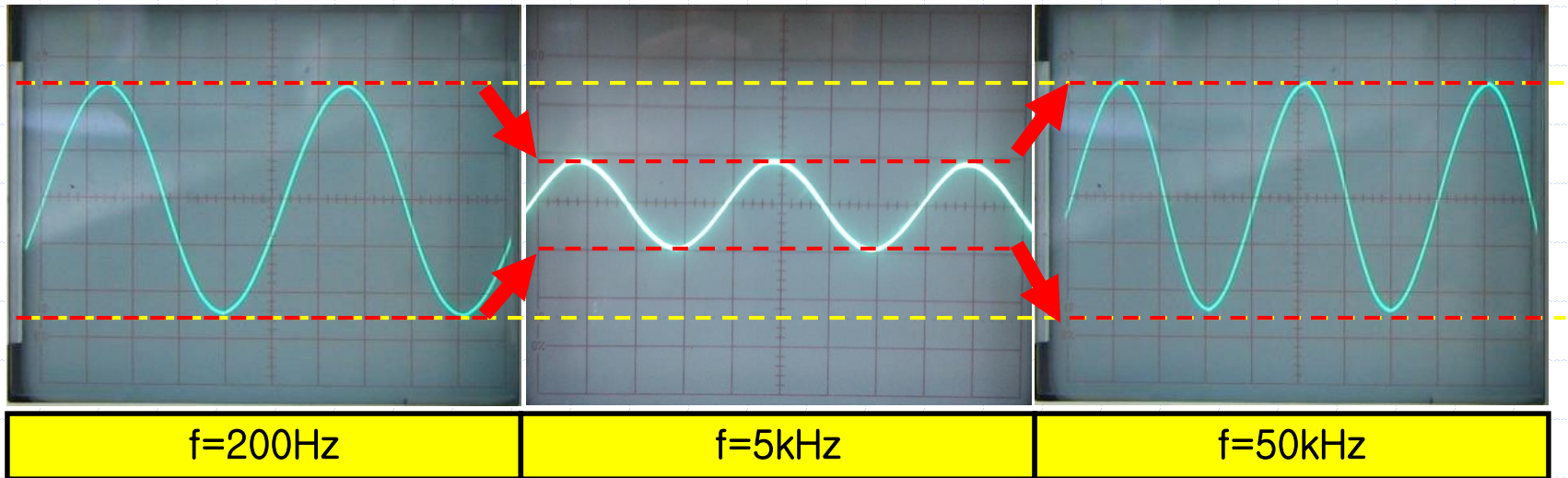
✓ 주파수 : 50kHz



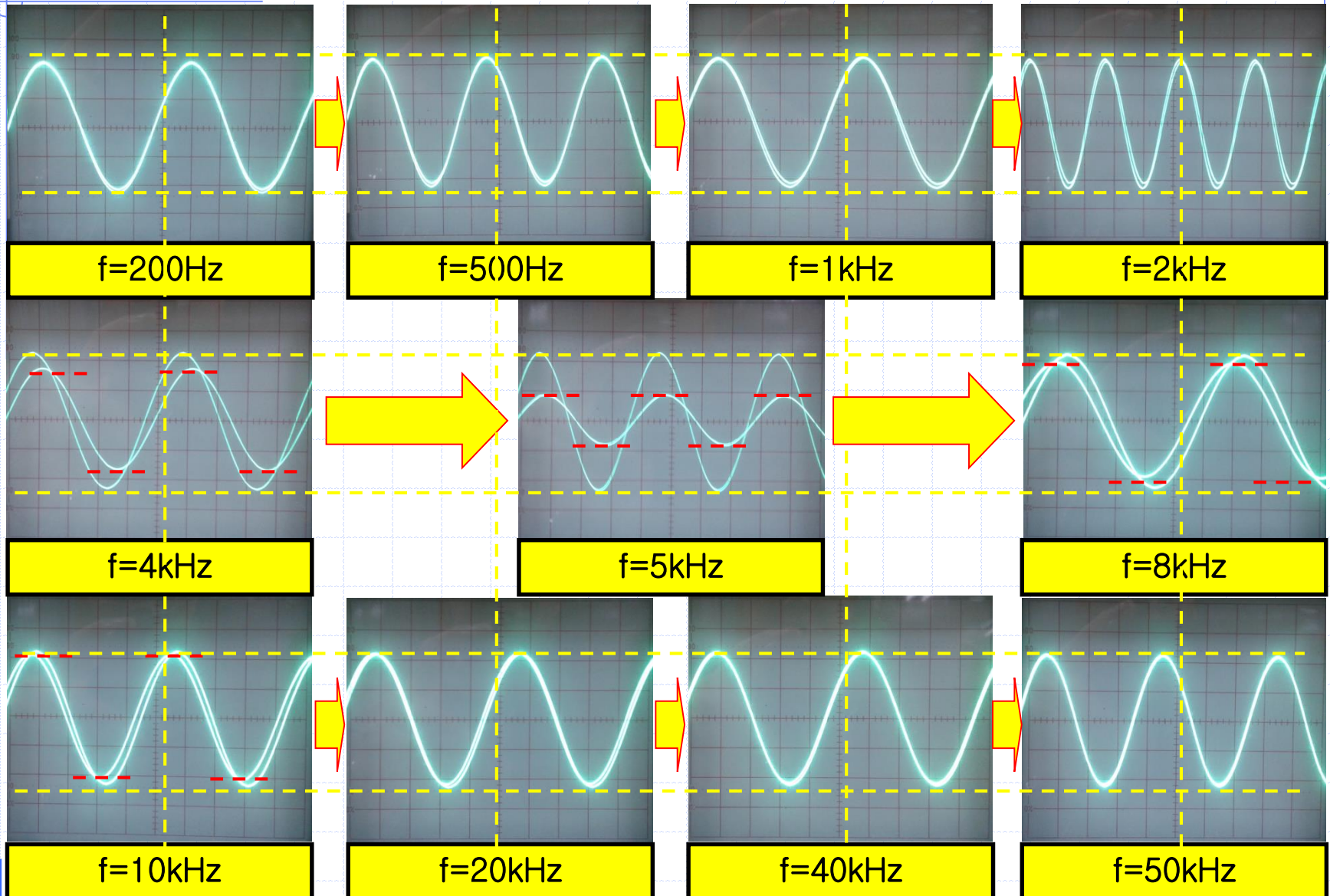
15-4. 주파수에 따른 전압

Frequency (Hz)	이론					실험				
	Vin (Vpp)	Vout (Vpp)	전압 이득		전체 전류 IT (mApp)	Vin (Vpp)	Vout (Vpp)	전압 이득		전체 전류 IT (mApp)
			이득	dB				이득	dB	
200	10	10	1.00	0.00	10	10	9.8	0.98	-0.18	9.8
500	10	9.99	1.00	-0.01	9.99	10	9.8	0.98	-0.18	9.8
1,000	10	9.98	1.00	-0.02	9.98	10	9.8	0.98	-0.18	9.8
2,000	10	9.89	0.99	-0.10	9.89	10	9.6	0.96	-0.35	9.6
3,000	10	9.6	0.96	-0.35	9.6	10	9.2	0.92	-0.72	9.2
4,000	10	8.26	0.83	-1.66	8.26	10	8	0.80	-1.94	8
5,000	10	0.41	0.04	-27.74	0.41	10	4.3	0.43	-7.33	4.3
6,000	10	7.45	0.75	-2.56	7.45	10	4.4	0.44	-7.13	4.4
7,000	10	9.05	0.91	-0.87	9.05	10	7.2	0.72	-2.85	7.2
8,000	10	9.5	0.95	-0.45	9.5	10	8.4	0.84	-1.51	8.4
9,000	10	9.68	0.97	-0.28	9.68	10	8.8	0.88	-1.11	8.8
10,000	10	9.78	0.98	-0.19	9.78	10	9	0.90	-0.92	9
15,000	10	9.93	0.99	-0.06	9.93	10	9.6	0.96	-0.35	9.6
20,000	10	9.96	1.00	-0.03	9.96	10	9.8	0.98	-0.18	9.8
30,000	10	9.99	1.00	-0.01	9.99	10	9.8	0.98	-0.18	9.8
40,000	10	9.99	1.00	-0.01	9.99	10	9.8	0.98	-0.18	9.8
50,000	10	9.99	1.00	-0.01	9.99	10	10	1.00	0.00	10

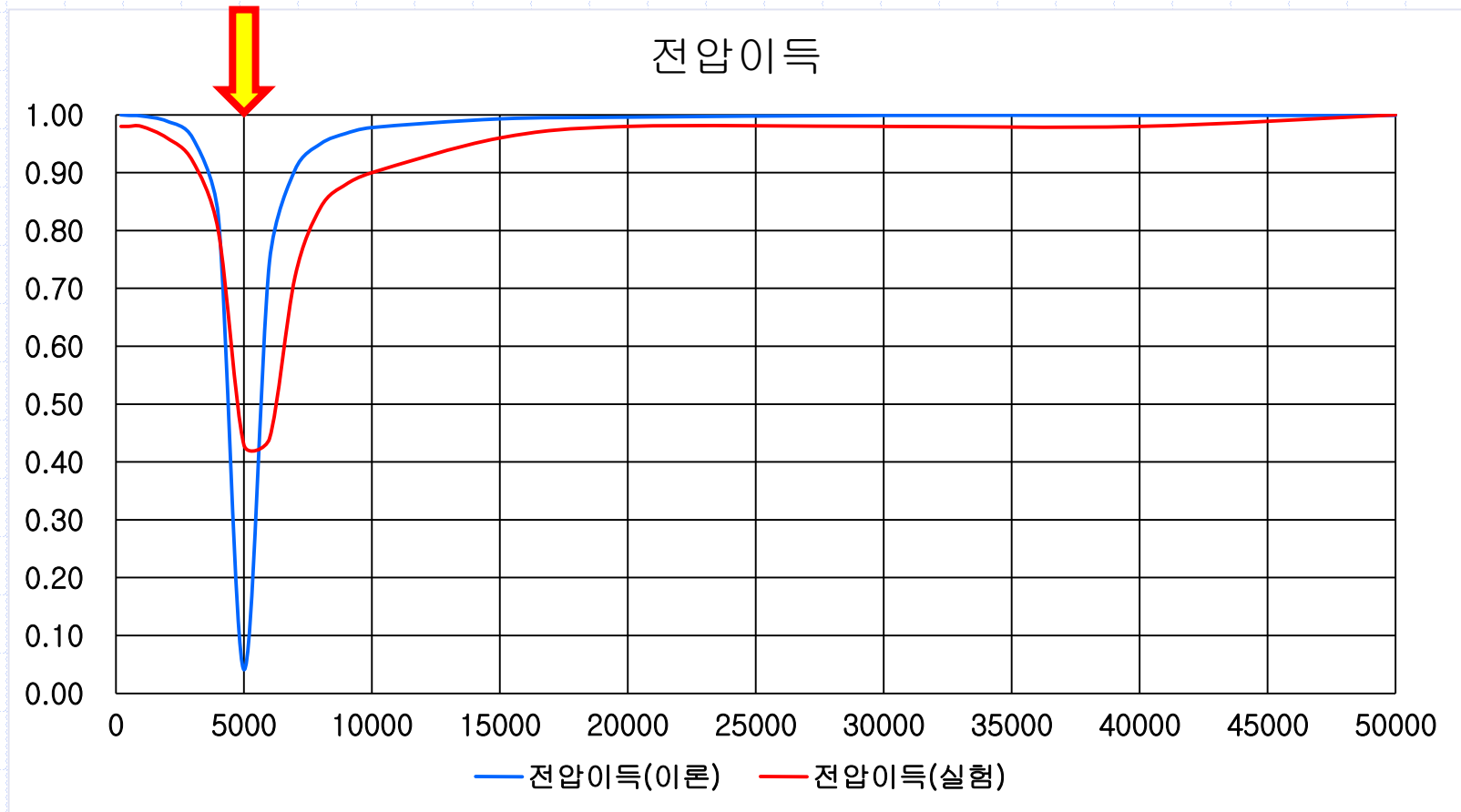
15-4. 주파수에 따른 전압



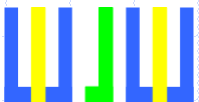
15-4. 주파수에 따른 전압



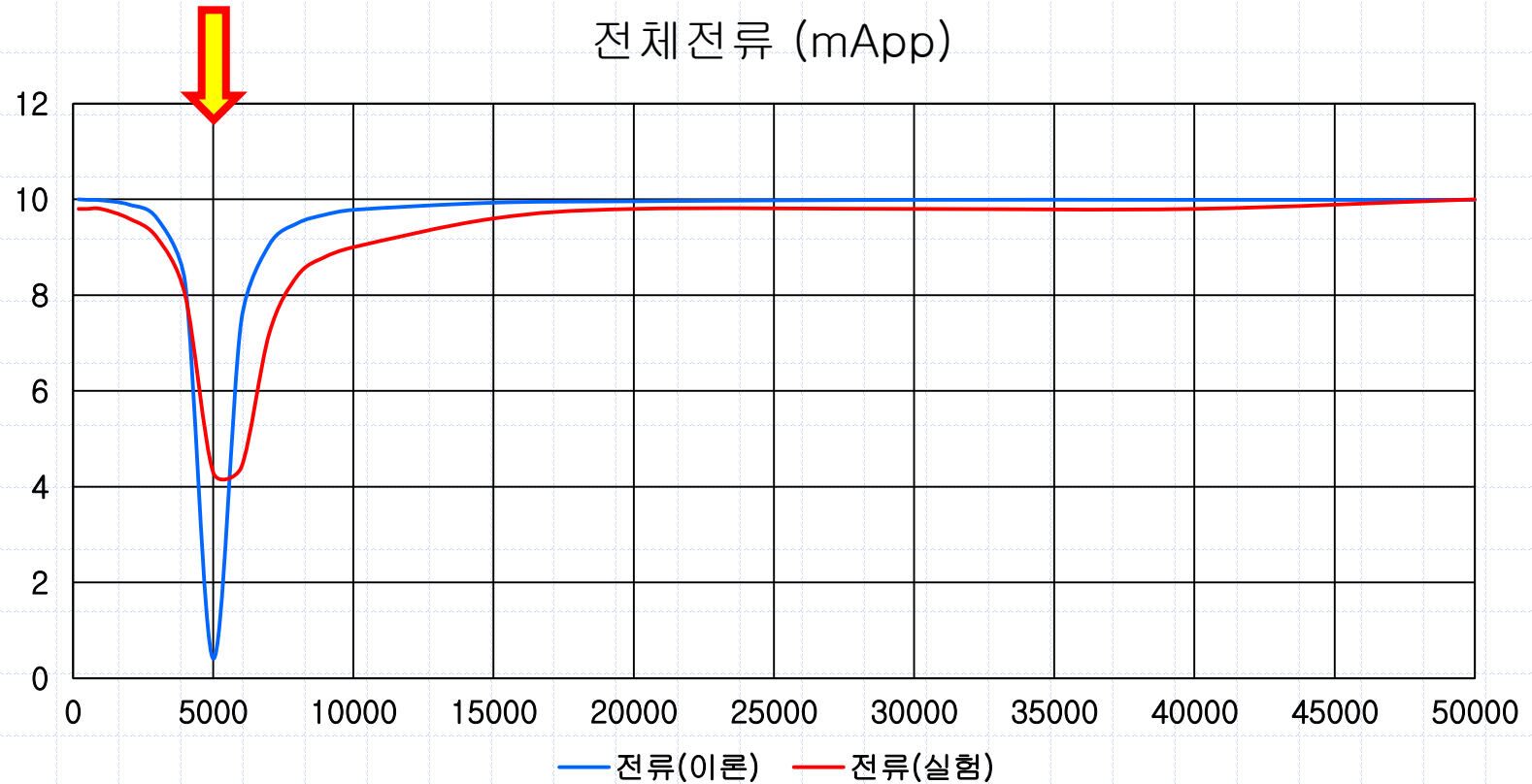
15-5. 공진 주파수



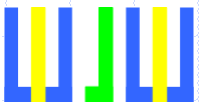
$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10\text{mH} \times 0.1\mu\text{F}}} = 5032.9\text{Hz}$$



15-5. 공진 주파수

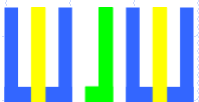
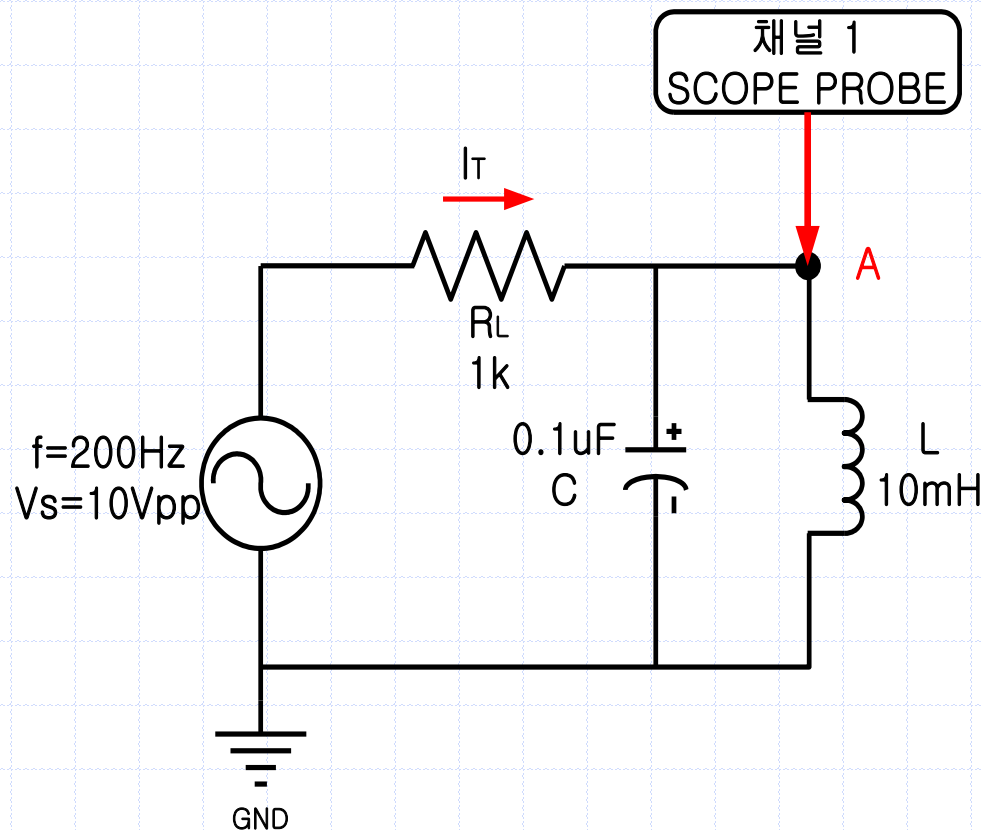


$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10mH \times 0.1\mu F}} = 5032.9Hz$$



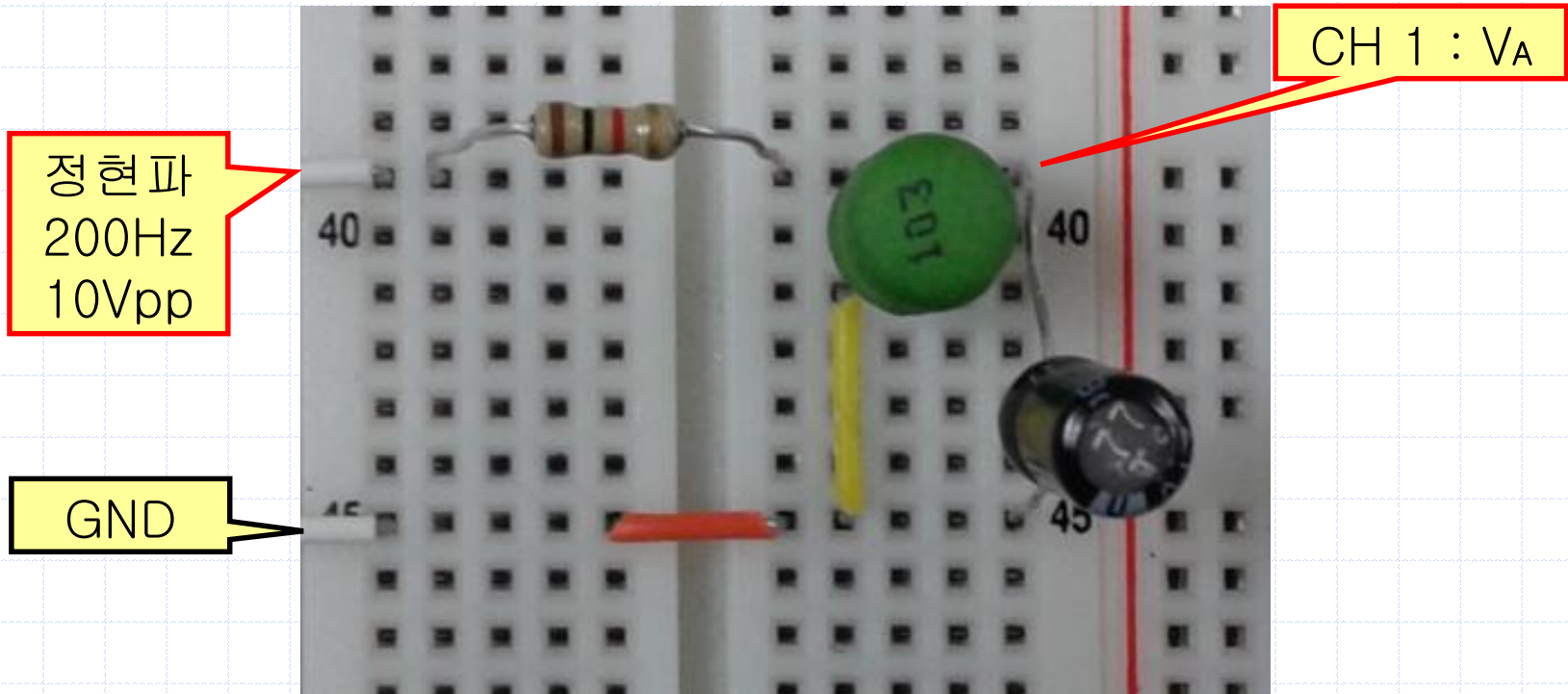
15-6. 주파수에 따른 전류, 임피던스

- ✓ 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.

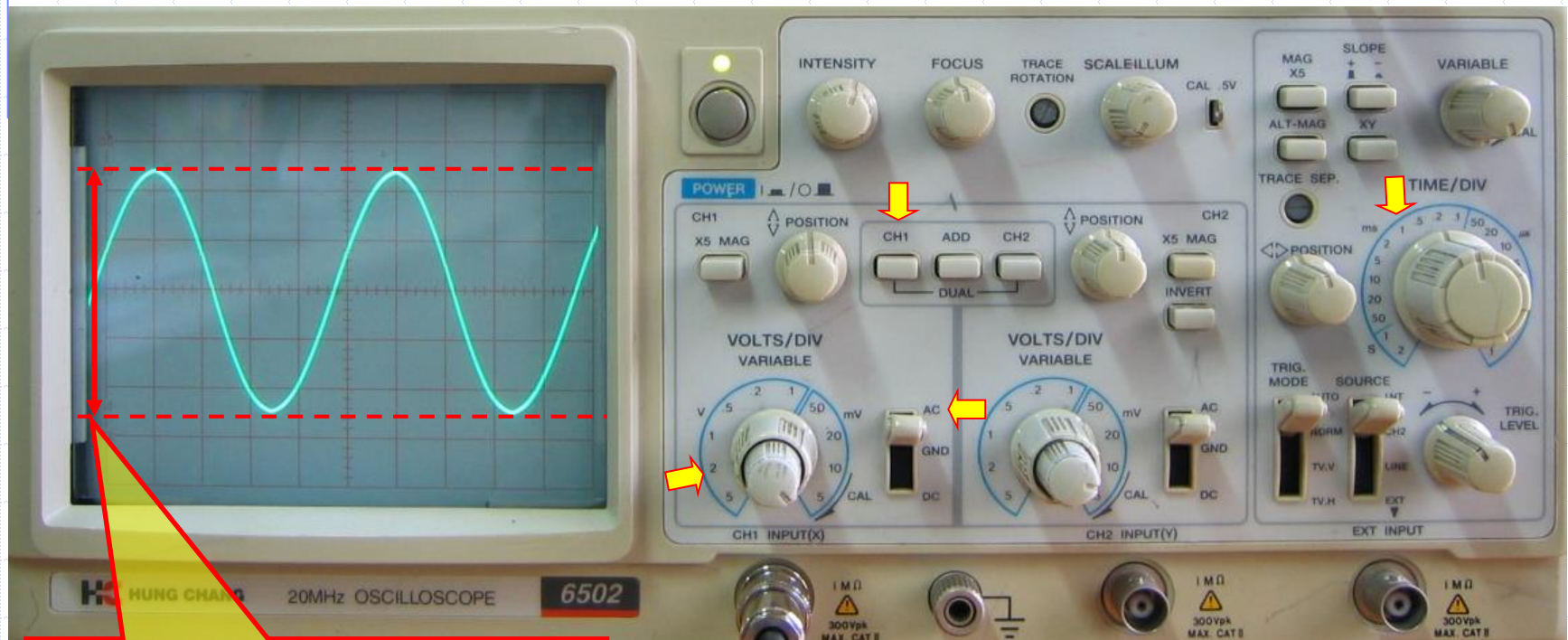
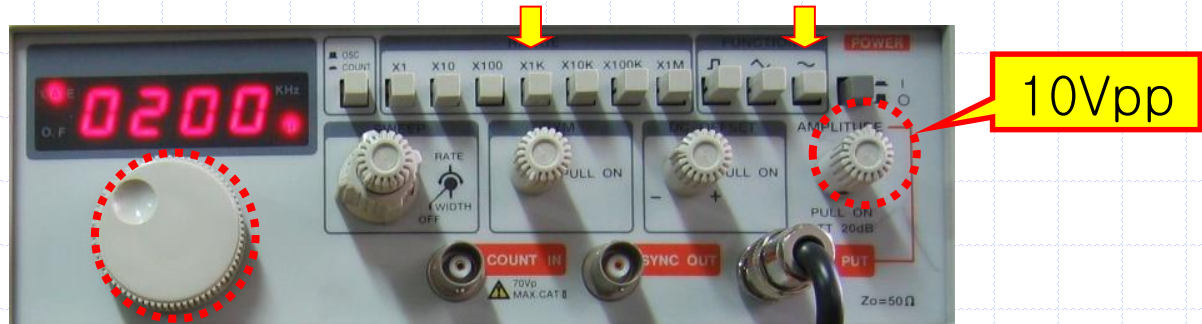


15-6. 주파수에 따른 전류, 임피던스

- ✓ 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.



