회로 이론/실습

14. 직렬 공진 회로

14. 직렬 공진 회로

14-1. 목적 및 배경

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

14-2. 소요 부품 및 장비

- 부품
  - 저항 (1/4W) : 10Ω, 1kΩ
  - 인덕터 : 10mH
  - 캐패시터 : 0.1uF
- 장비
  - 브레드 보드
  - 디지털 멀티미터 (Digital Multi-Meter)
  - 오실로스코프 (Oscilloscope)
  - 신호 발생기 (Function Generator)

14-3. 유용한 공식

✓ 직렬 공진 회로의 공진 주파수

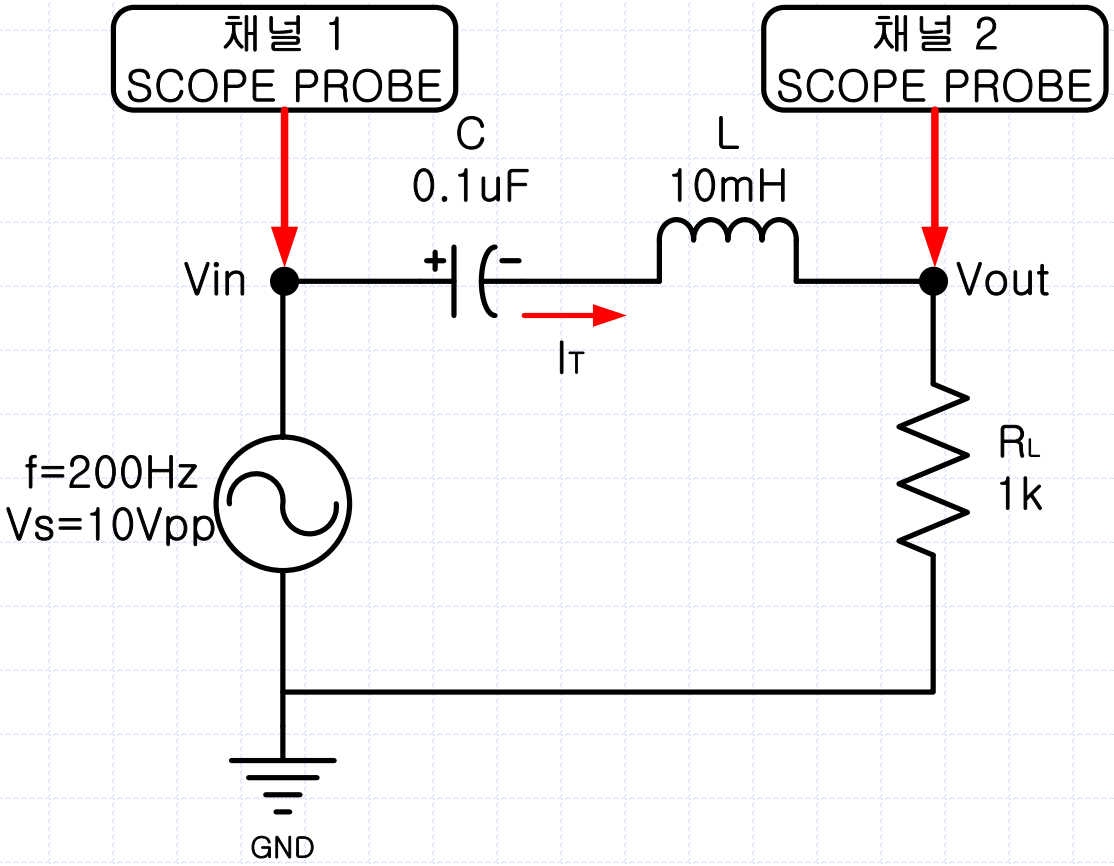
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