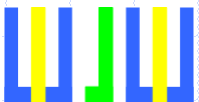
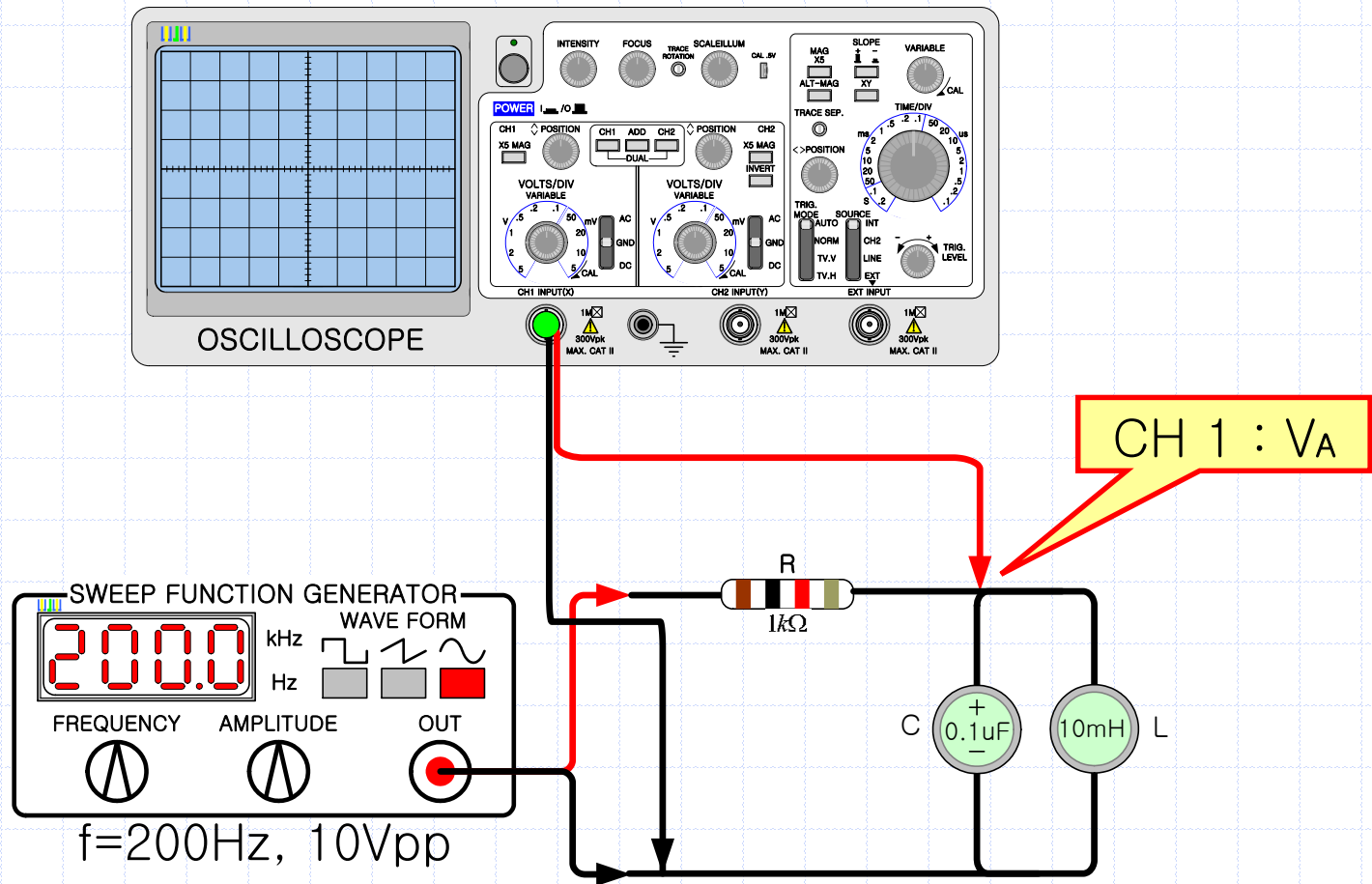
15-6. 주파수에 따른 전류, 임피던스



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

15-6. 주파수에 따른 전류, 임피던스

- ✓ 오실로스코프의 CH 1 을 이용하여 병렬 공진 회로 양단의 전압을 측정한다.

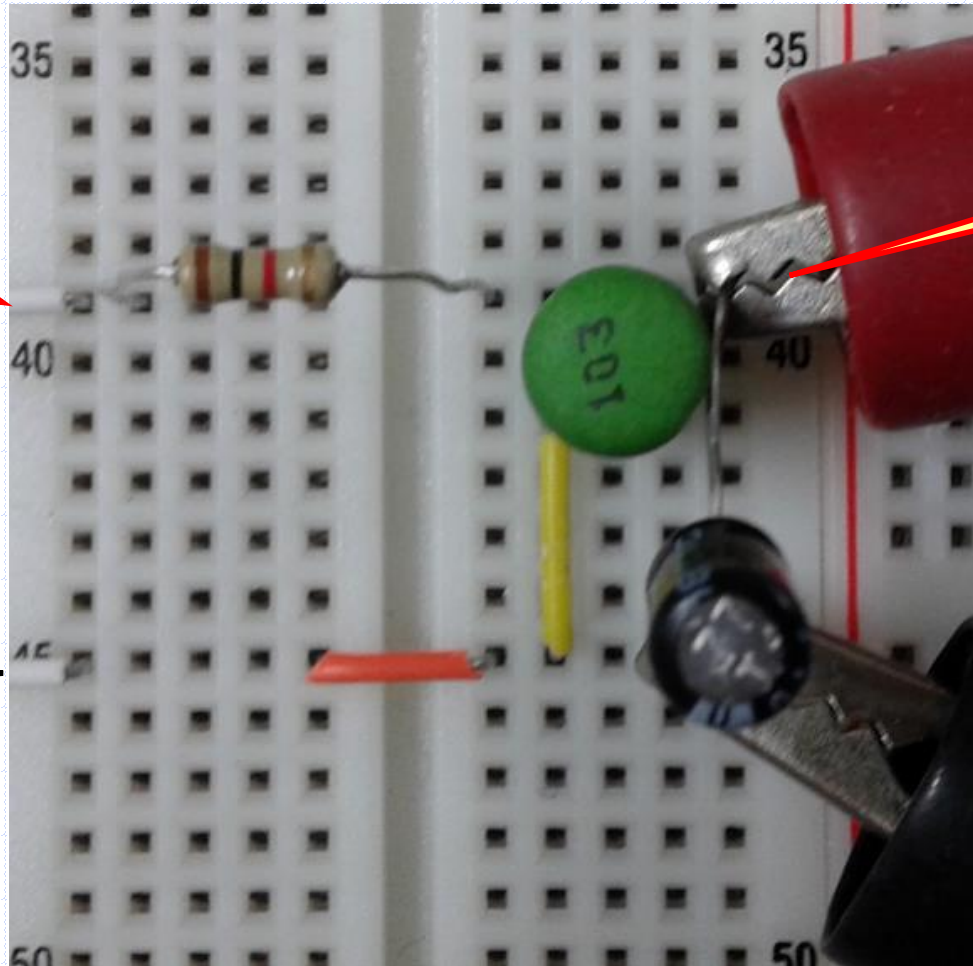


15-6. 주파수에 따른 전류, 임피던스

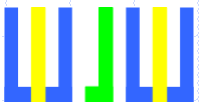
✓ 주파수 : 200Hz

정현파
200Hz
10Vpp

GND

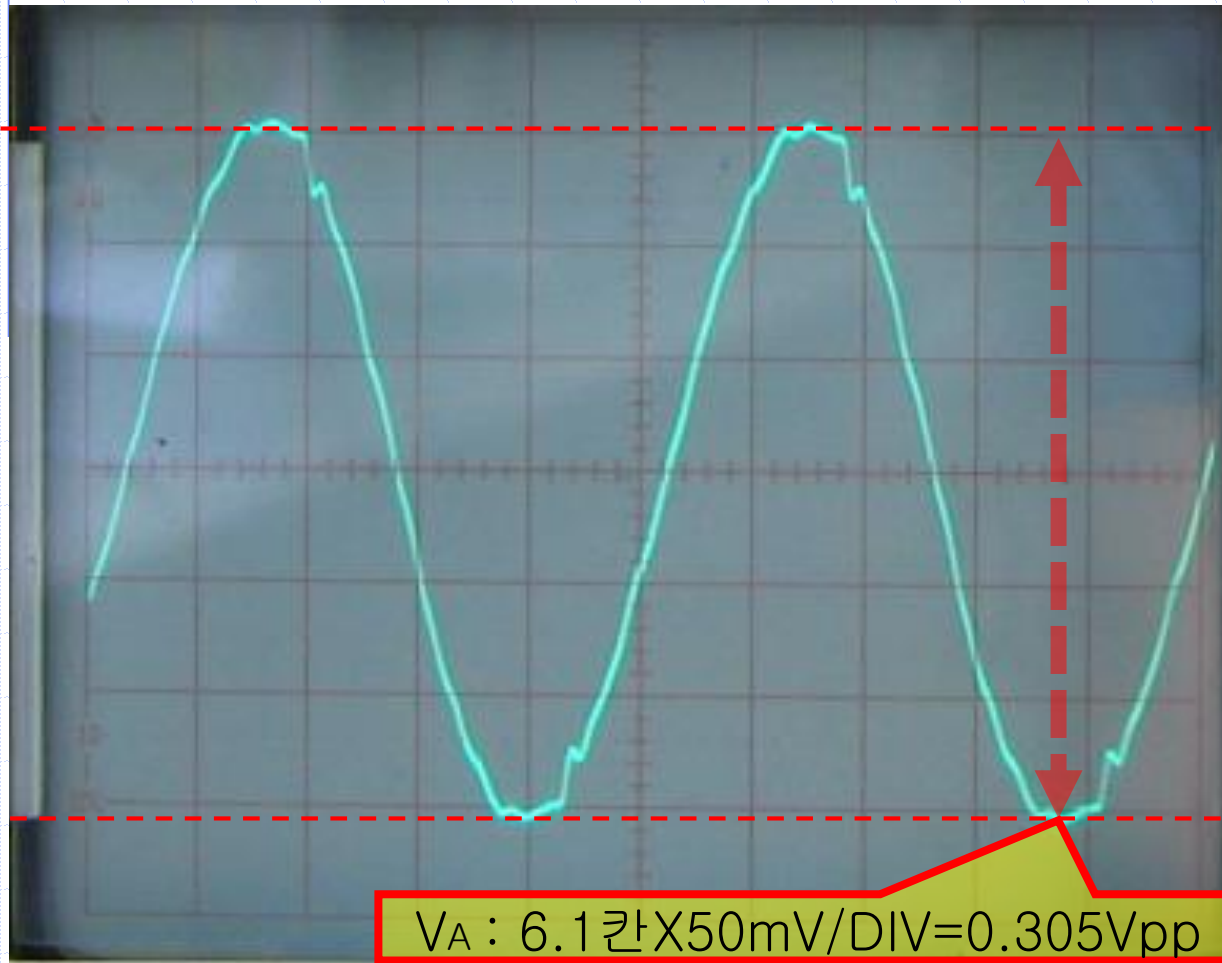


CH 1 : V_A



15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 200Hz

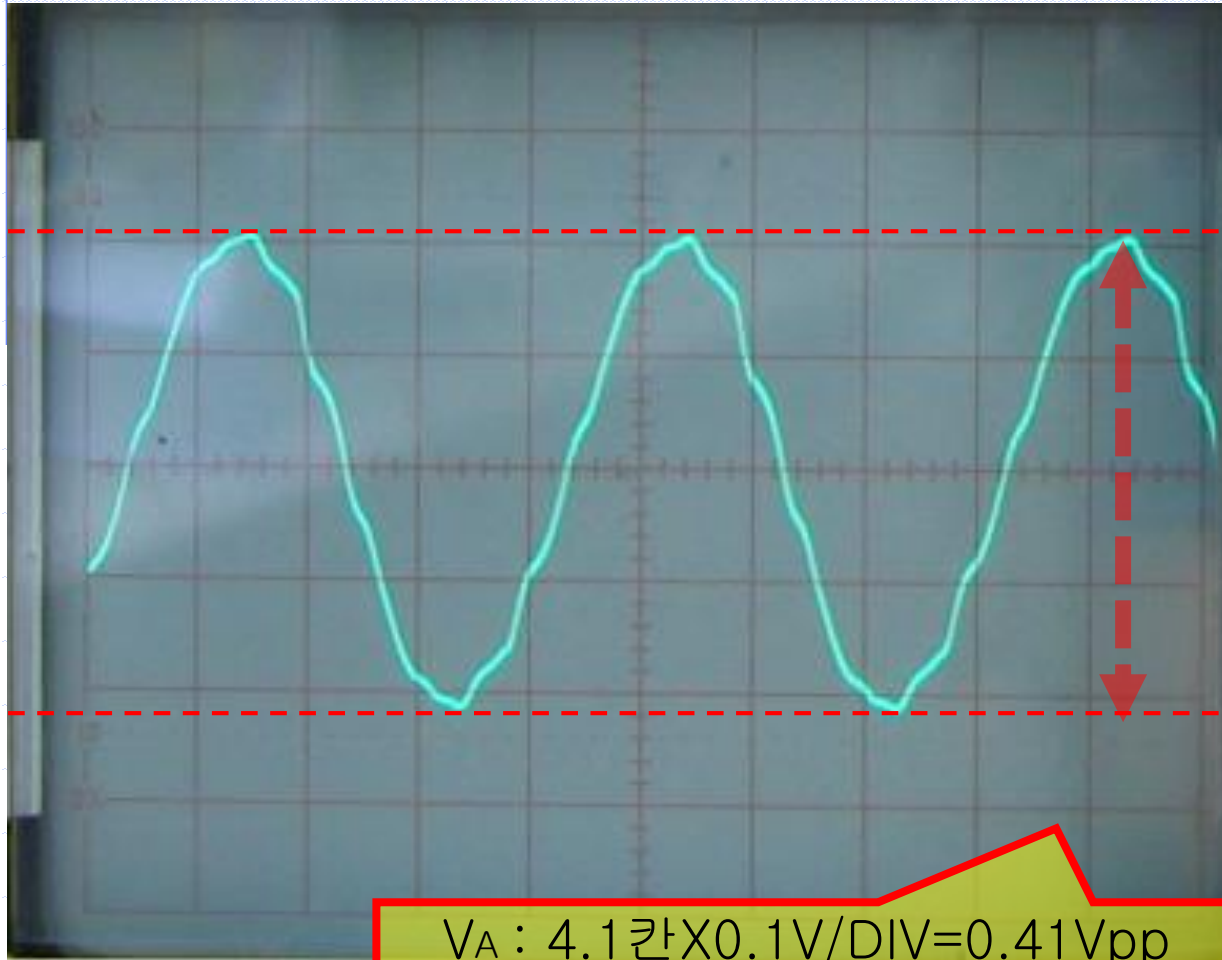


$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.305 V_{PP}}{9.8 \text{ mA}_{PP}} \\ &= 31.12 \Omega \end{aligned}$$

CH 1 : 50mV/DIV, Time : 1mS/DIV

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 500Hz



$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.41V_{PP}}{9.8mA_{PP}} \\ &= 41.84\Omega \end{aligned}$$

$V_A : 4.1 \text{ 칸} \times 0.1V/DIV = 0.41V_{pp}$

CH 1 : 0.1V/DIV, Time : 0.5mS/DIV

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 1kHz



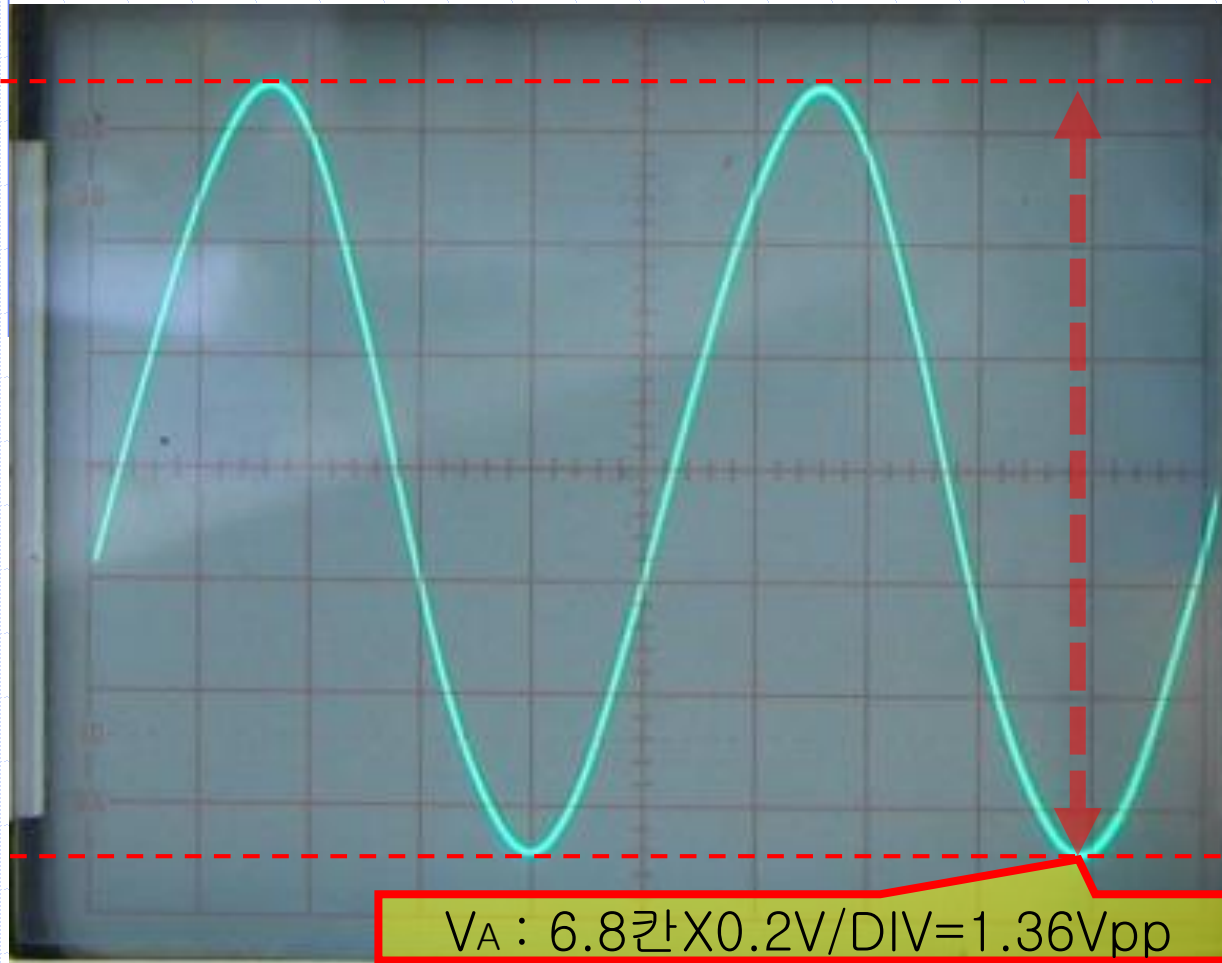
$V_A : 7 \text{ 칸} \times 0.1 \text{ V/DIV} = 0.7 \text{ V}_{pp}$

CH 1 : 0.1V/DIV, Time : 0.2mS/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.7V_{pp}}{9.8mA_{pp}} \\ &= 71.43\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 2kHz



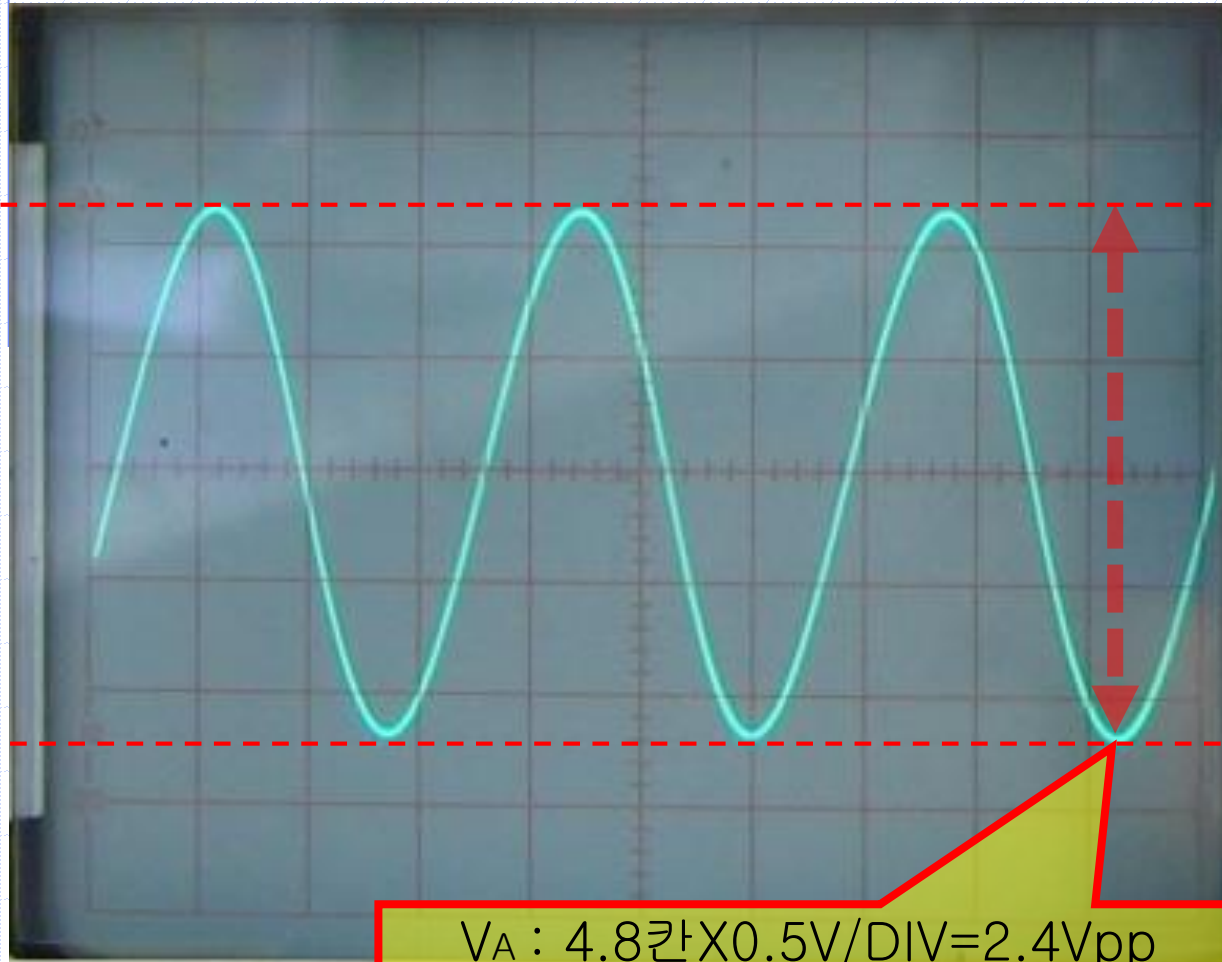
$V_A : 6.8 \text{칸} \times 0.2 \text{V/DIV} = 1.36 \text{V}_{pp}$

CH 1 : 50mV/DIV, Time : 1mS/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{1.36V_{pp}}{9.6mA_{pp}} \\ &= 141.67\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 3kHz



$V_A : 4.8 \text{칸} \times 0.5 \text{V/DIV} = 2.4 \text{V}_{pp}$

CH 1 : 0.5V/DIV, Time : 0.1ms/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{2.4V_{pp}}{9.2mA_{pp}} \\ &= 260.87\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 4kHz



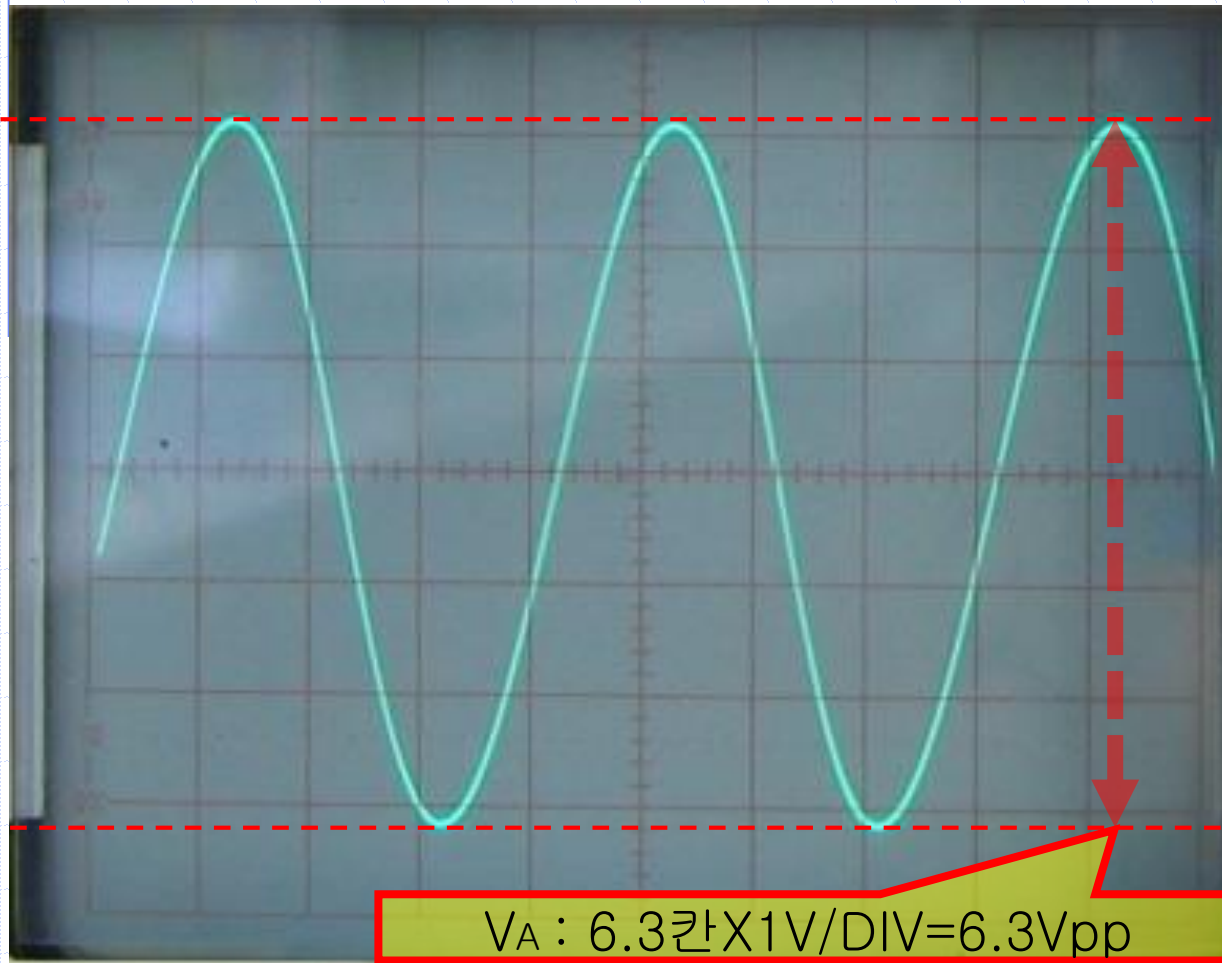
$V_A : 4\text{칸} \times 1\text{V/DIV} = 4\text{V}_{pp}$

CH 1 : 1V/DIV, Time : 50 μ S/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{4V_{PP}}{8mA_{PP}} \\ &= 500\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 5kHz



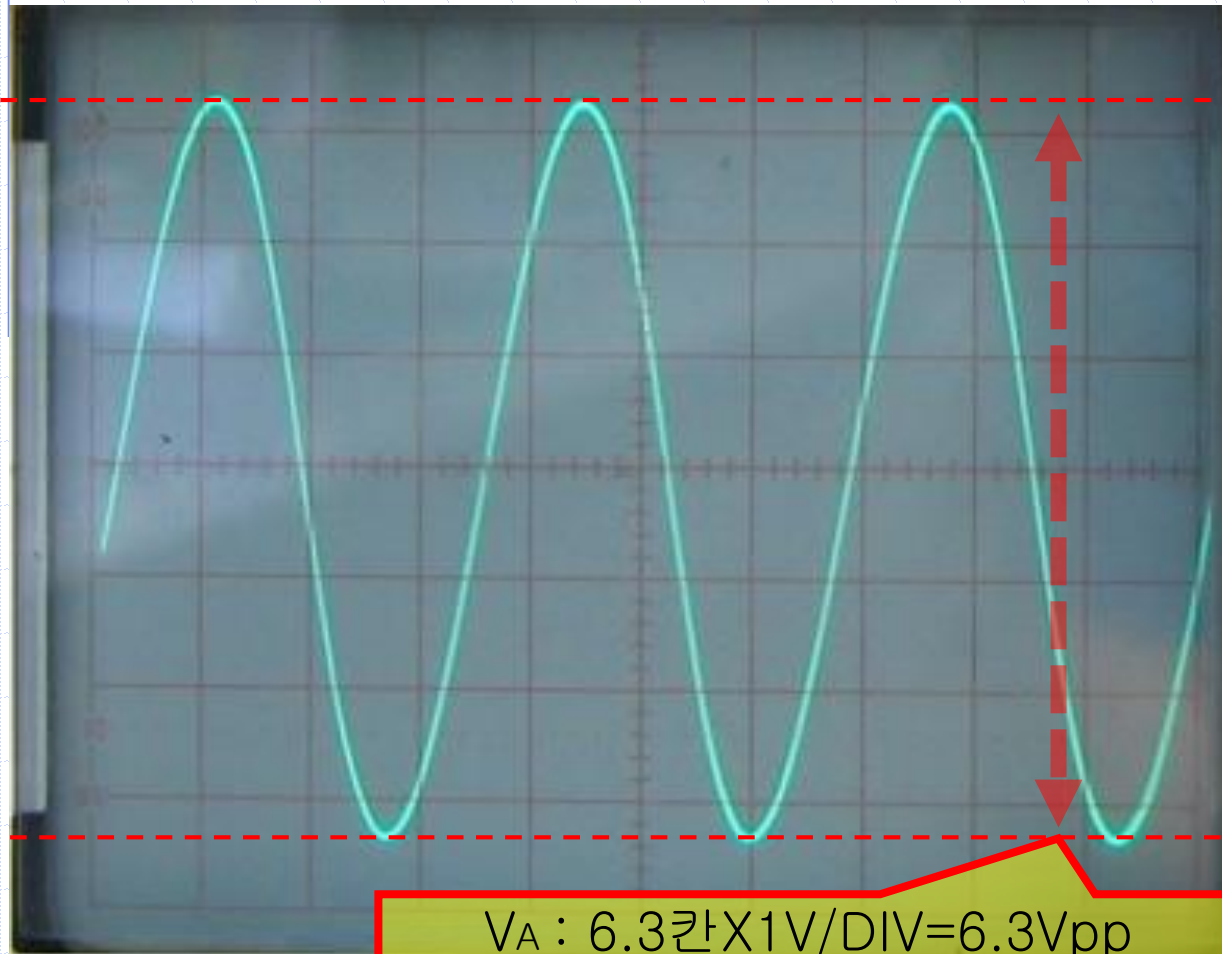
$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{6.3V_{PP}}{4.6mA_{PP}} \\ &= 1,369.57\Omega \end{aligned}$$

$V_A : 6.3\text{칸} \times 1\text{V/DIV} = 6.3\text{Vpp}$

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

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 6kHz



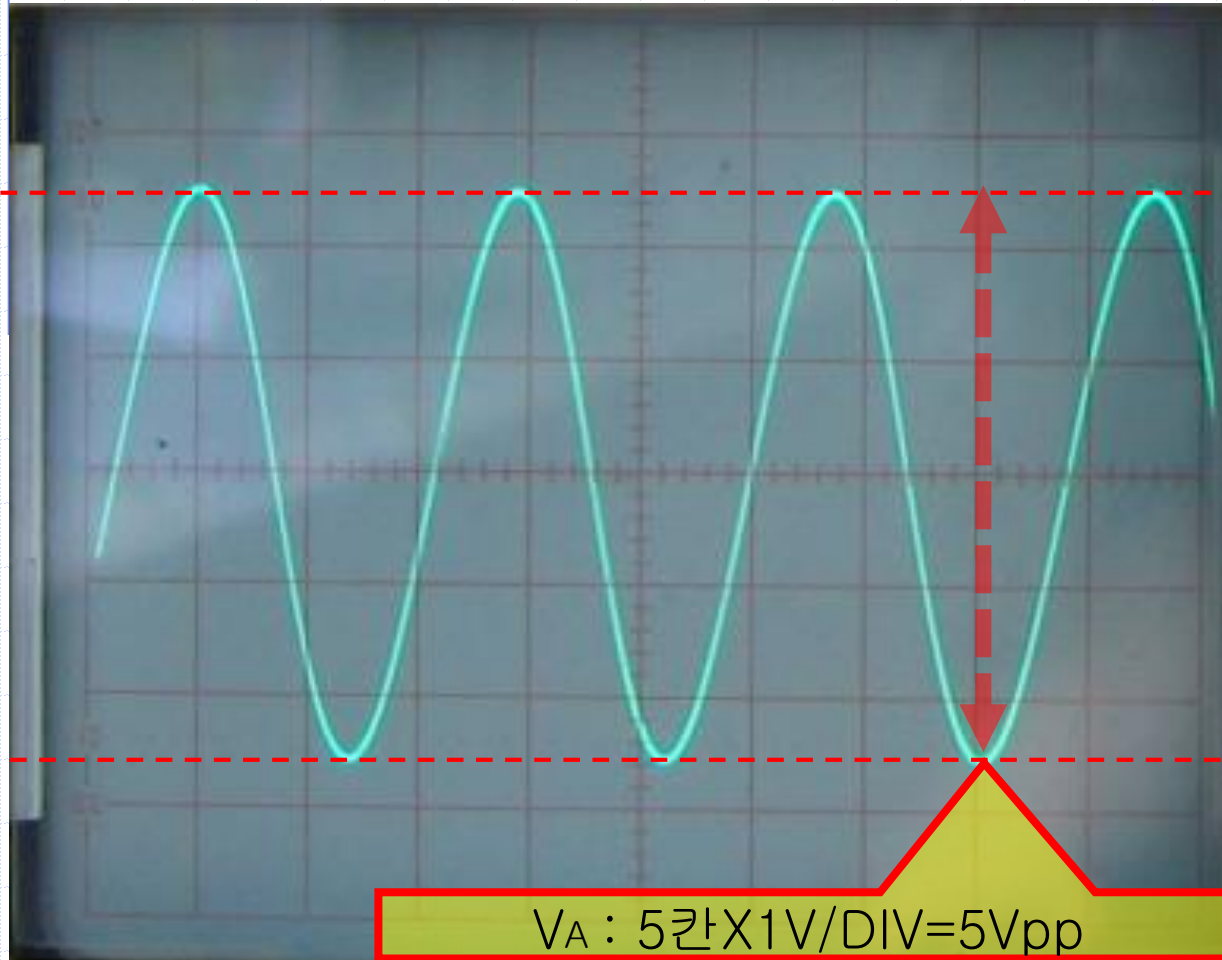
$V_A : 6.3 \text{ 칸} \times 1 \text{ V/DIV} = 6.3 \text{ V}_{pp}$

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

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{6.3V_{pp}}{4.4mA_{pp}} \\ &= 1,431.82\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 7kHz



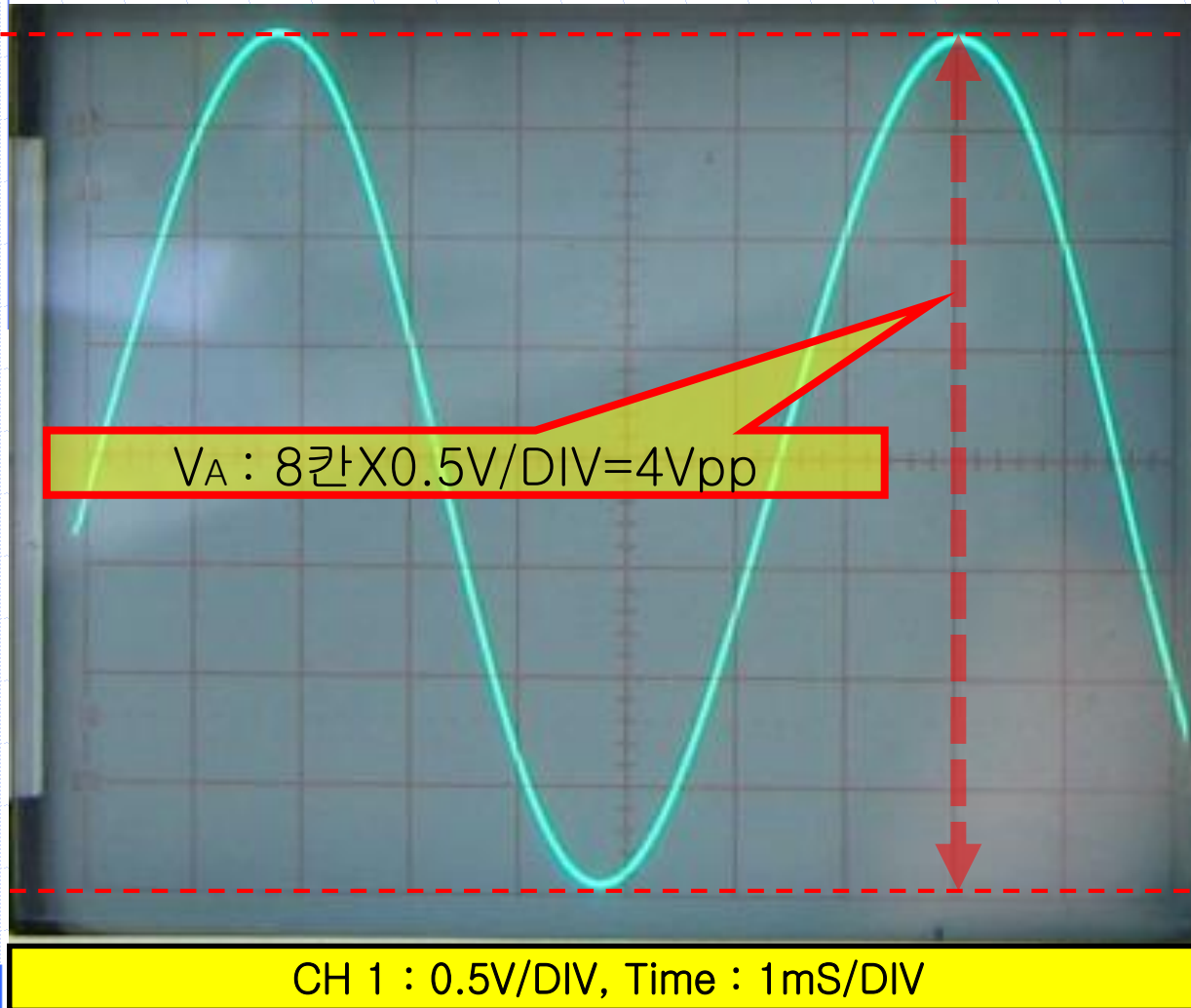
$V_A : 5\text{칸} \times 1\text{V/DIV} = 5\text{V}_{pp}$

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

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{5V_{pp}}{7.2mA_{pp}} \\ &= 694.44\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

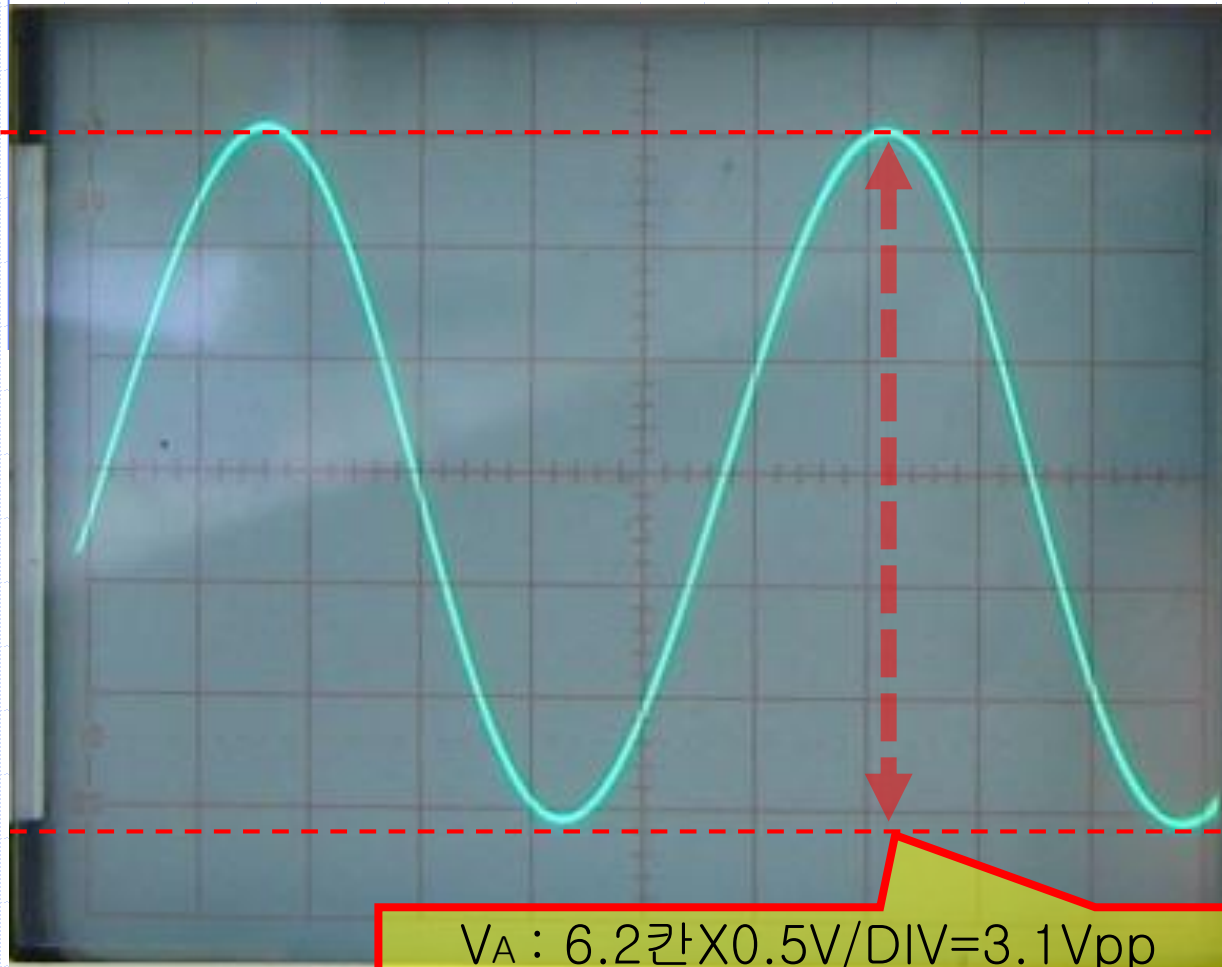
✓ 주파수 : 8kHz



$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{4V_{pp}}{8.4mA_{pp}} \\ &= 476.19\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 9kHz

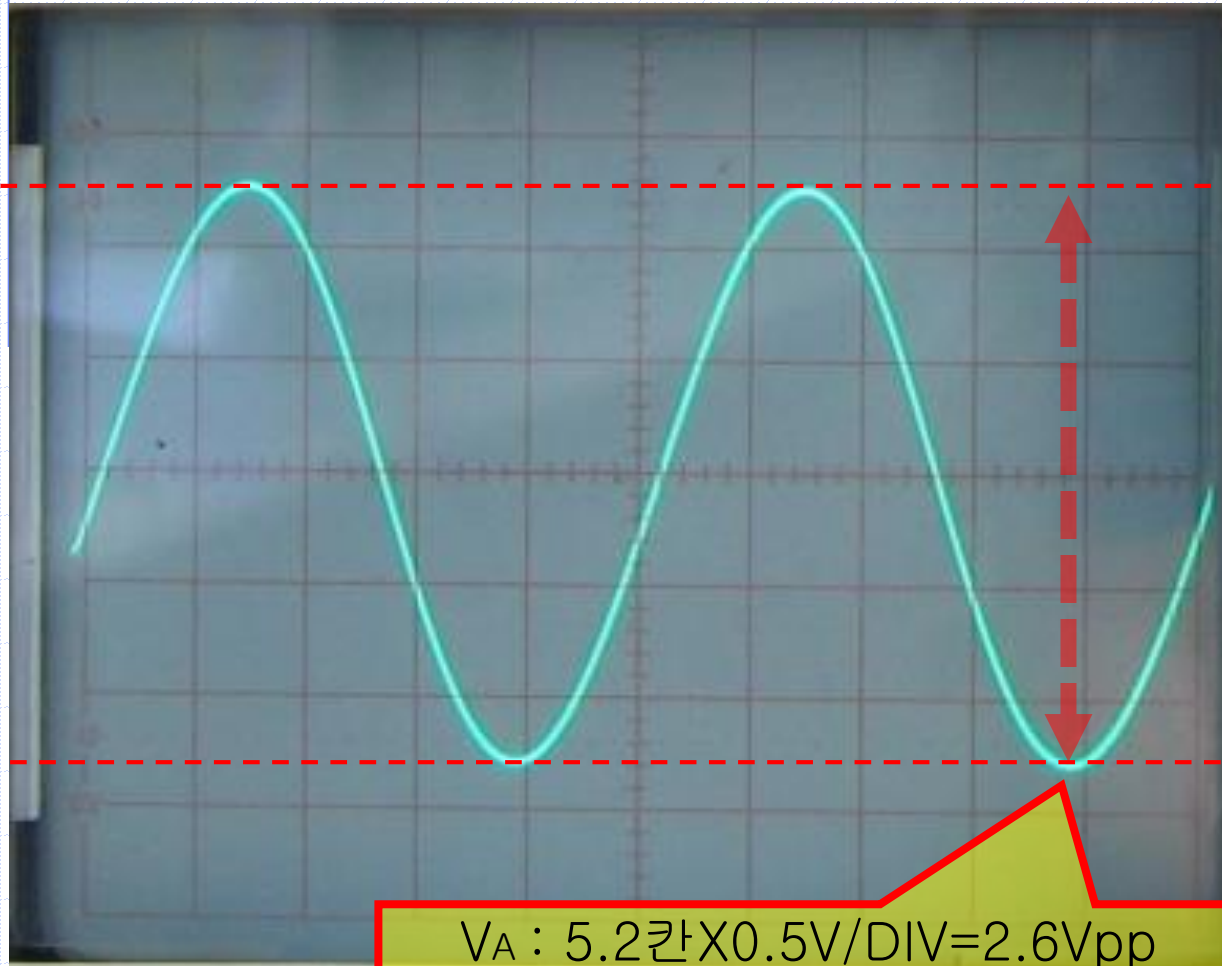


$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{3.1V_{pp}}{8.8mA_{pp}} \\ &= 352.27\Omega \end{aligned}$$

CH 1 : 0.5V/DIV, Time : 20uS/DIV

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 10kHz



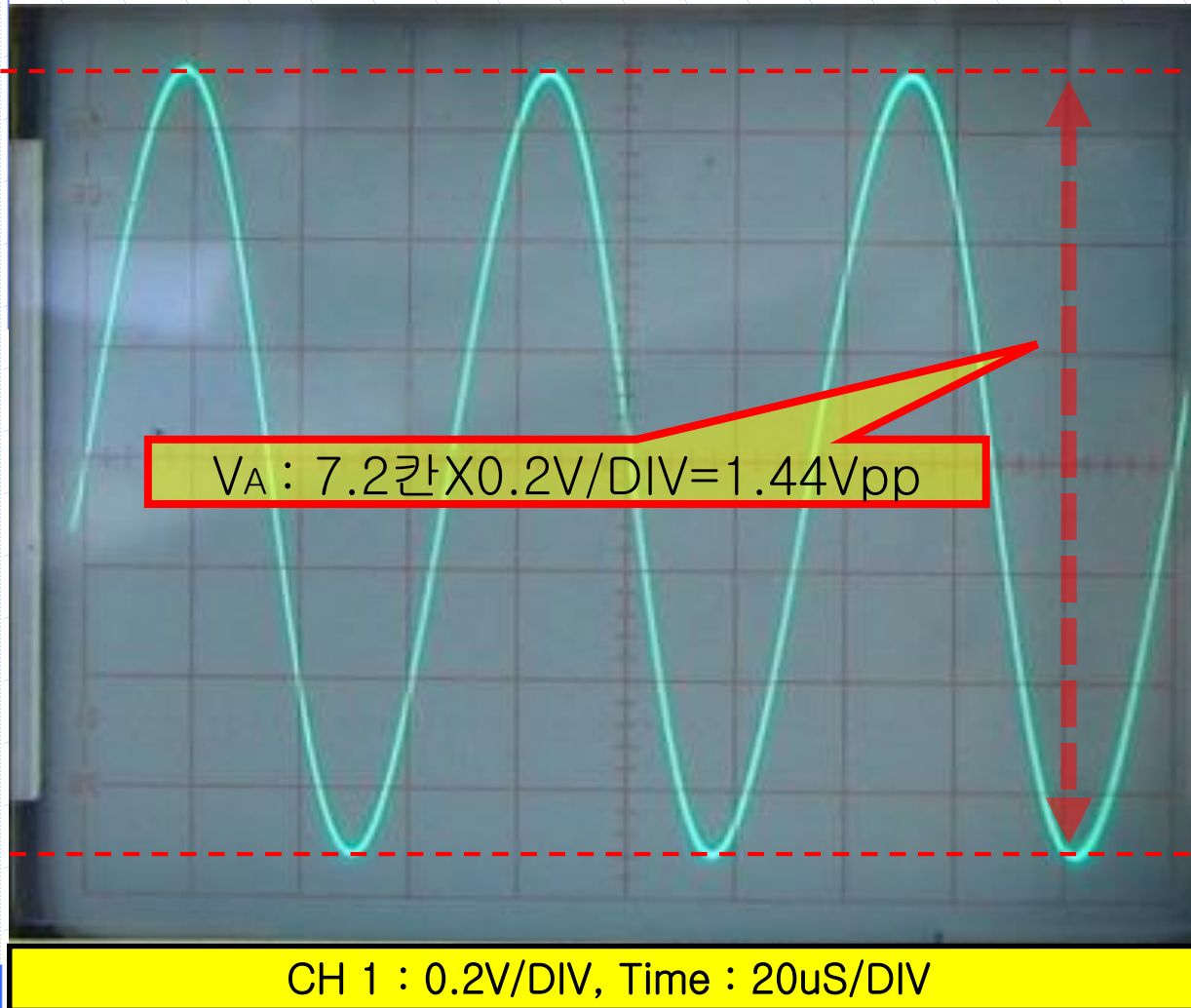
$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{2.6V_{pp}}{9mA_{pp}} \\ &= 288.89\Omega \end{aligned}$$