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

$$Z = R + jX = R + j(X_L - X_C) = R + j(2\pi fL - \frac{1}{2\pi fC})$$

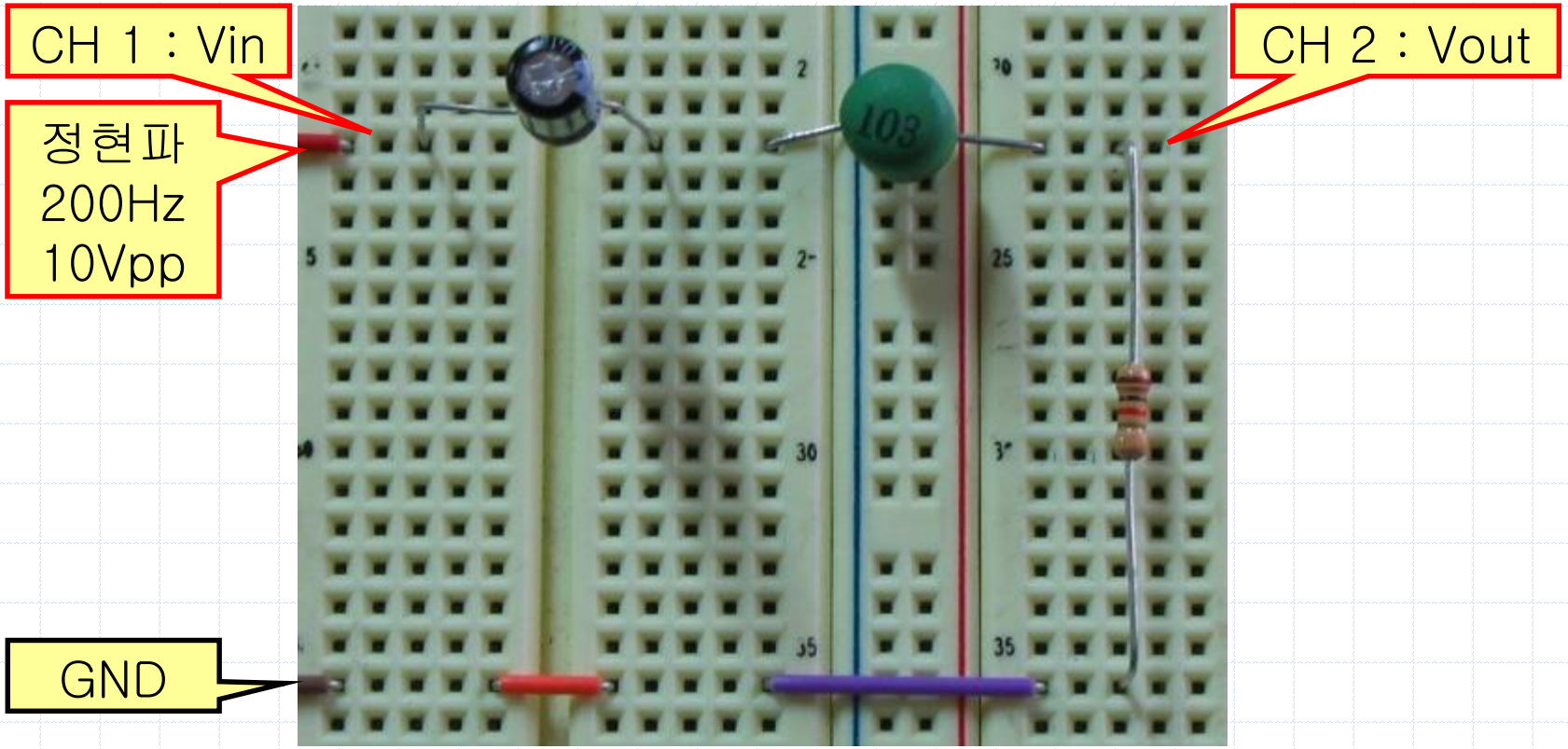
14-4. 주파수에 따른 전압

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

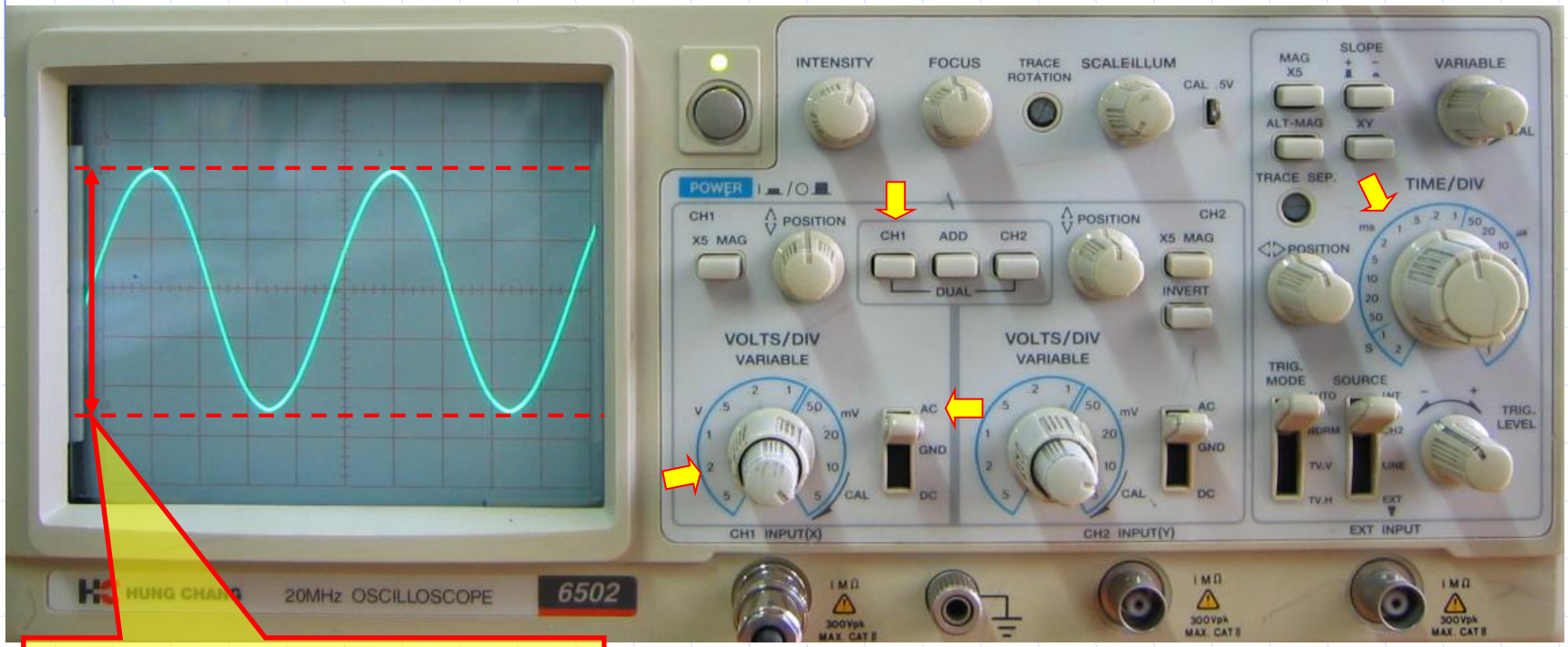