$V_A : 5.2\text{칸} \times 0.5V/DIV = 2.6V_{pp}$

CH 1 : 0.5V/DIV, Time : 20 μ S/DIV

15-6. 주파수에 따른 전류, 임피던스

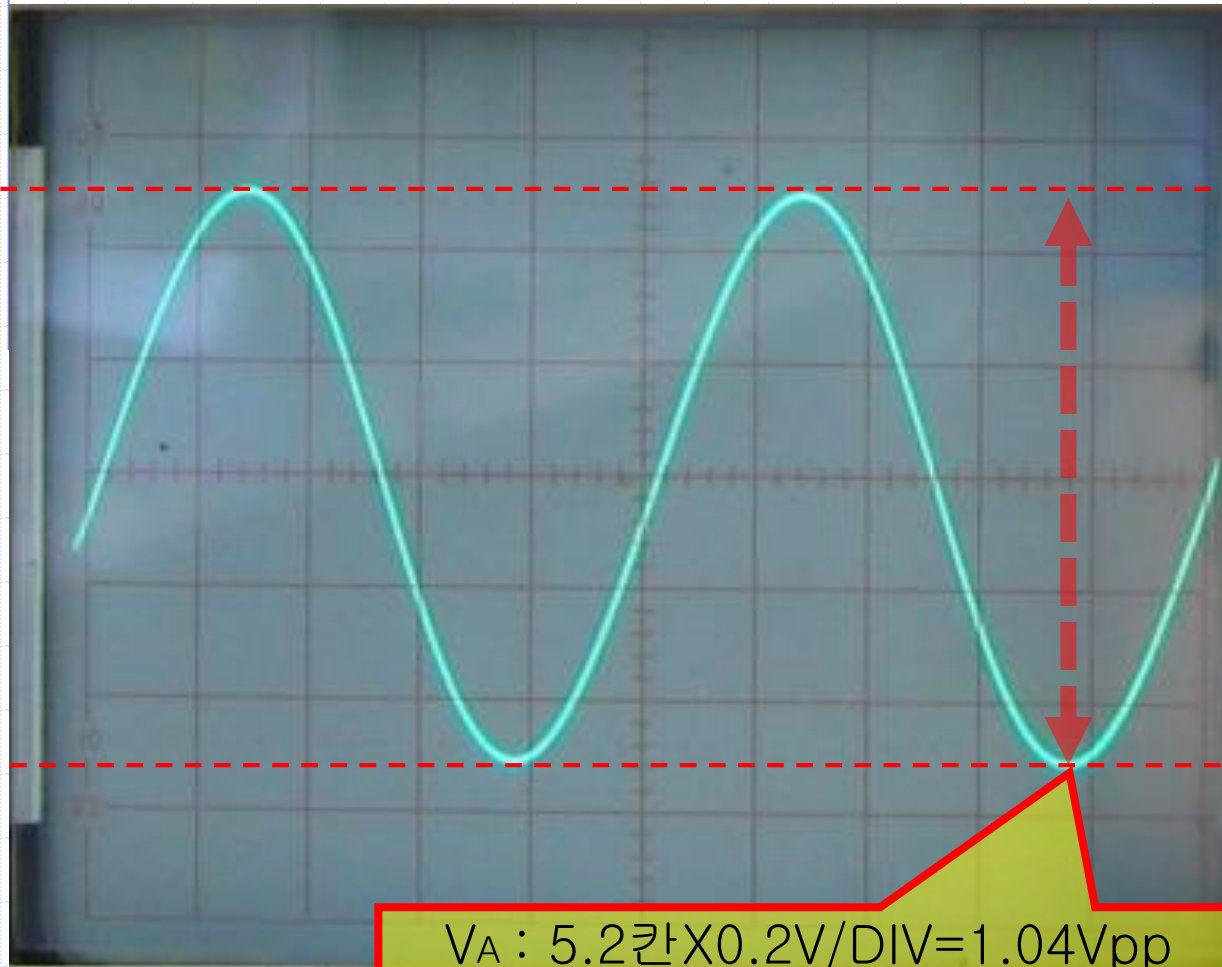
✓ 주파수 : 15kHz



$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{1.44V_{pp}}{9.6mA_{pp}} \\ &= 150\Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 20kHz



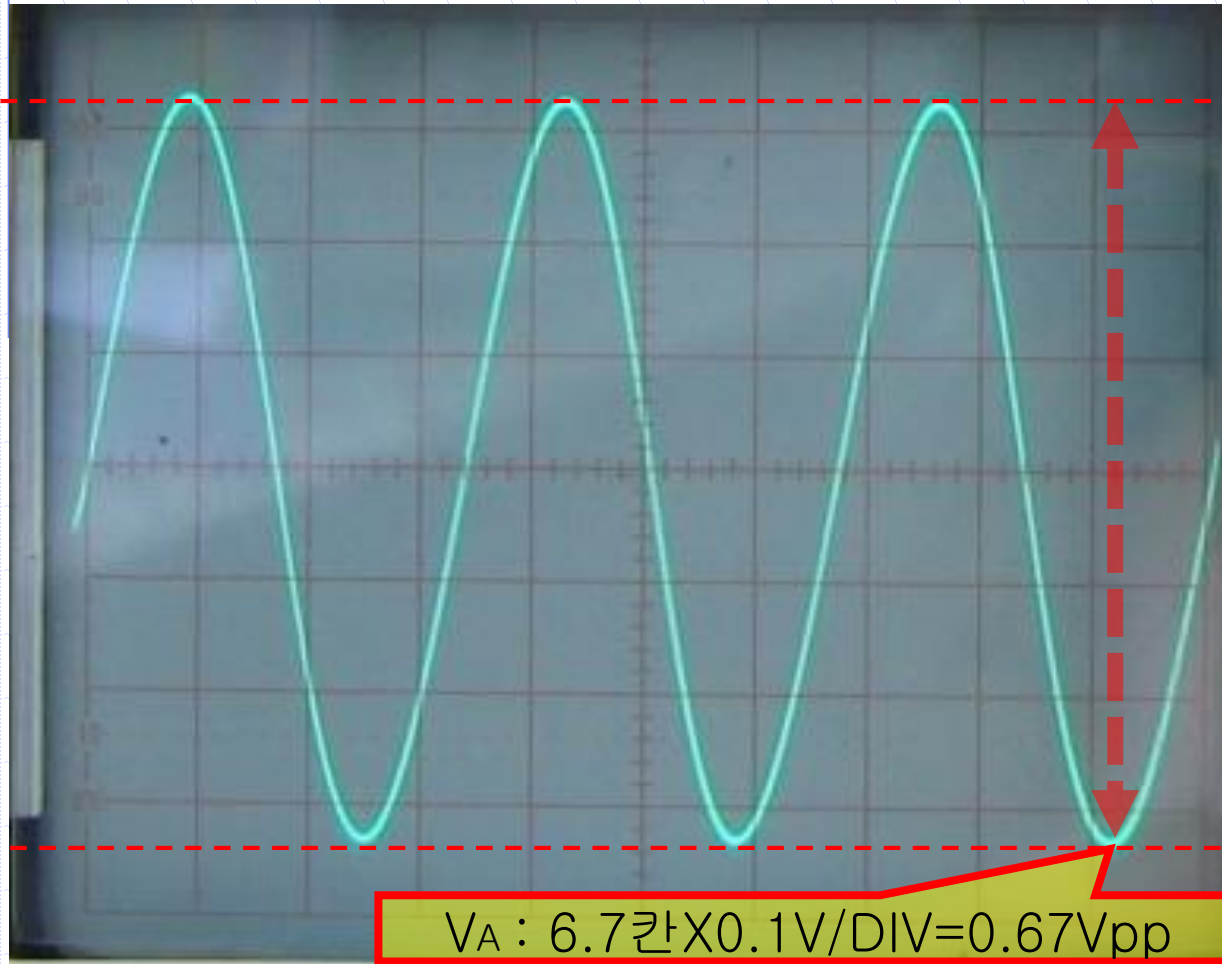
$V_A : 5.2 \text{칸} \times 0.2 \text{V/DIV} = 1.04 \text{V}_{pp}$

CH 1 : 0.2V/DIV, Time : 10μS/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{1.04 V_{pp}}{9.8 \text{mA}_{pp}} \\ &= 106.12 \Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 30kHz



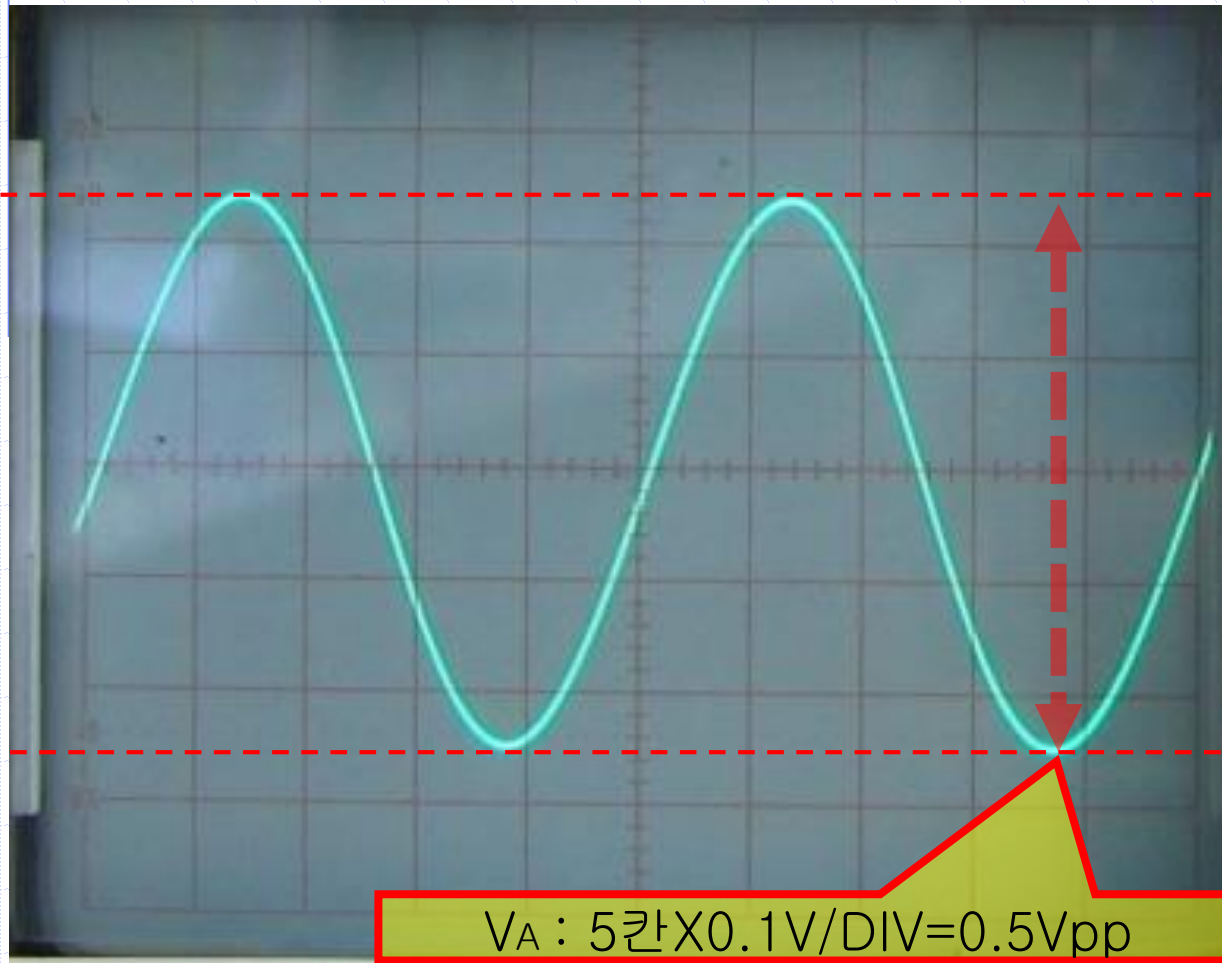
$V_A : 6.7 \text{ 칸} \times 0.1 \text{ V/DIV} = 0.67 \text{ V}_{pp}$

CH 1 : 0.1V/DIV, Time : 10uS/DIV

$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.67 V_{pp}}{9.8 \text{ mA}_{pp}} \\ &= 68.37 \Omega \end{aligned}$$

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 40kHz

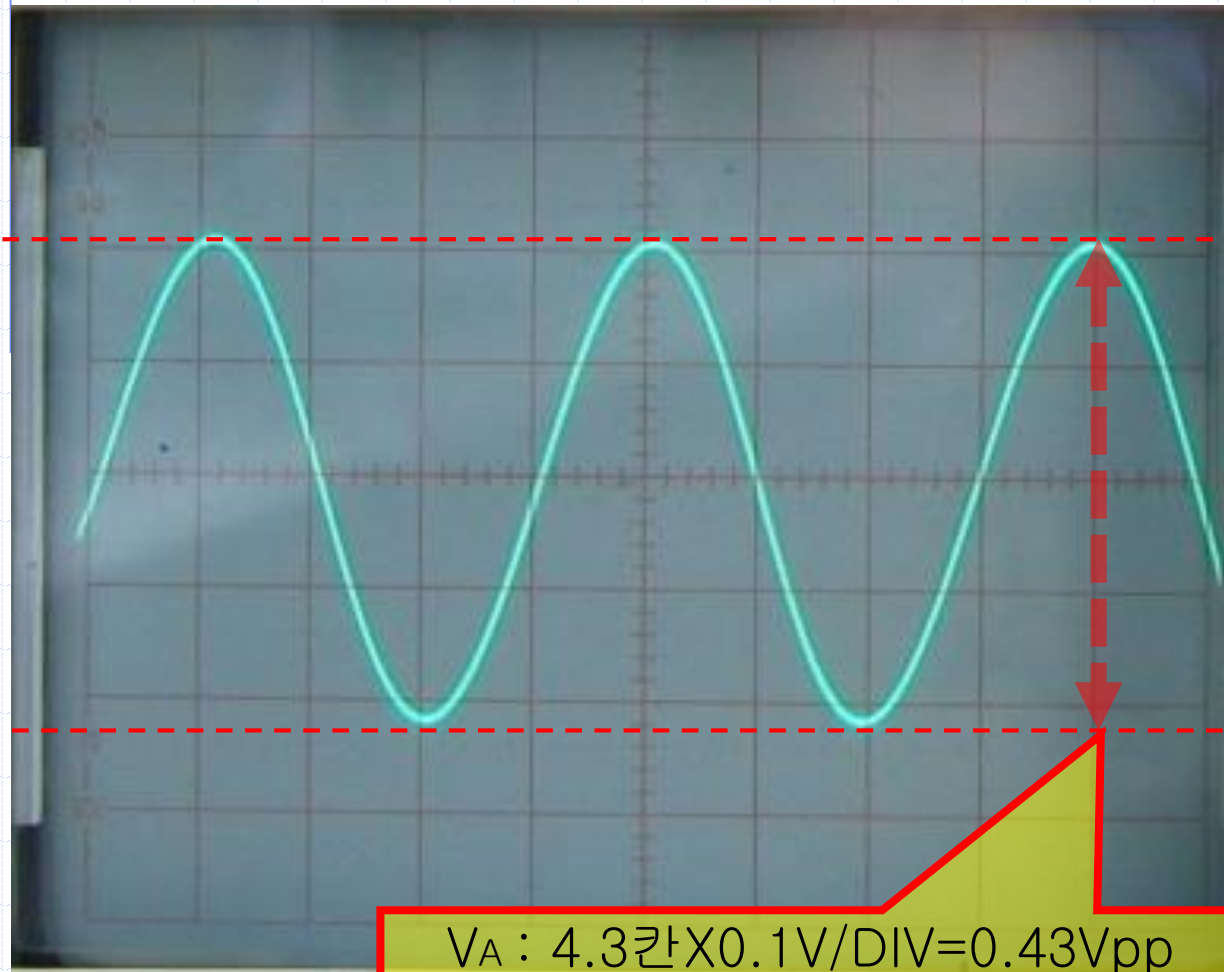


$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.5V_{pp}}{9.8mA_{pp}} \\ &= 51.02\Omega \end{aligned}$$

CH 1 : 0.1V/DIV, Time : 10uS/DIV

15-6. 주파수에 따른 전류, 임피던스

✓ 주파수 : 50kHz

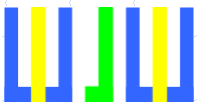


$$\begin{aligned} |Z| &= \frac{V_{AB}}{I_T} \\ &= \frac{0.43V_{pp}}{10mA_{pp}} \\ &= 43\Omega \end{aligned}$$

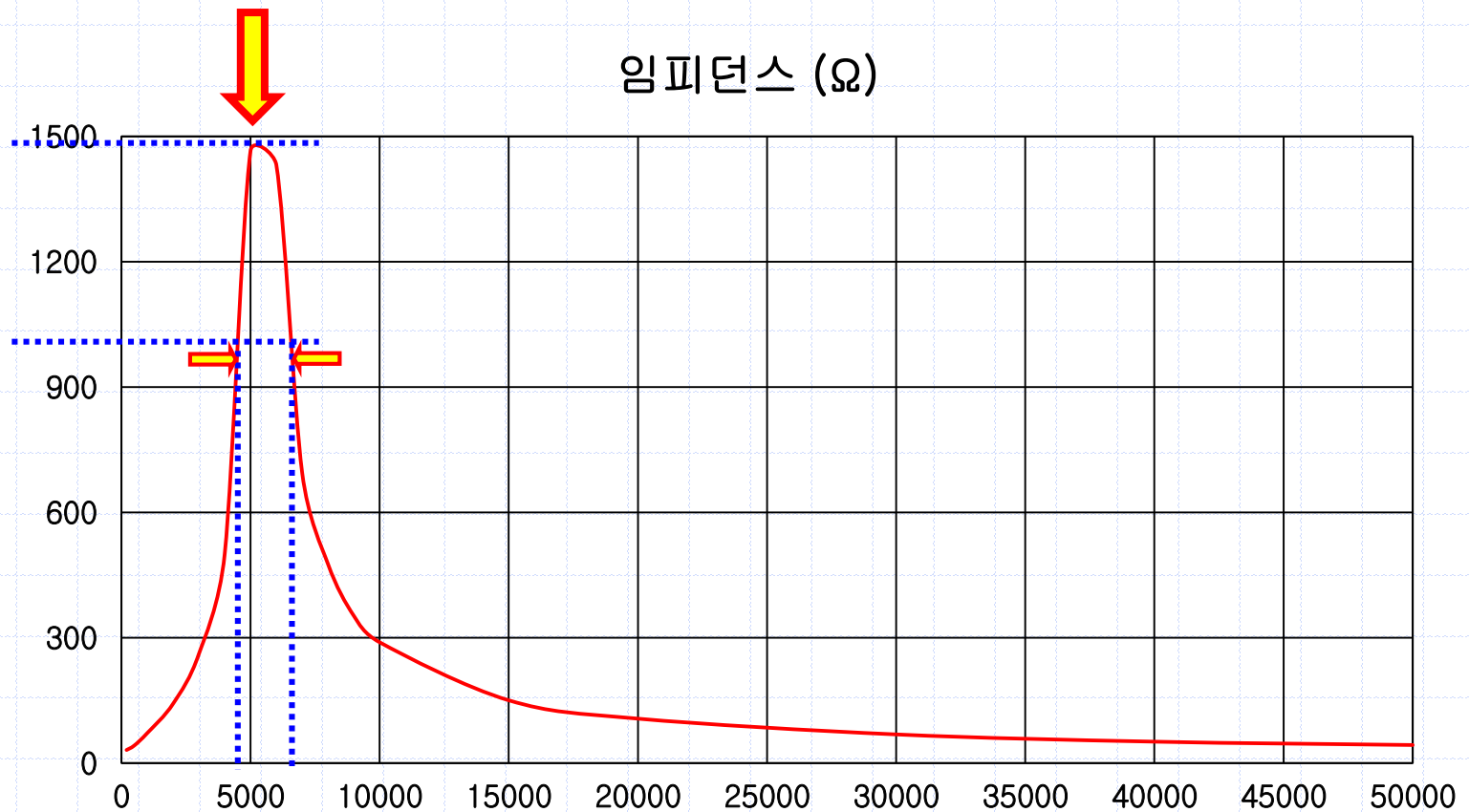
CH 1 : 0.1V/DIV, Time : 10uS/DIV

15-6. 주파수에 따른 전류, 임피던스

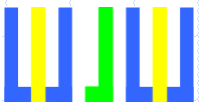
Frequency (Hz)	이 론			실 험		
	VA (Vpp)	전체 전류 IT (mApp)	임피던스 Z (Ω)	VA (Vpp)	전체 전류 IT (mApp)	임피던스 Z (Ω)
200	0.13	10	13.00	0.305	9.8	31.12
500	0.32	9.99	32.03	0.41	9.8	41.84
1,000	0.65	9.98	65.13	0.7	9.8	71.43
2,000	1.48	9.89	149.65	1.36	9.6	141.67
3,000	2.81	9.6	292.71	2.4	9.2	260.87
4,000	5.64	8.26	682.81	4	8.0	500.00
5,000	9.99	0.41	24,365.85	6.3	4.3	1,465.12
6,000	6.67	7.45	895.3	6.3	4.4	1,431.82
7,000	4.26	9.05	470.72	5	7.2	694.44
8,000	3.13	9.5	329.47	4	8.4	476.19
9,000	2.49	9.68	257.23	3.1	8.8	352.27
10,000	2.08	9.78	212.68	2.6	9.0	288.89
15,000	1.19	9.93	119.84	1.44	9.6	150.00
20,000	0.85	9.96	85.34	1.04	9.8	106.12
30,000	0.55	9.99	55.06	0.67	9.8	68.37
40,000	0.4	9.99	40.04	0.5	9.8	51.02
50,000	0.32	9.99	32.03	0.43	10	43.00



15-7. 대역폭 측정

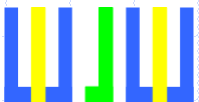
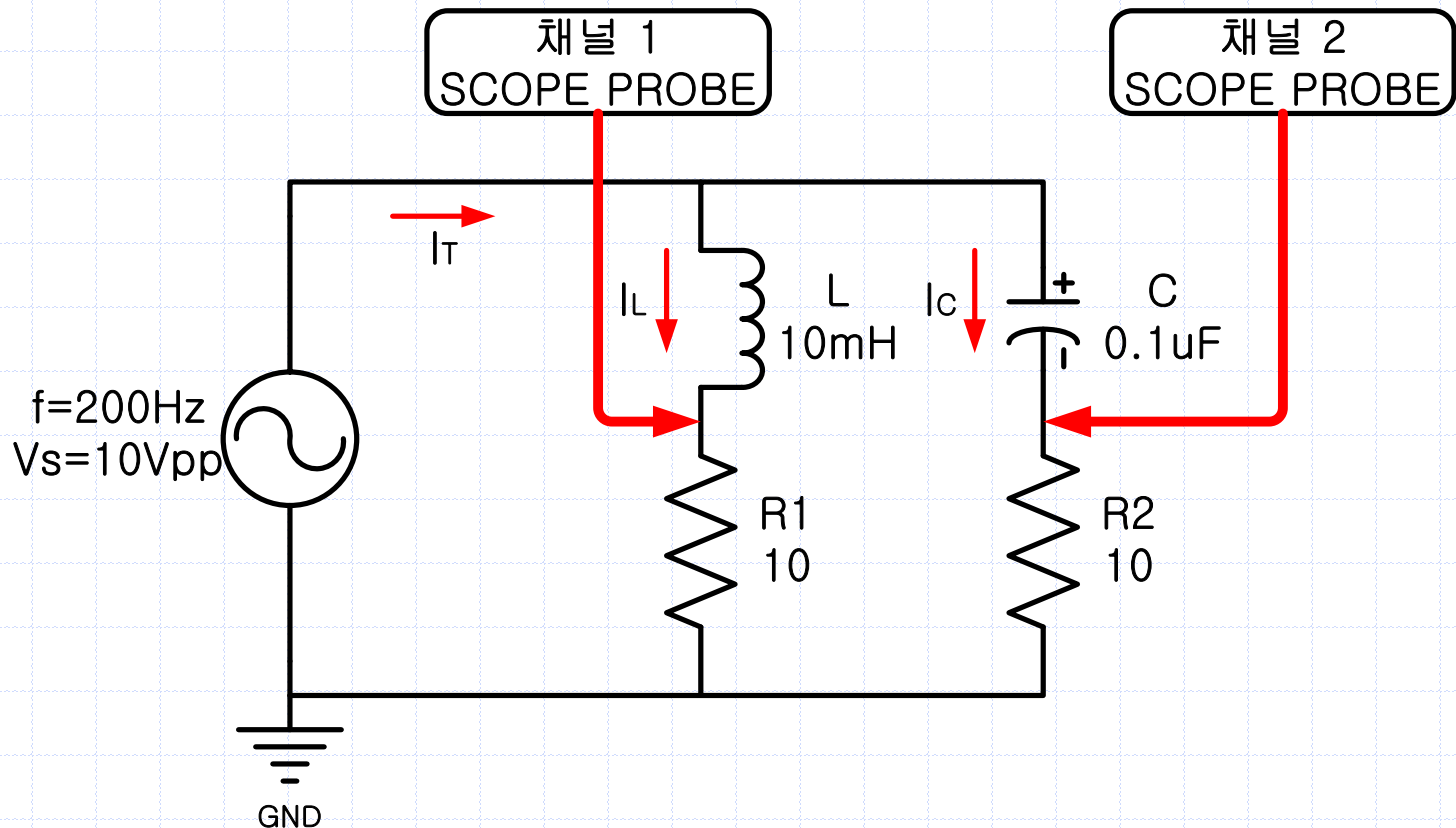


$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10\text{mH} \times 0.1\mu\text{F}}} = 5032.9\text{Hz}$$



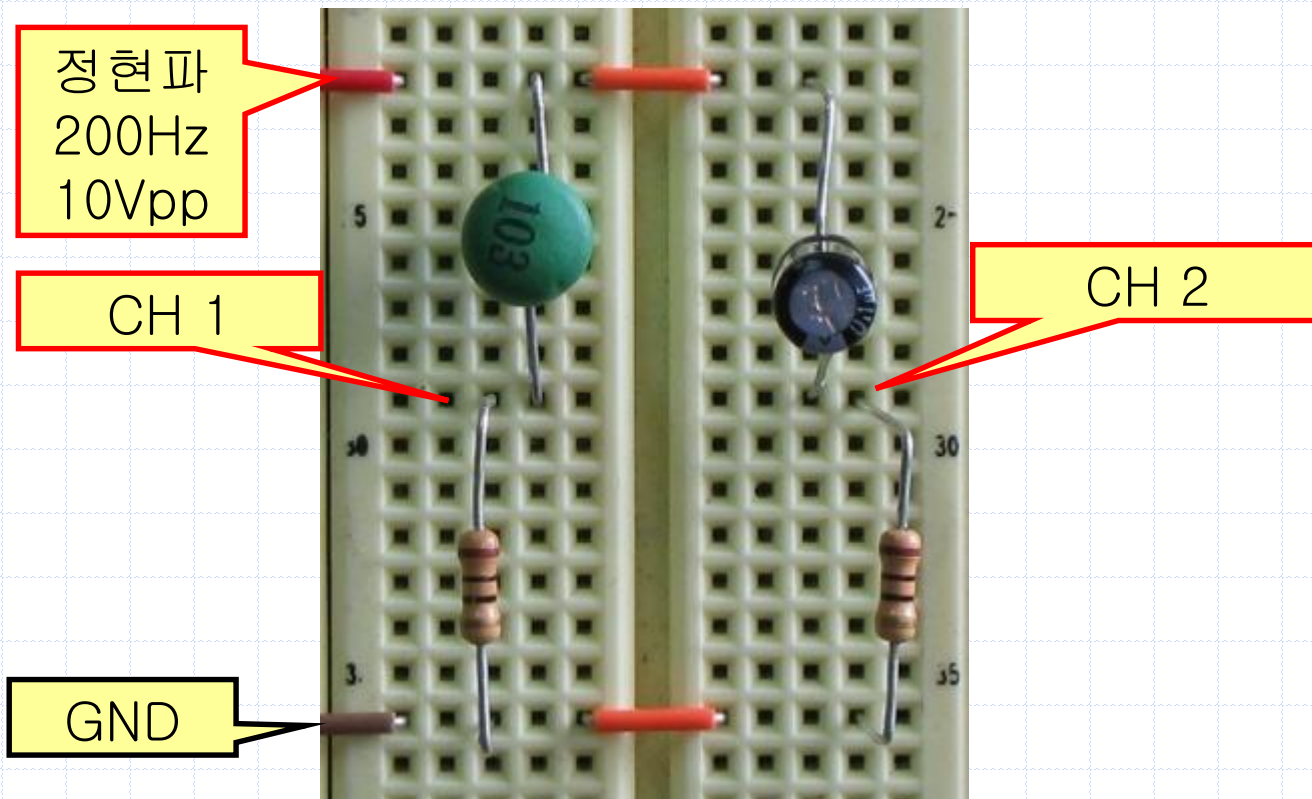
15-8. 주파수에 따른 위상 변화

- 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.

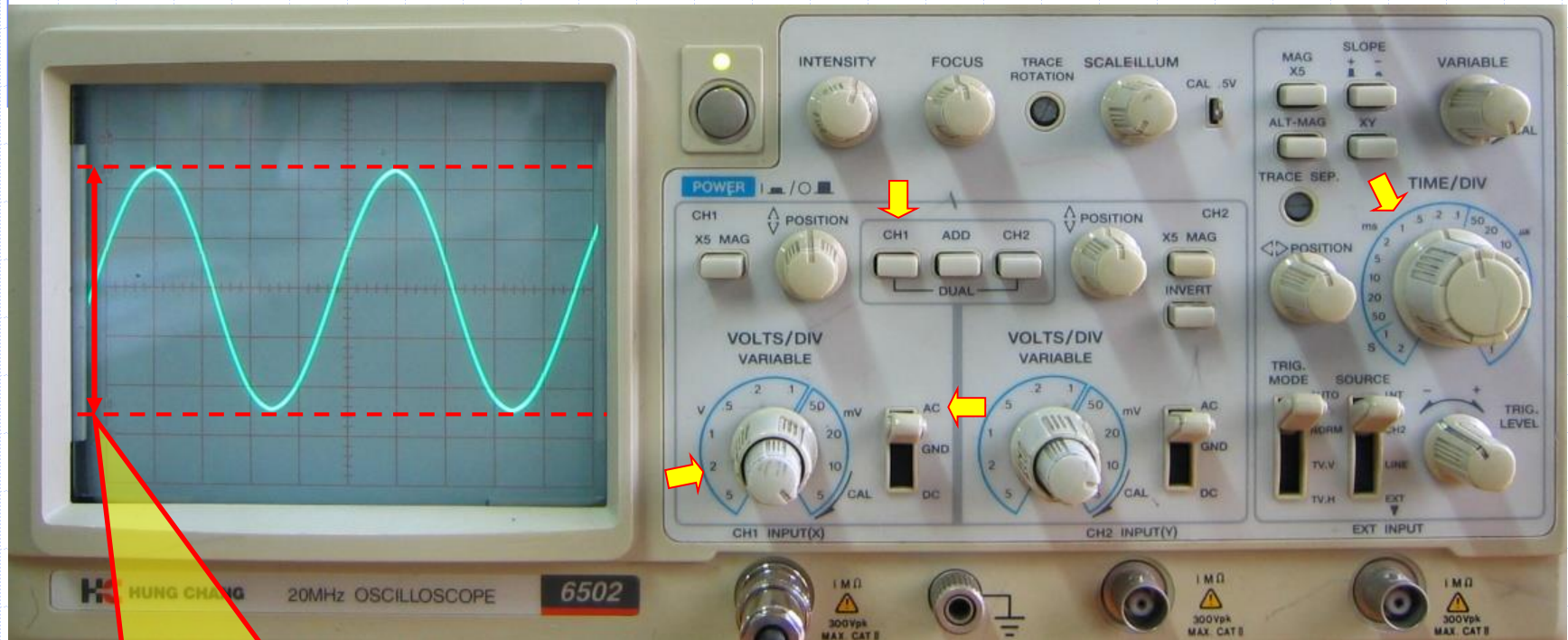
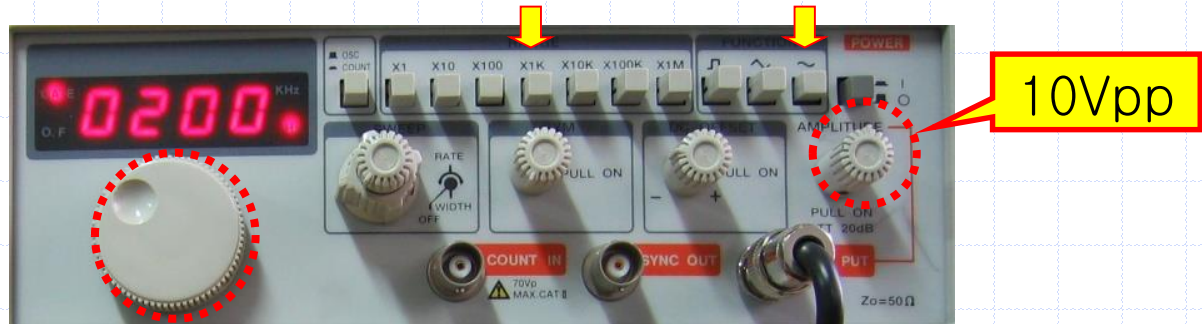


15-8. 주파수에 따른 위상 변화

- ✓ 다음과 같이 회로를 연결하고, 신호발생기를 조절하여 주파수 200Hz, 10Vpp 의 정현파가 나오도록 한다.



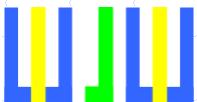
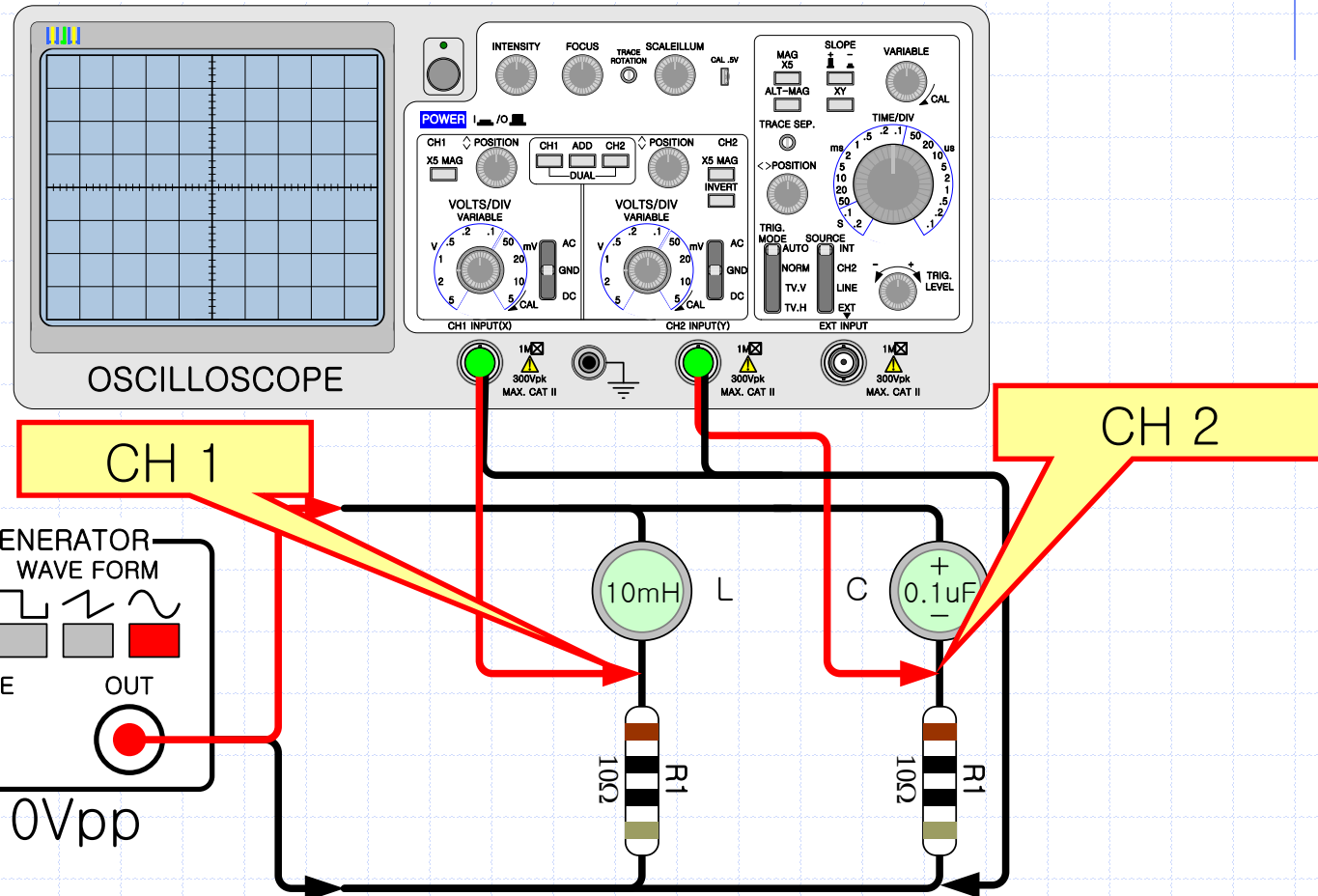
15-8. 주파수에 따른 위상 변화



5칸 X 2V/DIV = 10Vpp

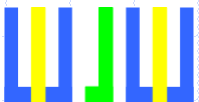
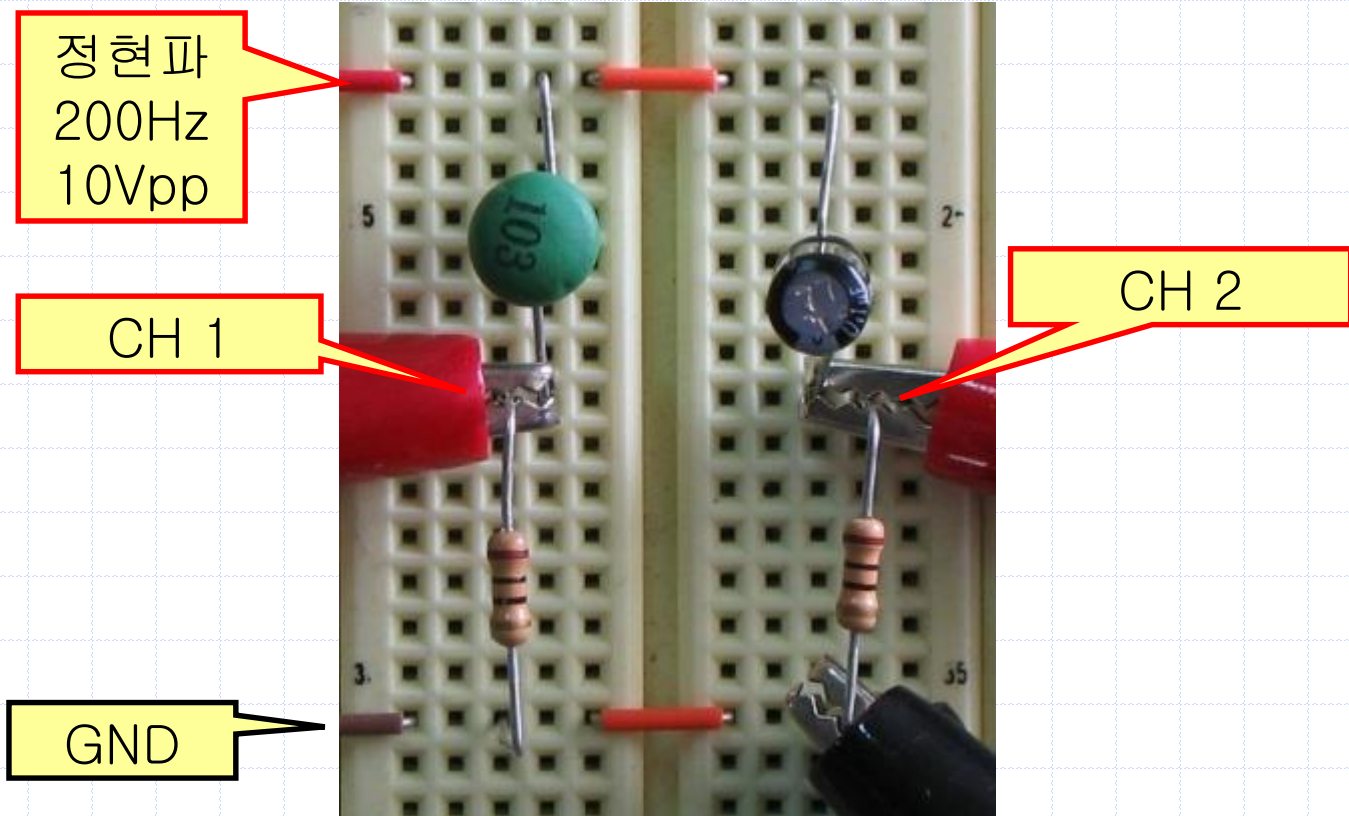
15-8. 주파수에 따른 위상 변화

- ✓ 오실로스코프의 CH 1 을 이용하여 입력 전압(V_{in})을 측정하고, CH 2는 출력 전압(V_{out})을 측정한다.

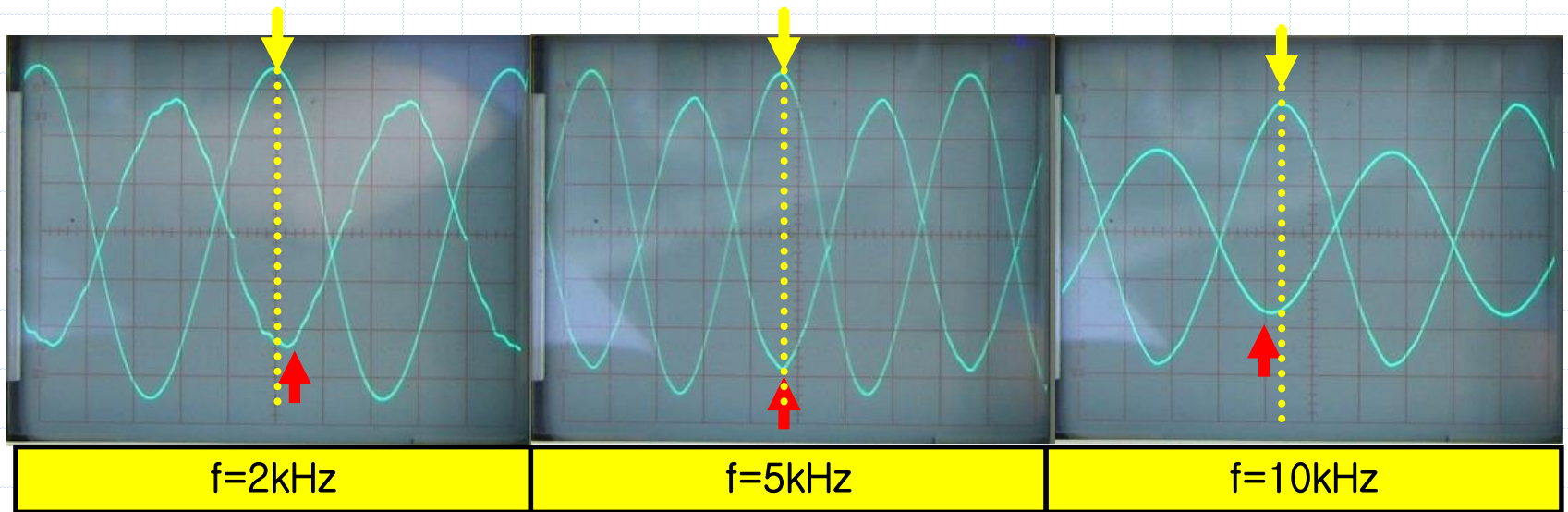


15-8. 주파수에 따른 위상 변화

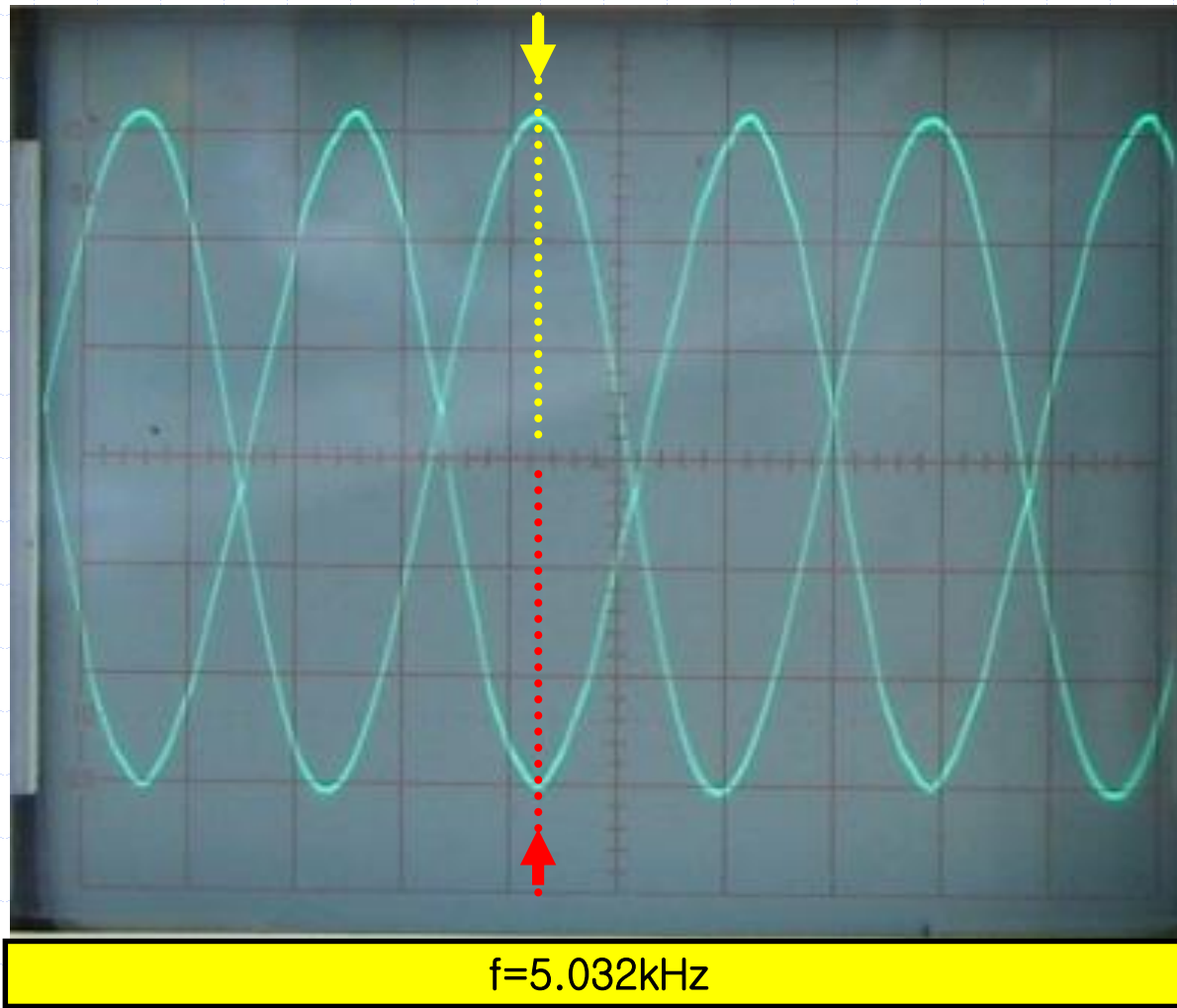
✓ 주파수 : 200Hz



15-8. 주파수에 따른 위상 변화

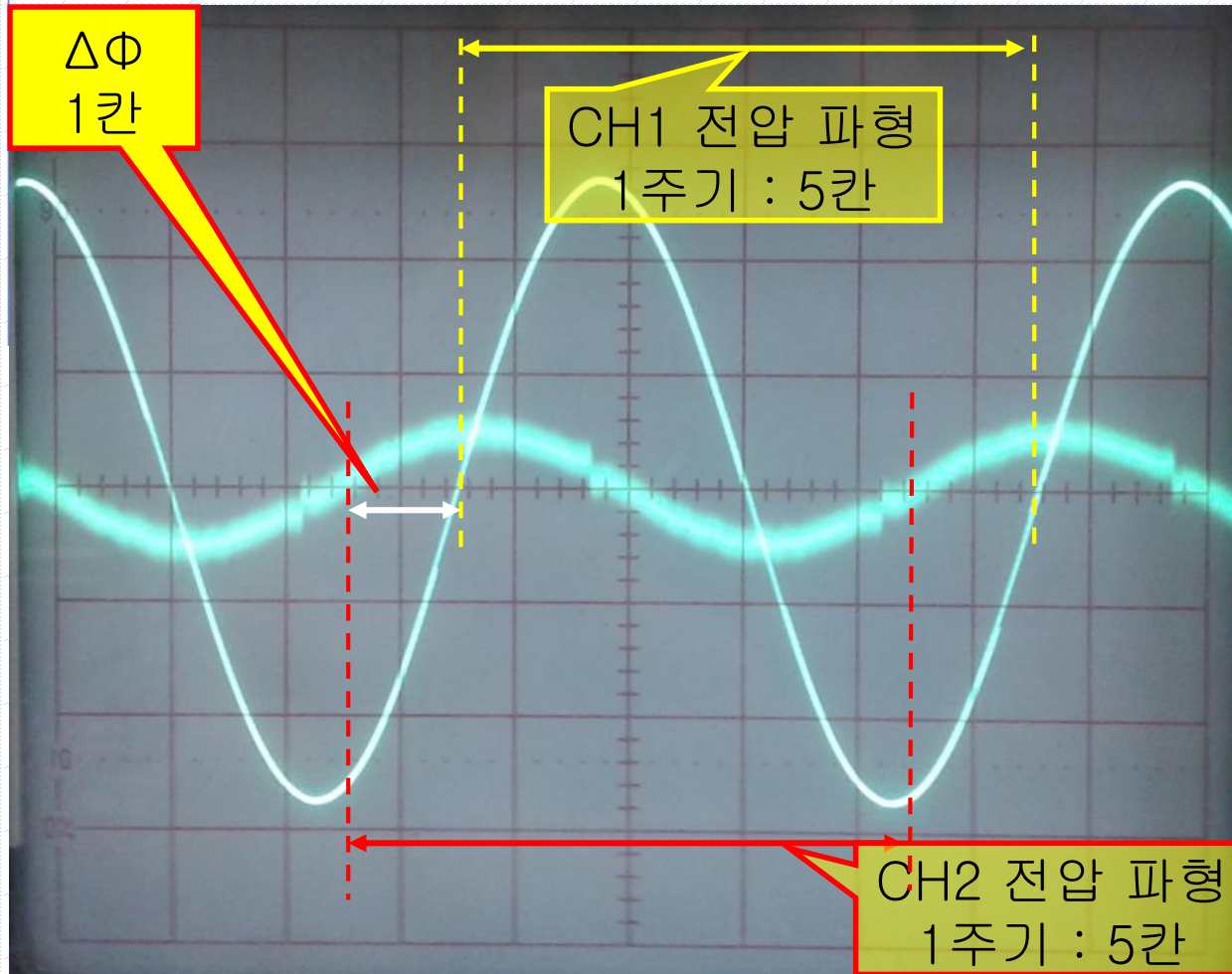


15-8. 주파수에 따른 위상 변화



15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 200Hz)



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

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

$$5\text{mSec} : 1\text{mSec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 72^\circ$$