14-4. 주파수에 따른 전압

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

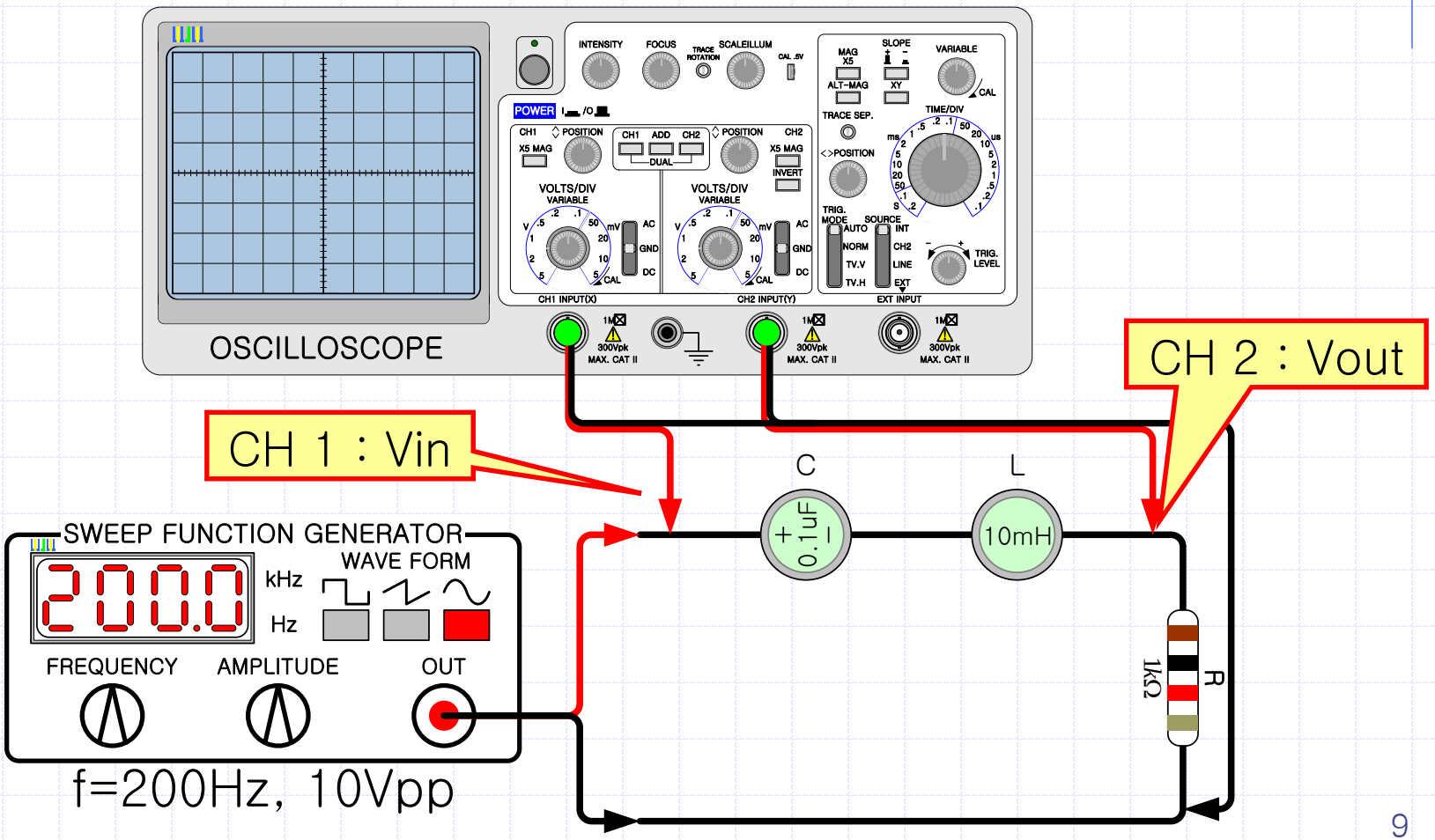


14-4. 주파수에 따른 전압