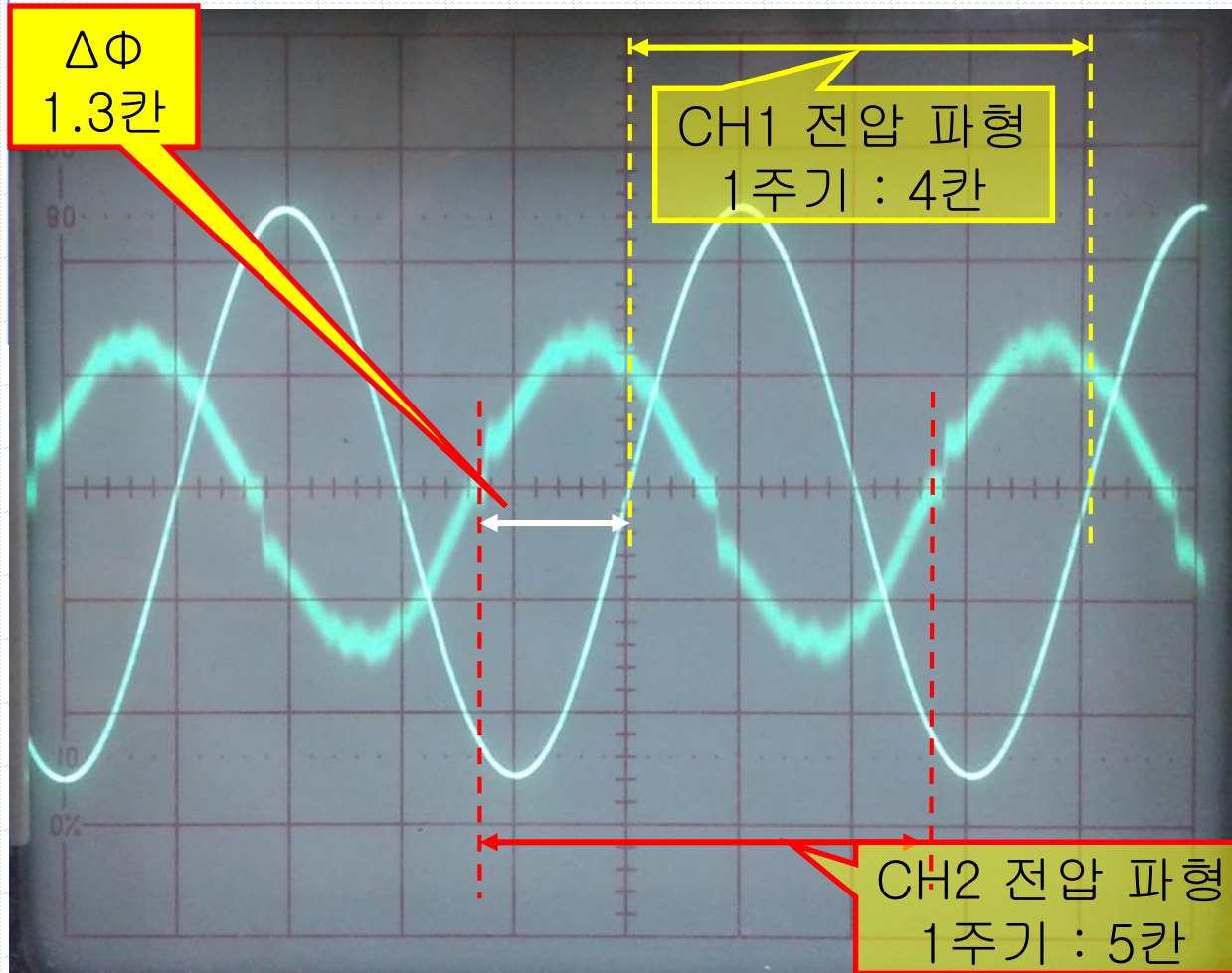
$$V_{R1} = 1.12V_{pp}$$

$$V_{R2} = 6mV_{pp}$$

CH 1 : 0.2V/DIV, CH 2 : 5mV/DIV, Time : 1mS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 500Hz)



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

$$\Delta t = 1.3\text{칸} \times 0.5\text{mSec} = 0.65\text{mSec}$$

$$2\text{mSec} : 0.65\text{mSec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 117^\circ$$

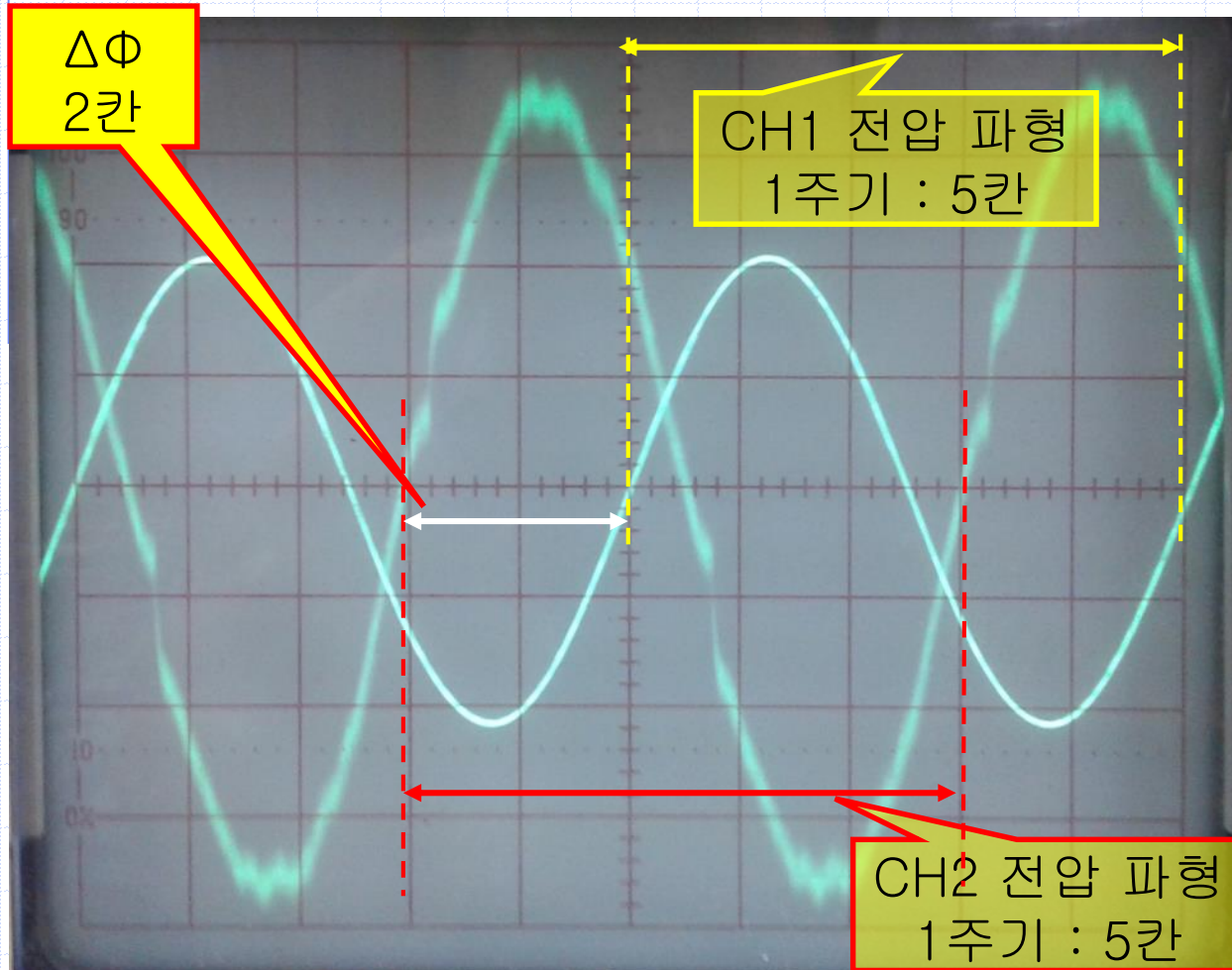
$$V_{R1} = 1.1V_{pp}$$

$$V_{R2} = 15mV_{pp}$$

CH 1 : 0.2V/DIV, CH 2 : 5mV/DIV, Time : 0.5mS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 1kHz)



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

$$\Delta t = 2\text{칸} \times 0.2\text{mSec} = 0.4\text{mSec}$$

$$1\text{mSec} : 0.4\text{mSec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 144^\circ$$

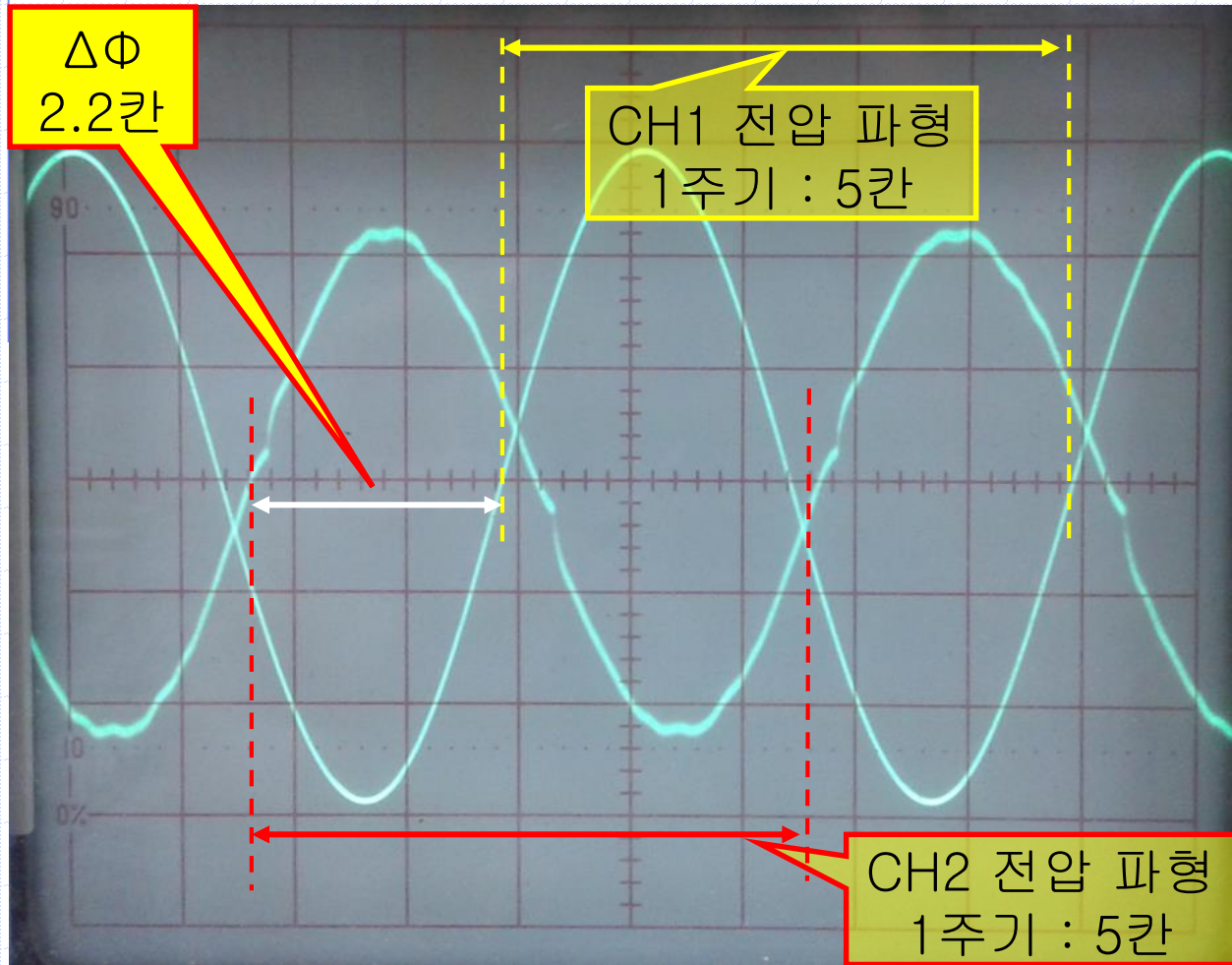
$$V_{R1} = 0.86V_{pp}$$

$$V_{R2} = 38mV_{pp}$$

CH 1 : 0.2V/DIV, CH 2 : 5mV/DIV, Time : 0.2mS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 2kHz)



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

$$\Delta t = 2.2\text{칸} \times 0.1\text{mSec} \\ = 0.22\text{mSec}$$

$$0.5\text{mSec} : 0.22\text{mSec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 144^\circ$$

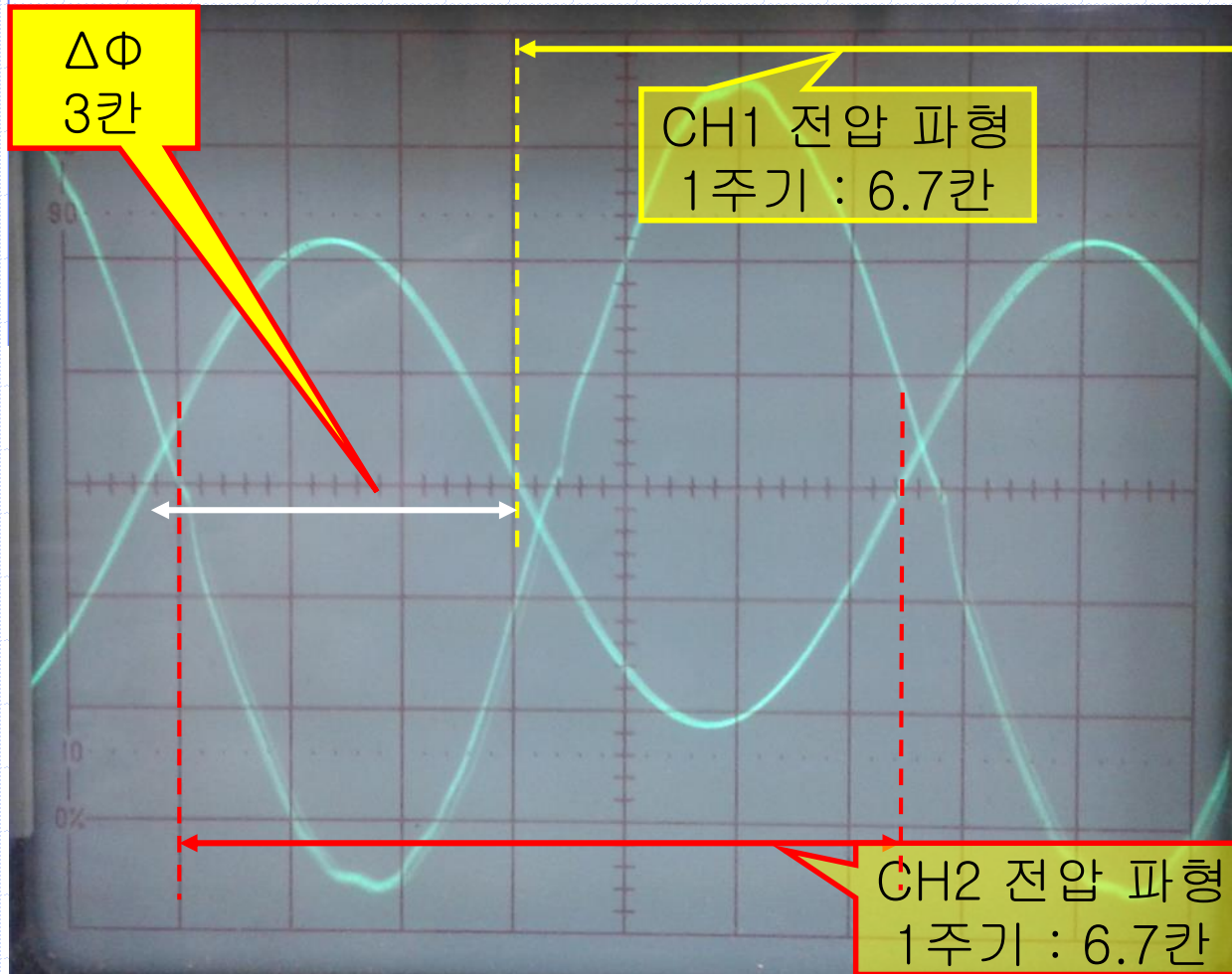
$$V_{R1} = 0.6V_{pp}$$

$$V_{R2} = 88mV_{pp}$$

CH 1 : 0.1V/DIV, CH 2 : 20mV/DIV, Time : 0.1mS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 3kHz)



$$1T = 6.67 \text{ 칸} \times 50 \mu\text{Sec} \\ = 333.3 \mu\text{Sec}$$

$$\Delta t = 3 \text{ 칸} \times 50 \mu\text{Sec} \\ = 150 \mu\text{Sec}$$

$$333.3 \mu\text{Sec} : 150 \mu\text{Sec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 162^\circ$$

$$V_{R1} = 0.44 V_{pp}$$

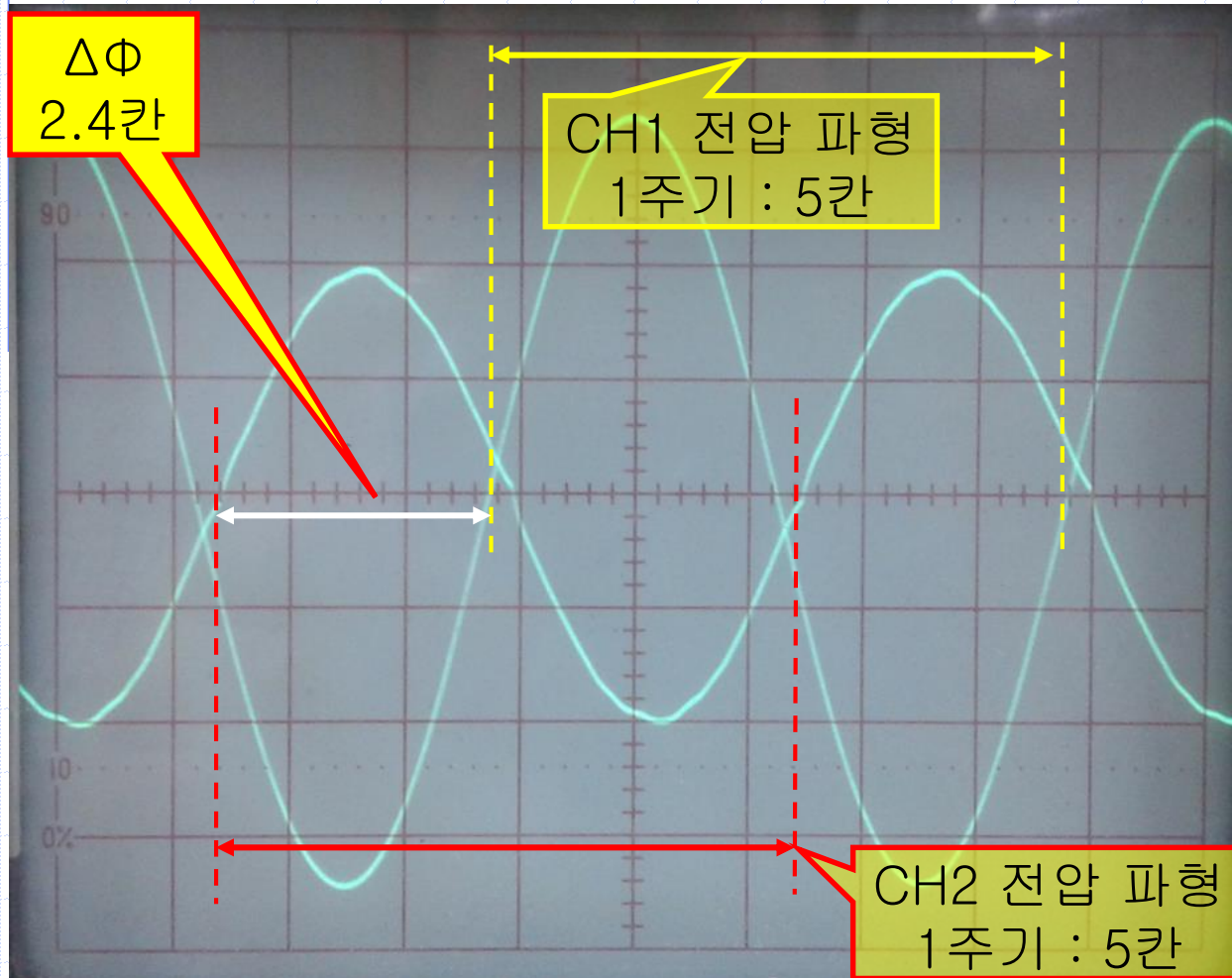
$$V_{R2} = 150 mV_{pp}$$

CH2 전압 파형
1 주기 : 6.7 칸

CH 1 : 0.1V/DIV, CH 2 : 20mV/DIV, Time : 50uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 4kHz)



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

$$\Delta t = 2.4\text{칸} \times 50\mu\text{Sec} = 120\mu\text{Sec}$$

$$250\mu\text{Sec} : 120\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 172.8^\circ$$

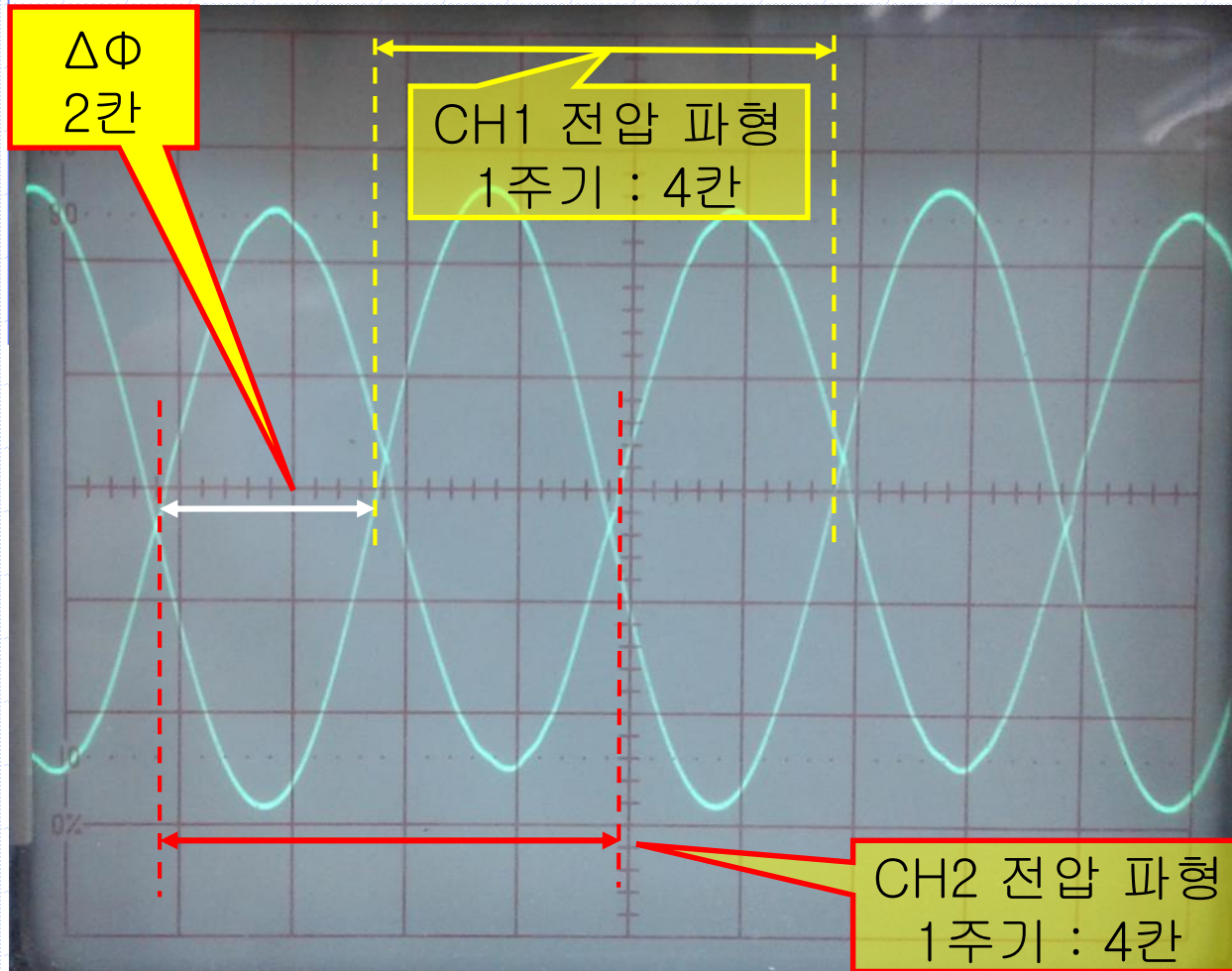
$$V_{R1} = 350\text{mV}_{pp}$$

$$V_{R2} = 200\text{mV}_{pp}$$

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

15-8. 주파수에 따른 위상 변화

- ✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 5kHz)



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

$$\Delta t = 2\cancel{\text{칸}} \times 50\mu\text{Sec} \\ = 100\mu\text{Sec}$$

$$200\mu\text{Sec} : 100\mu\text{Sec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 180^\circ$$