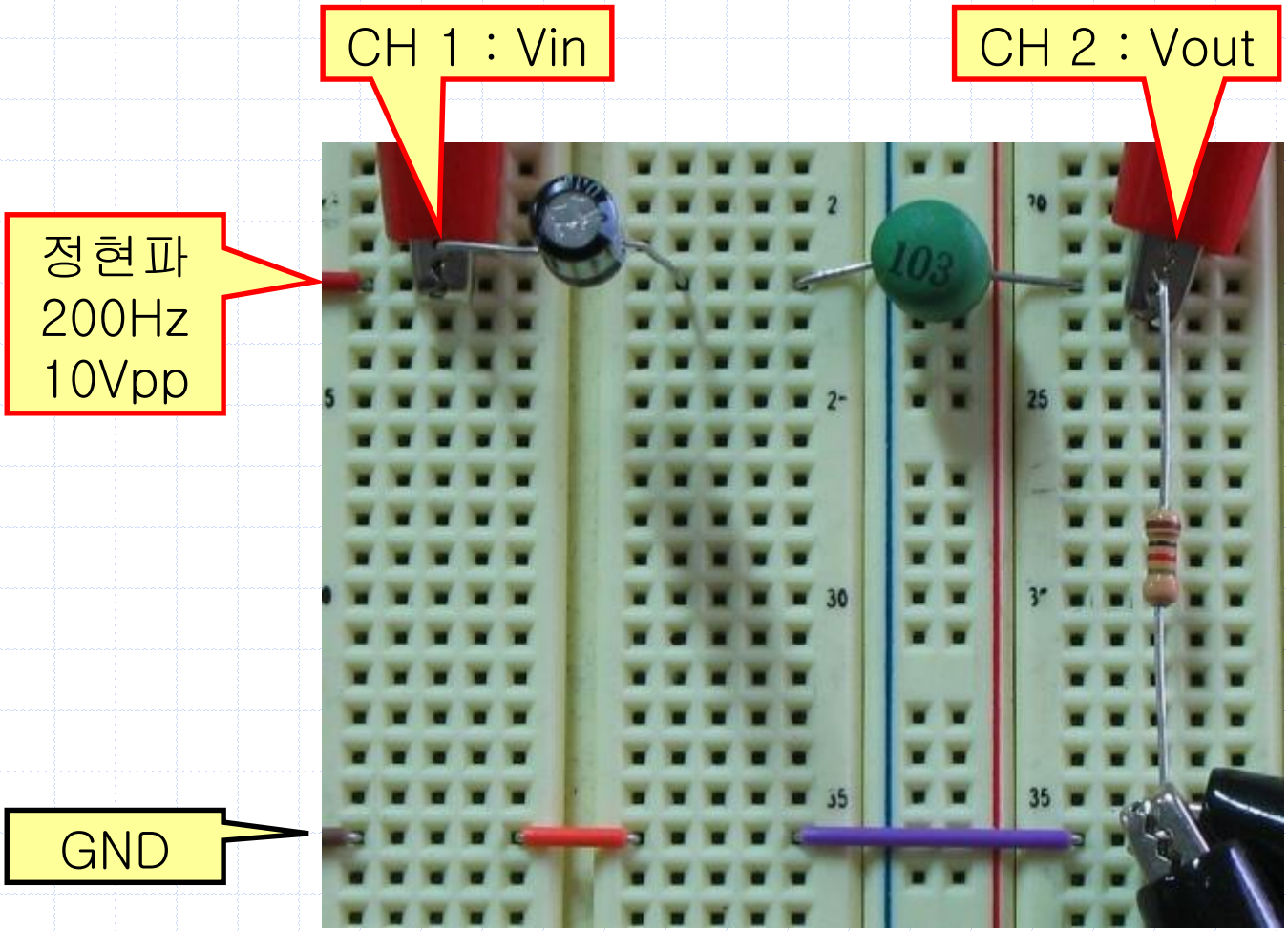
14-4. 주파수에 따른 전압

- 오실로스코프의 CH 1 을 이용하여 입력 전압 (Vin) 을 측정하고, CH 2 는 출력 전압 (Vout) 을 측정한다.



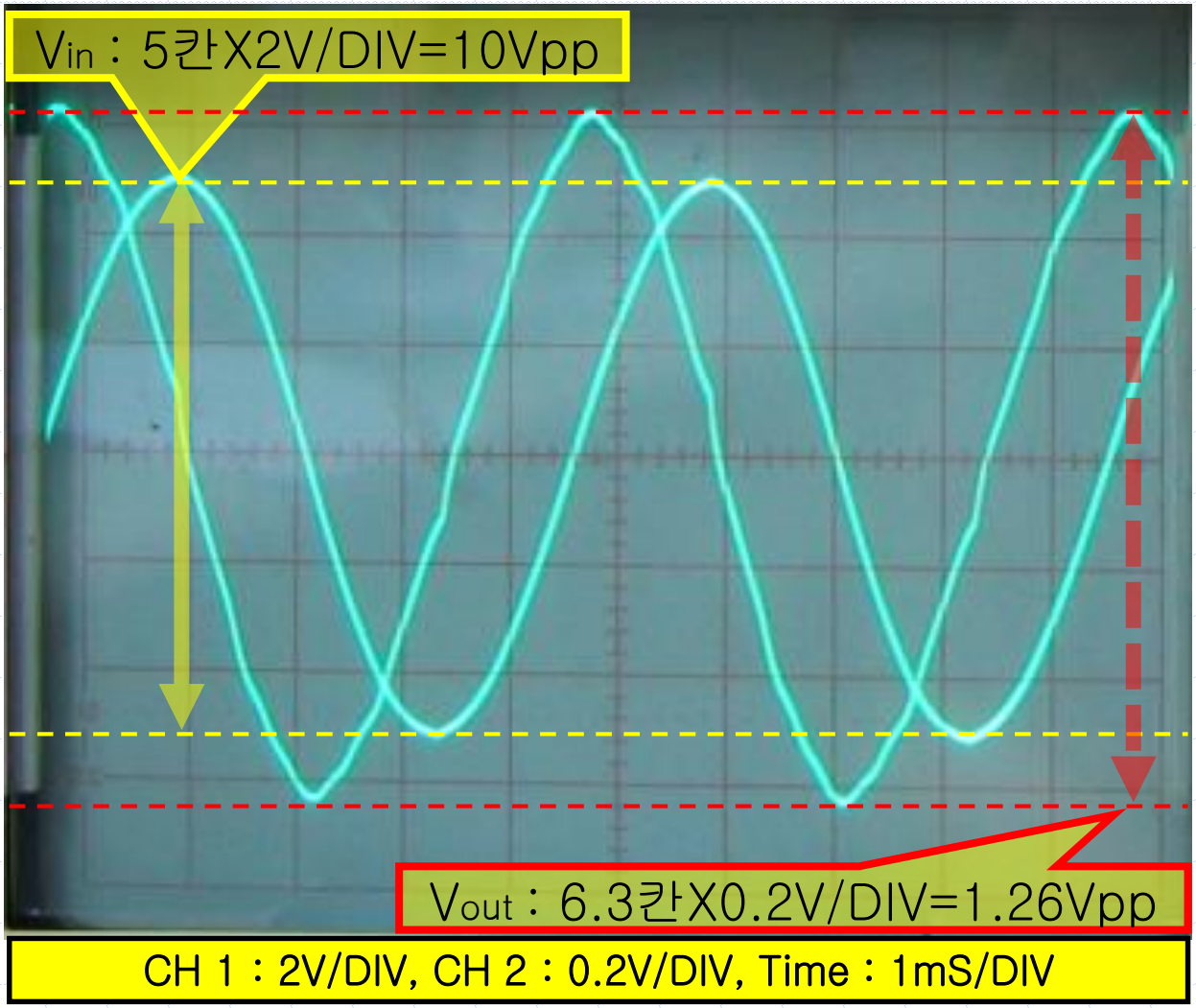
14-4. 주파수에 따른 전압

- ✓ 주파수 : 200Hz