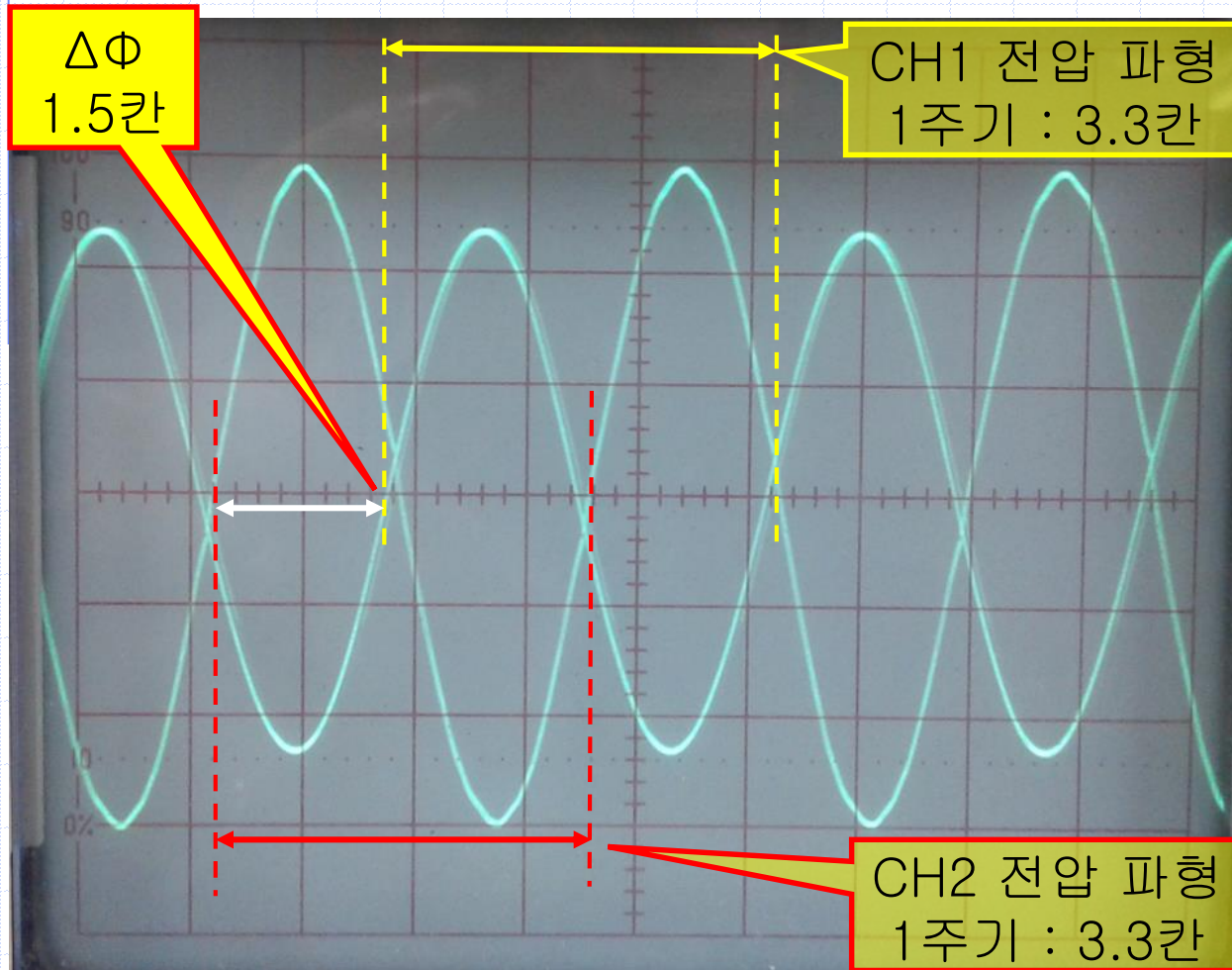
$$V_{R1} = 290\text{mV}_{pp}$$

$$V_{R2} = 280\text{mV}_{pp}$$

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

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 6kHz)



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

$$\Delta t = 1.5\text{칸} \times 50\mu\text{Sec} = 75\mu\text{Sec}$$

$$165\mu\text{Sec} : 75\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 163.6^\circ$$

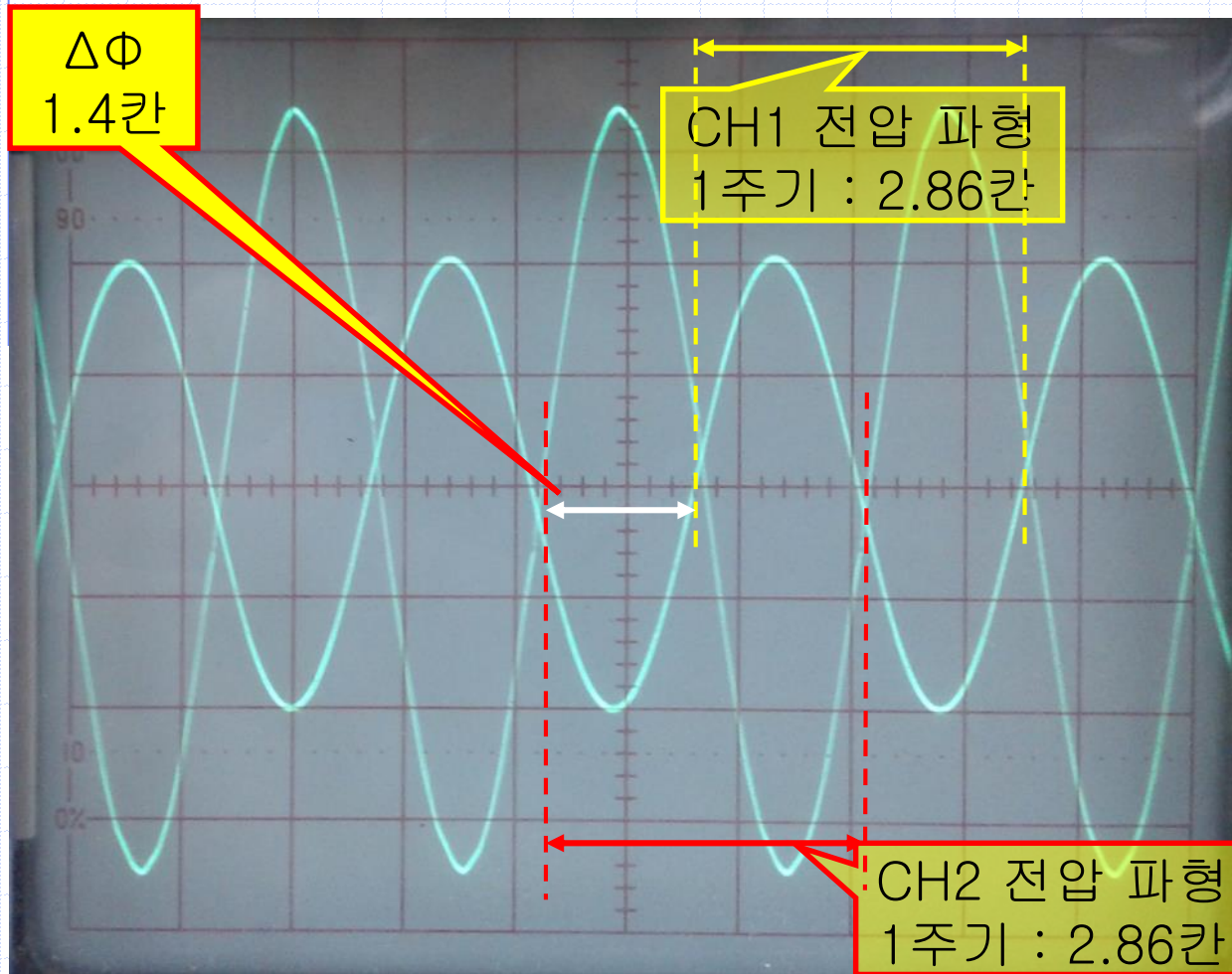
$$V_{R1} = 240\text{mV}_{pp}$$

$$V_{R2} = 300\text{mV}_{pp}$$

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

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 7kHz)



$$1T = 2.86 \text{칸} \times 50\mu\text{Sec} \\ = 143\mu\text{Sec}$$

$$\Delta t = 1.4 \text{칸} \times 50\mu\text{Sec} \\ = 70\mu\text{Sec}$$

$$143\mu\text{Sec} : 70\mu\text{Sec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 176.2^\circ$$

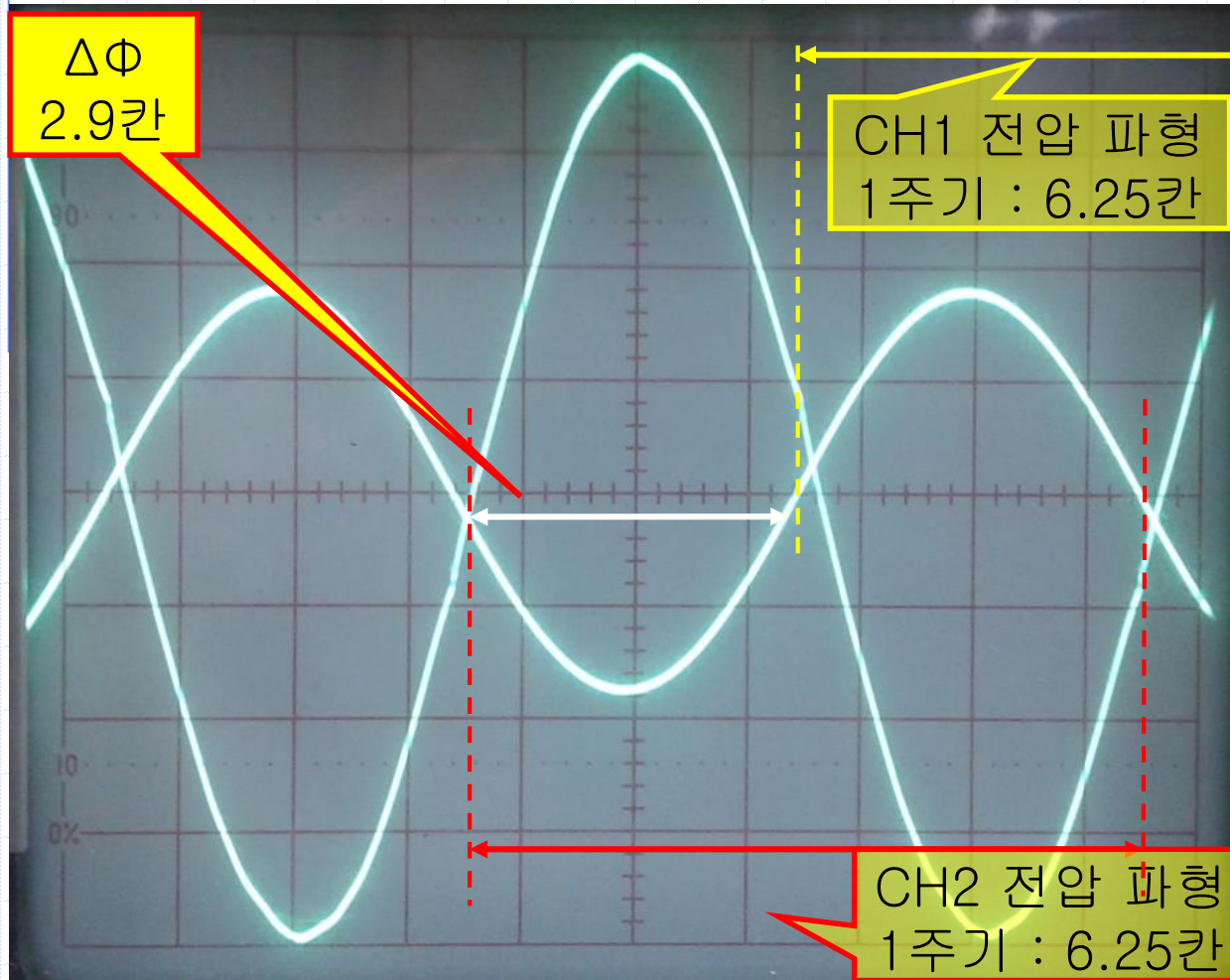
$$V_{R1} = 205mV_{pp}$$

$$V_{R2} = 350mV_{pp}$$

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

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 8kHz)



$$1T = 6.25 \text{칸} \times 20 \mu\text{Sec} = 125 \mu\text{Sec}$$

$$\Delta t = 2.9 \text{칸} \times 20 \mu\text{Sec} = 58 \mu\text{Sec}$$

$$125 \mu\text{Sec} : 58 \mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 167^\circ$$

$$V_{R1} = 180 \text{mV}_{pp}$$

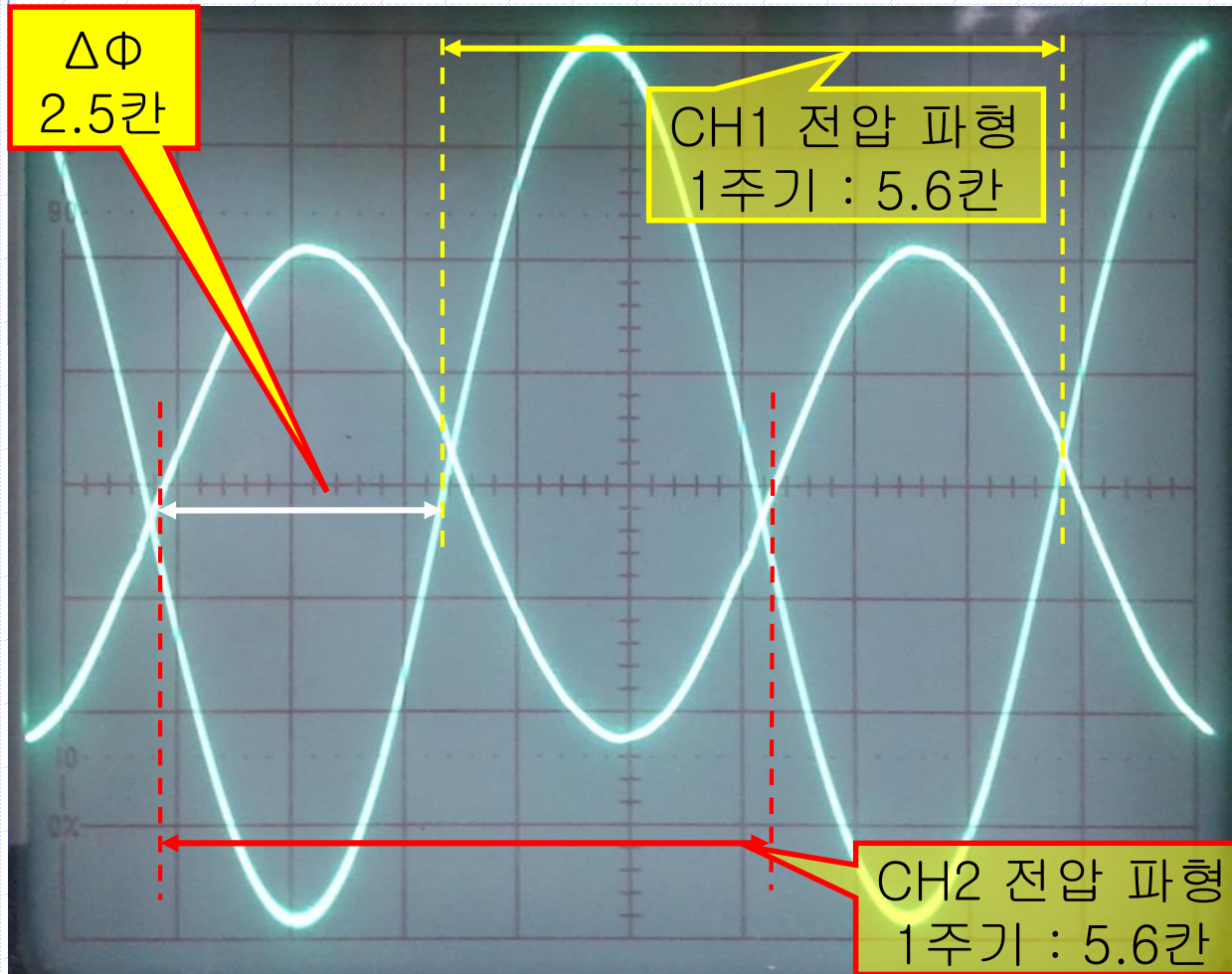
$$V_{R2} = 400 \text{mV}_{pp}$$

CH2 전압 파형
1주기 : 6.25칸

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

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 9kHz)



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

$$\Delta t = 2.5 \text{칸} \times 20\mu\text{Sec} = 50\mu\text{Sec}$$

$$112\mu\text{Sec} : 50\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 160.7^\circ$$

$$V_{R1} = 160\text{mV}_{pp}$$

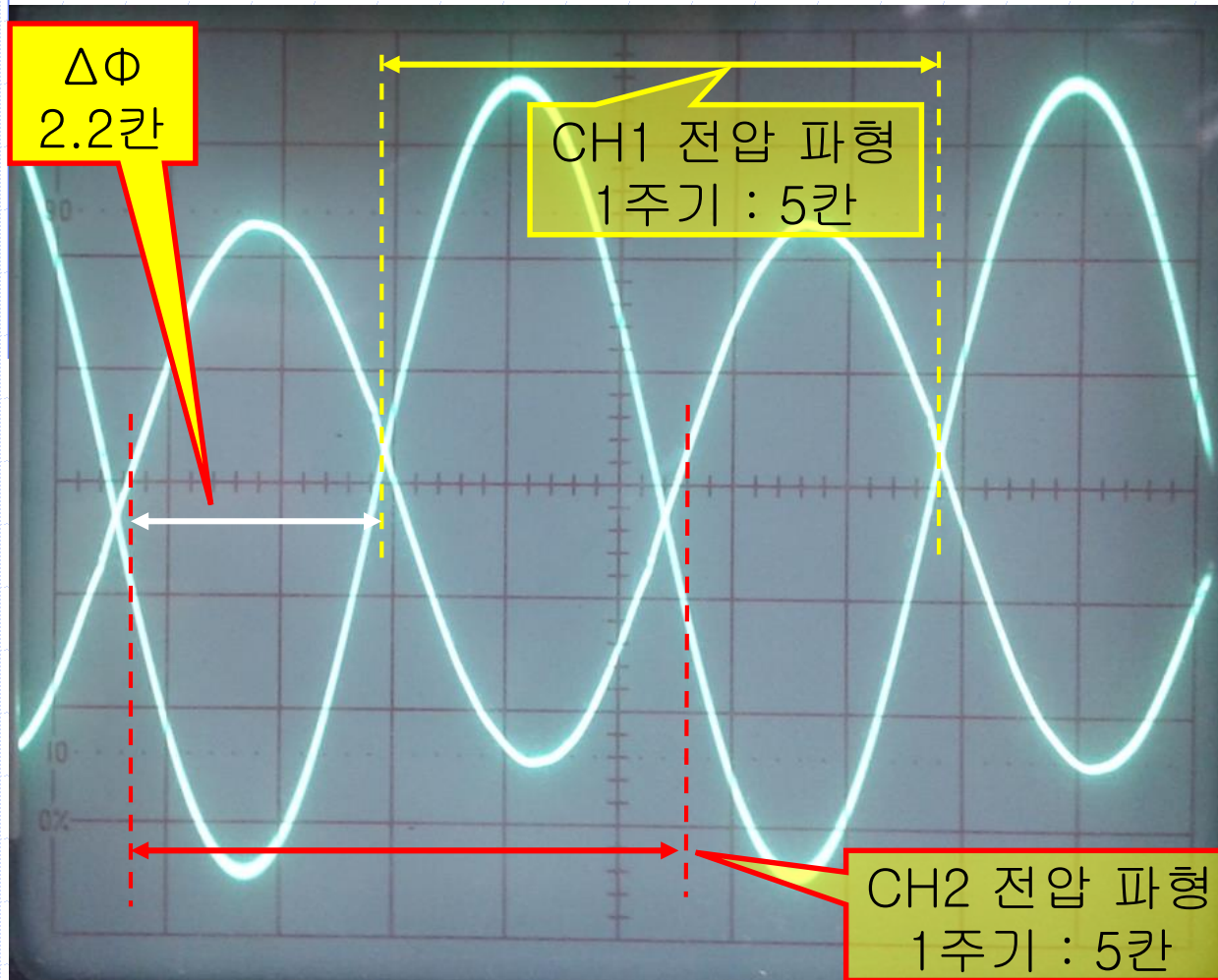
$$V_{R2} = 430\text{mV}_{pp}$$

CH2 전압 파형
1주기 : 5.6칸

CH 1 : 20mV/DIV, CH 2 : 0.1V/DIV, Time : 20uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 10kHz)



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

$$\Delta t = 2.2\text{칸} \times 20\mu\text{Sec} = 44\mu\text{Sec}$$

$$100\mu\text{Sec} : 44\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 158.4^\circ$$

$$V_{R1} = 140\text{mV}_{pp}$$

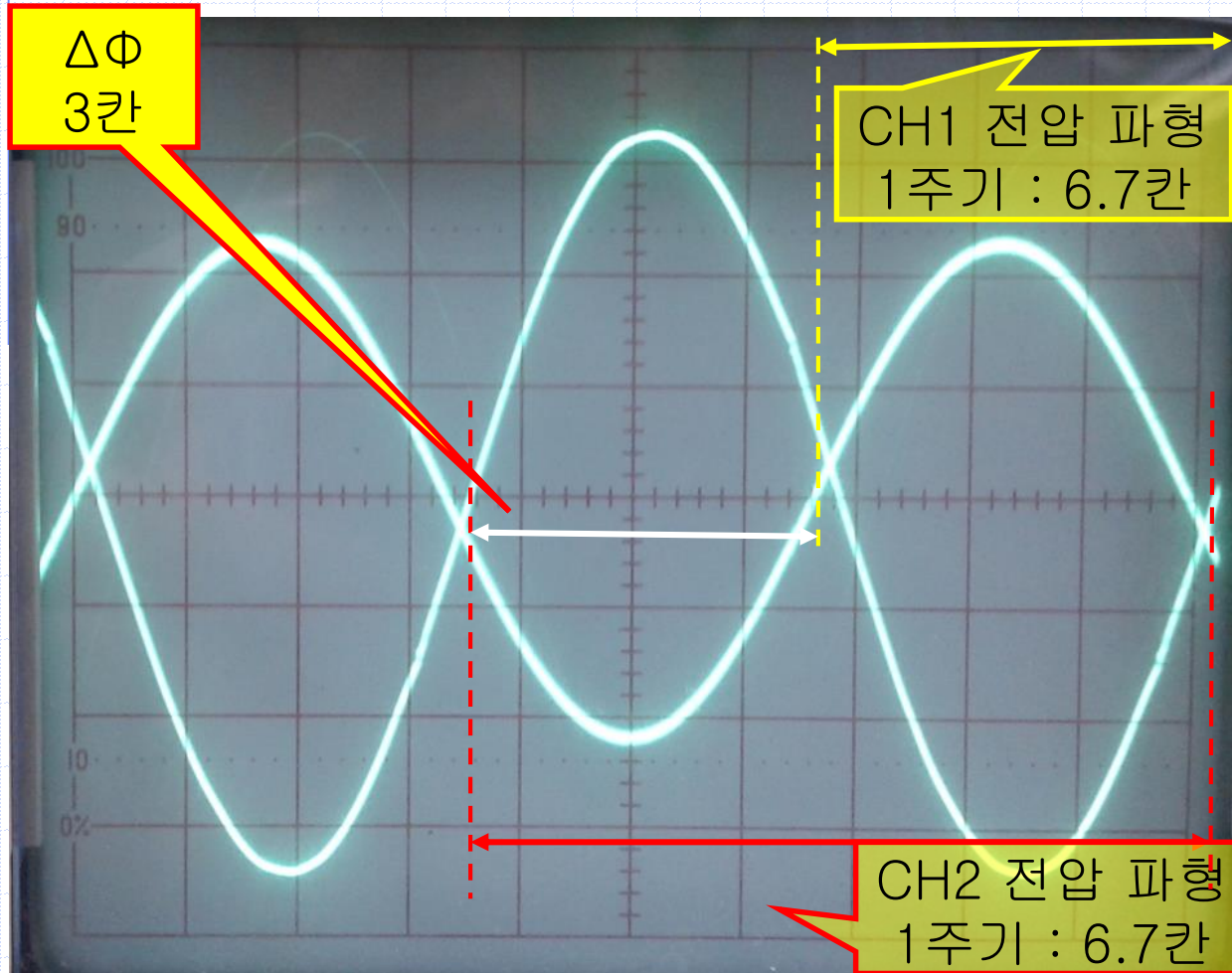
$$V_{R2} = 500\text{mV}_{pp}$$

CH2 전압 파형
1주기 : 5칸

CH 1 : 20mV/DIV, CH 2 : 0.1V/DIV, Time : 20uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 15kHz)



$$1T = 6.7 \text{ 칸} \times 10 \mu\text{Sec} = 67 \mu\text{Sec}$$

$$\Delta t = 3 \text{ 칸} \times 10 \mu\text{Sec} = 30 \mu\text{Sec}$$

$$67 \mu\text{Sec} : 30 \mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 161.2^\circ$$

$$V_{R1} = 90 \text{ mV}_{pp}$$

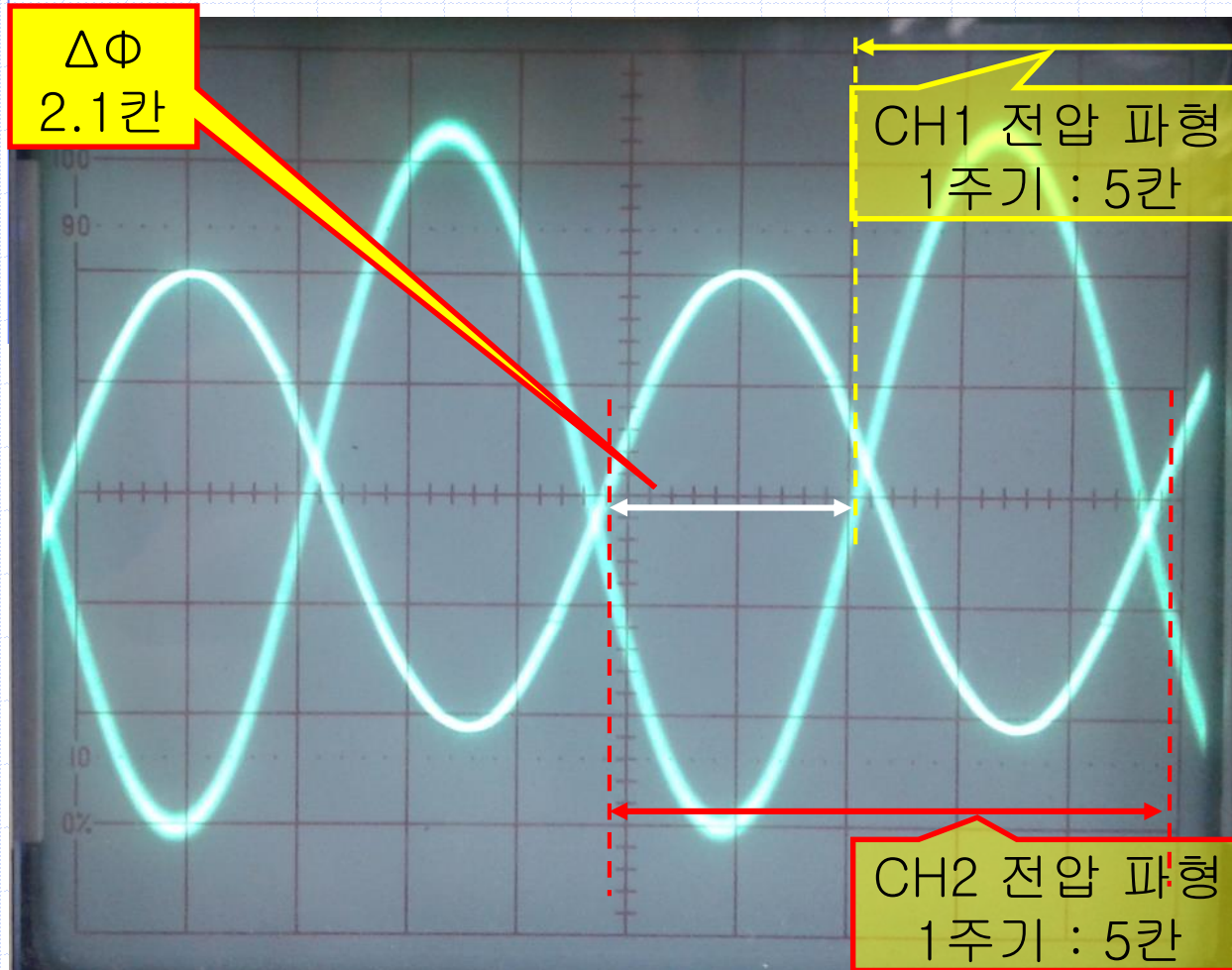
$$V_{R2} = 700 \text{ mV}_{pp}$$

CH2 전압 파형
1주기 : 6.7칸

CH 1 : 20mV/DIV, CH 2 : 0.1V/DIV, Time : 10uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 20kHz)



$$1T = 5\cancel{\text{칸}} \times 10\mu\text{Sec} = 50\mu\text{Sec}$$

$$\Delta t = 2.1\cancel{\text{칸}} \times 10\mu\text{Sec} = 21\mu\text{Sec}$$

$$50\mu\text{Sec} : 21\mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 151.2^\circ$$

$$V_{R1} = 65mV_{pp}$$

$$V_{R2} = 850mV_{pp}$$

CH 1 : 10mV/DIV, CH 2 : 0.2V/DIV, Time : 10uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 30kHz)



$$1T = 3.3 \text{칸} \times 10 \mu\text{Sec} = 33 \mu\text{Sec}$$

$$\Delta t = 1.8 \text{칸} \times 10 \mu\text{Sec} = 18 \mu\text{Sec}$$

$$33 \mu\text{Sec} : 18 \mu\text{Sec} = 360^\circ : \Delta\theta$$

$$\Delta\theta = 196.4^\circ$$

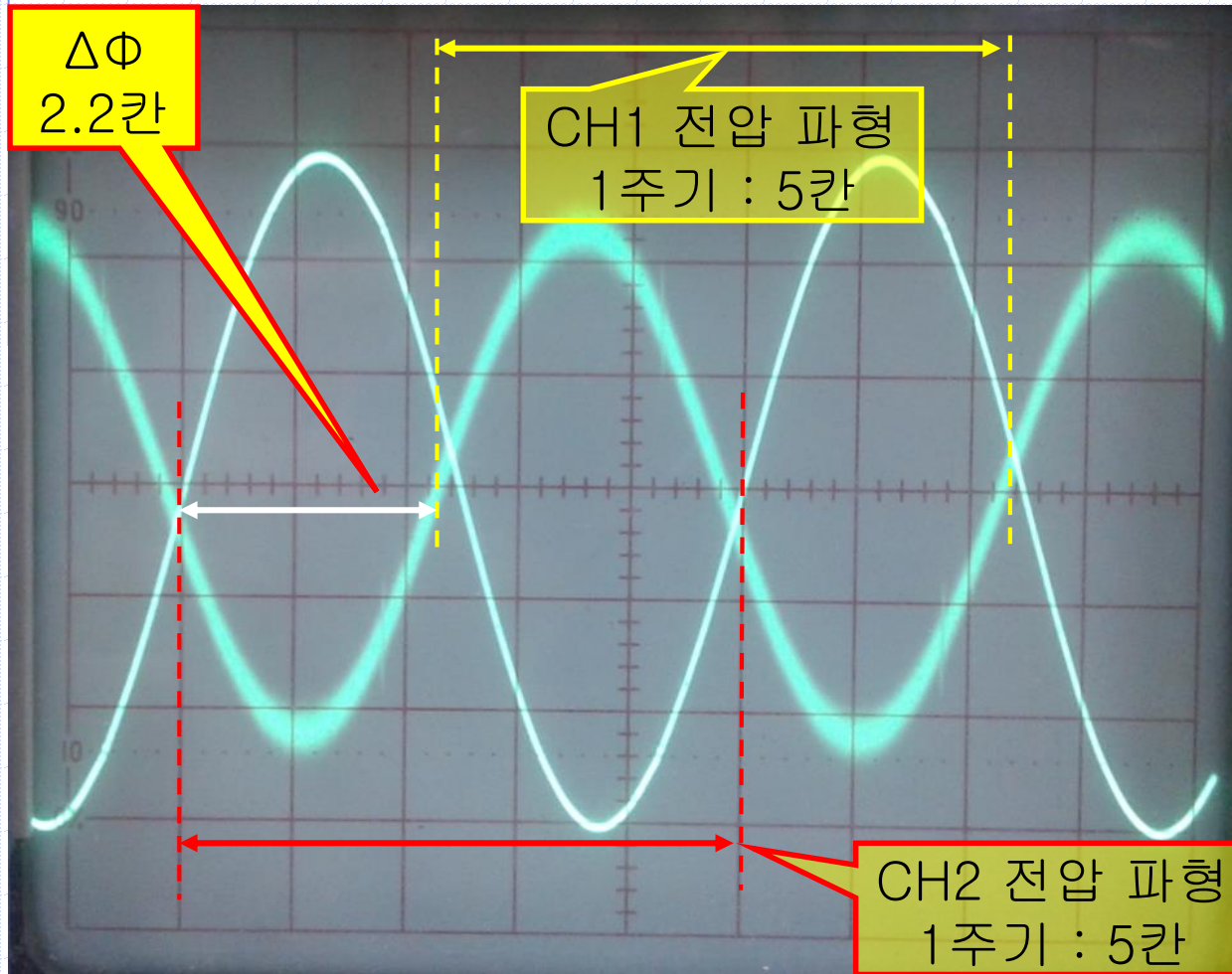
$$V_{R1} = 38 \text{mV}_{pp}$$

$$V_{R2} = 1.1 \text{V}_{pp}$$

CH 1 : 5mV/DIV, CH 2 : 0.2V/DIV, Time : 10uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 40kHz)



$$1T = 5\text{칸} \times 5\mu\text{Sec} \\ = 25\mu\text{Sec}$$

$$\Delta t = 2.2\text{칸} \times 5\mu\text{Sec} \\ = 11\mu\text{Sec}$$

$$25\mu\text{Sec} : 11\mu\text{Sec} \\ = 360^\circ : \Delta\theta$$

$$\Delta\theta = 158.4^\circ$$

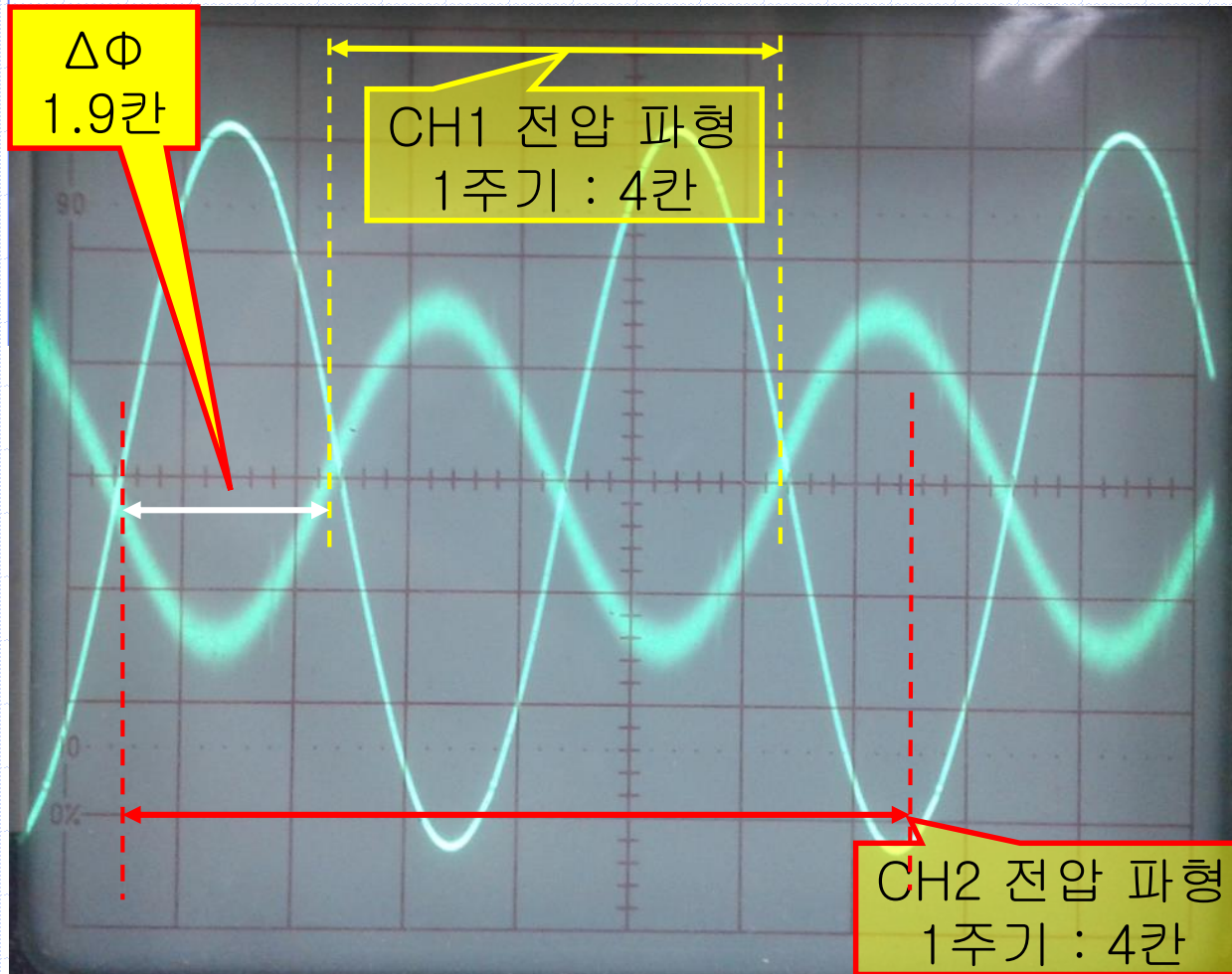
$$V_{R1} = 25\text{mV}_{pp}$$

$$V_{R2} = 1.2\text{V}_{pp}$$

CH 1 : 0.2V/DIV, CH 2 : 5mV/DIV, Time : 5uS/DIV

15-8. 주파수에 따른 위상 변화

✓ 위상차 및 V_{R1} 과 V_{R2} 를 측정하라. (주파수 : 50kHz)



$$1T = 4\cancel{\text{칸}} \times 5\mu\text{Sec} = 20\mu\text{Sec}$$

$$\Delta t = 1.9\cancel{\text{칸}} \times 5\mu\text{Sec} = 9.5\mu\text{Sec}$$

$$20\mu\text{Sec} : 9.5\mu\text{Sec} = 360^\circ : \Delta\theta$$

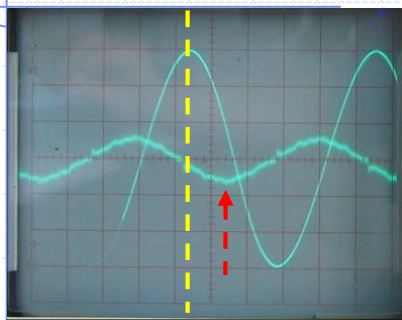
$$\Delta\theta = 171^\circ$$

$$V_{R1} = 15mV_{pp}$$

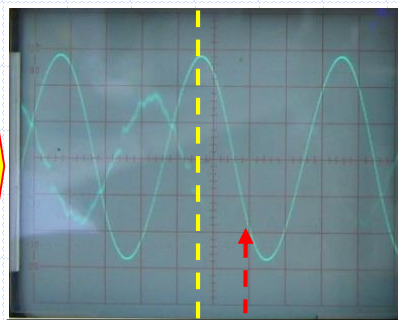
$$V_{R2} = 1.3V_{pp}$$

CH 1 : 5mV/DIV, CH 2 : 0.2V/DIV, Time : 5uS/DIV

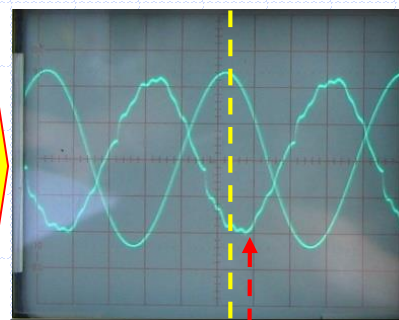
15-8. 주파수에 따른 위상 변화



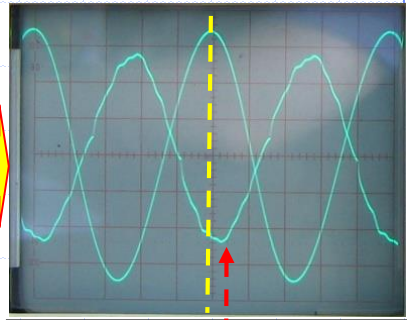
$f=200\text{Hz}$



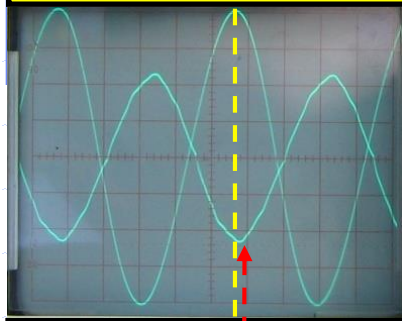
$f=500\text{Hz}$



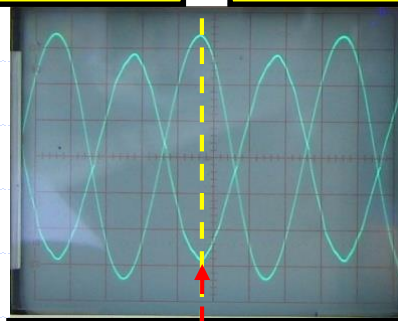
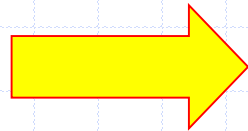
$f=1\text{kHz}$



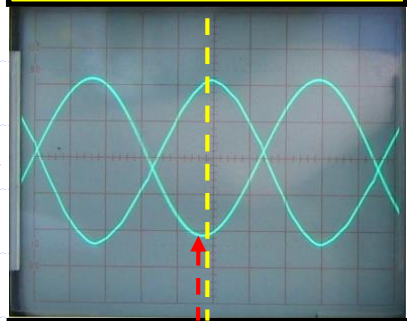
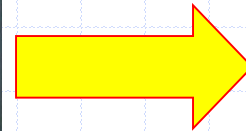
$f=2\text{kHz}$



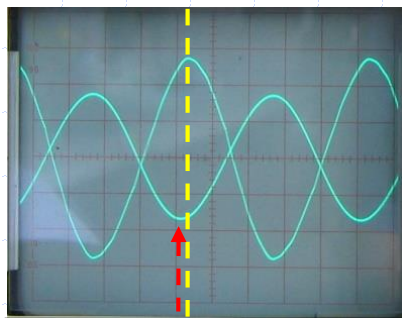
$f=4\text{kHz}$



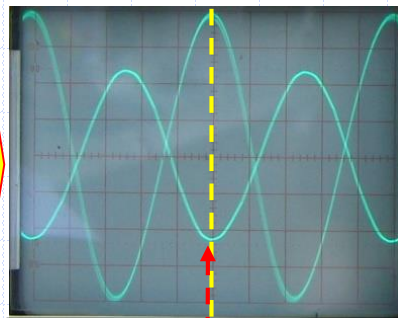
$f=5\text{kHz}$



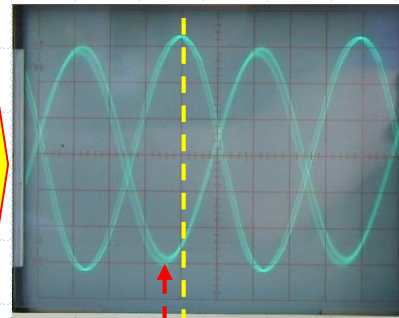
$f=8\text{kHz}$



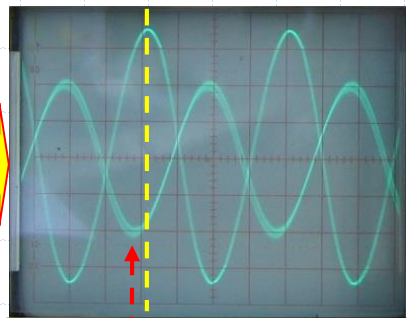
$f=10\text{kHz}$



$f=20\text{kHz}$



$f=40\text{kHz}$

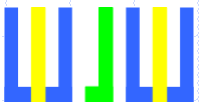
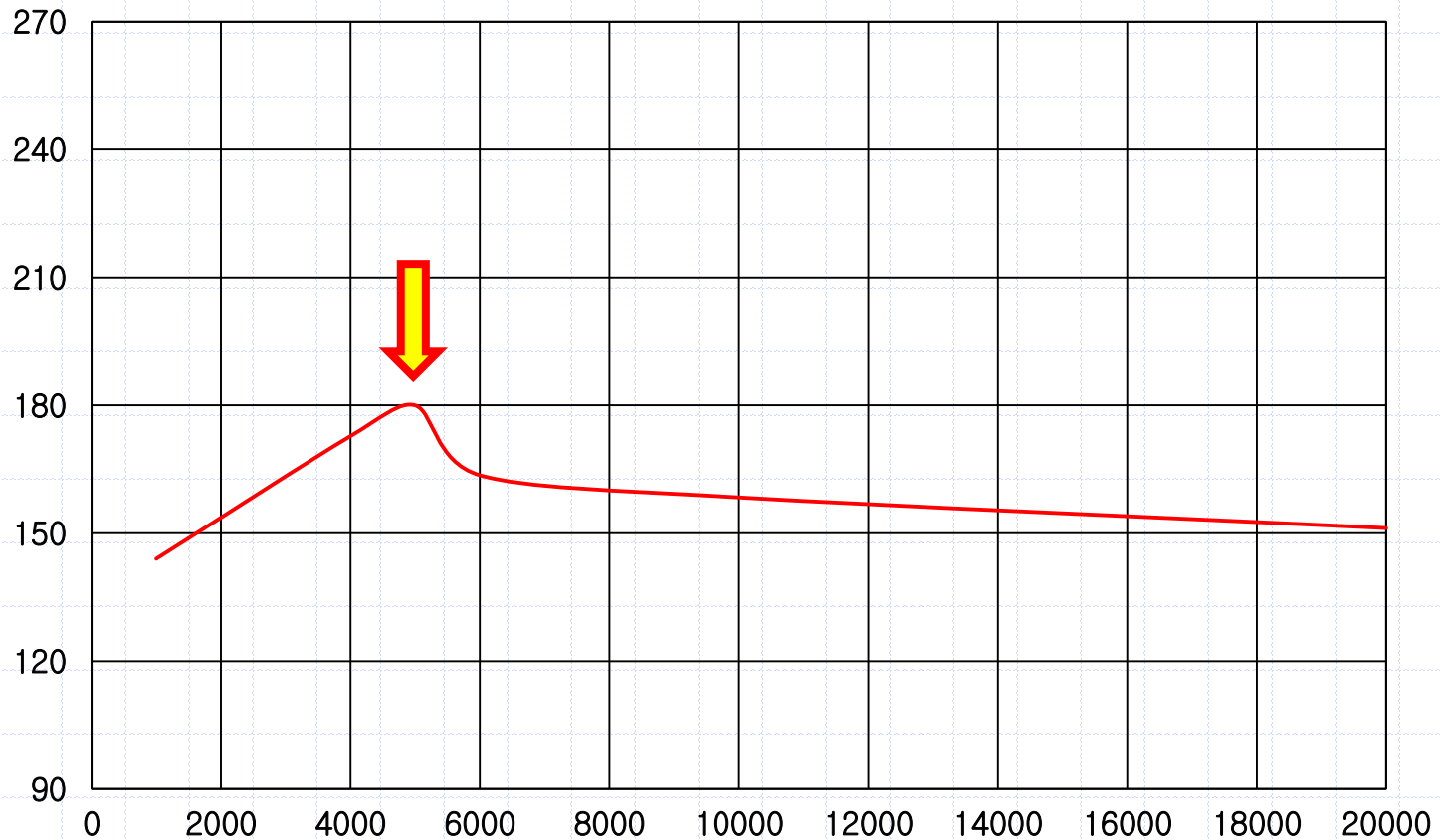


$f=50\text{kHz}$



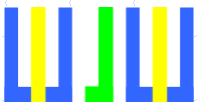
15-8. 주파수에 따른 위상 변화

위상차 (도)



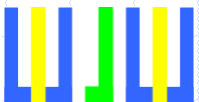
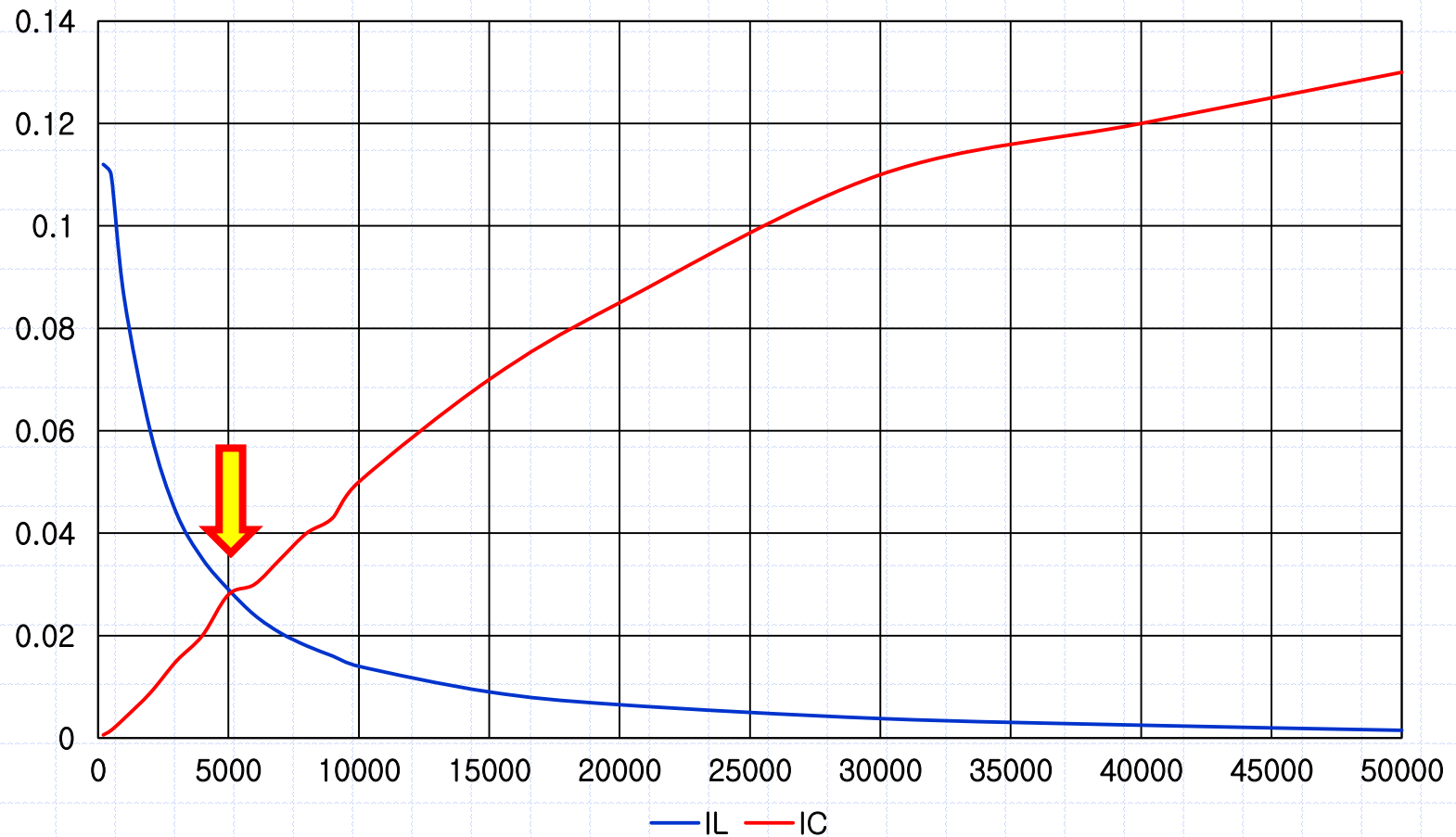
15-9. 주파수에 따른 전류, 리액턴스

Frequency (Hz)	V _{R1} (V _{pp})	I _L (mA _{pp})	X _L (Ω)	V _{R2} (V _{pp})	I _C (mA _{pp})	X _C (Ω)
200	1.12	112	89.29	0.006	0.6	16,666.67
500	1.1	110	90.91	0.015	1.5	6,666.67
1,000	0.86	86	116.28	0.038	3.8	2,631.58
2,000	0.6	60	166.67	0.088	8.8	1,136.36
3,000	0.44	44	227.27	0.15	15	666.67
4,000	0.35	35	285.71	0.2	20	500.00
5,000	0.29	29	344.83	0.28	28	357.14
6,000	0.24	24	416.67	0.3	30	333.33
7,000	0.205	20.5	487.80	0.35	35	285.71
8,000	0.18	18	555.56	0.4	40	250.00
9,000	0.16	16	625.00	0.43	43	232.56
10,000	0.14	14	714.29	0.5	50	200.00
15,000	0.09	9	1,111.11	0.7	70	142.86
20,000	0.065	6.5	1,538.46	0.85	85	117.65
30,000	0.038	3.8	2,631.58	1.1	110	90.91
40,000	0.025	2.5	4,000.00	1.2	120	83.33
50,000	0.015	1.5	6,666.67	1.3	130	76.92



15-9. 주파수에 따른 전류, 리액턴스

전류 (A)



15-9. 주파수에 따른 전류, 리액턴스