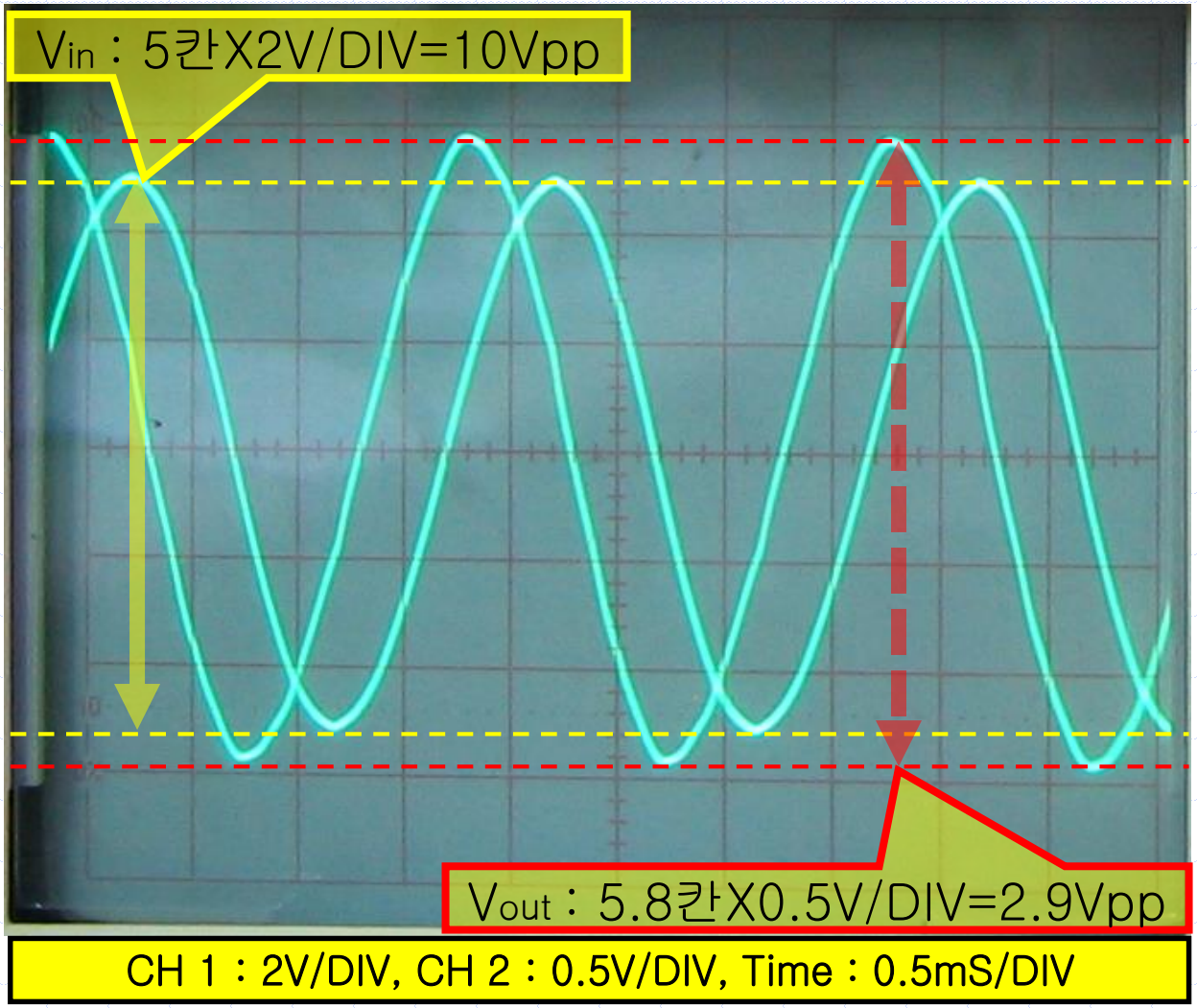
14-4. 주파수에 따른 전압

- ✓ 주파수 : 200Hz



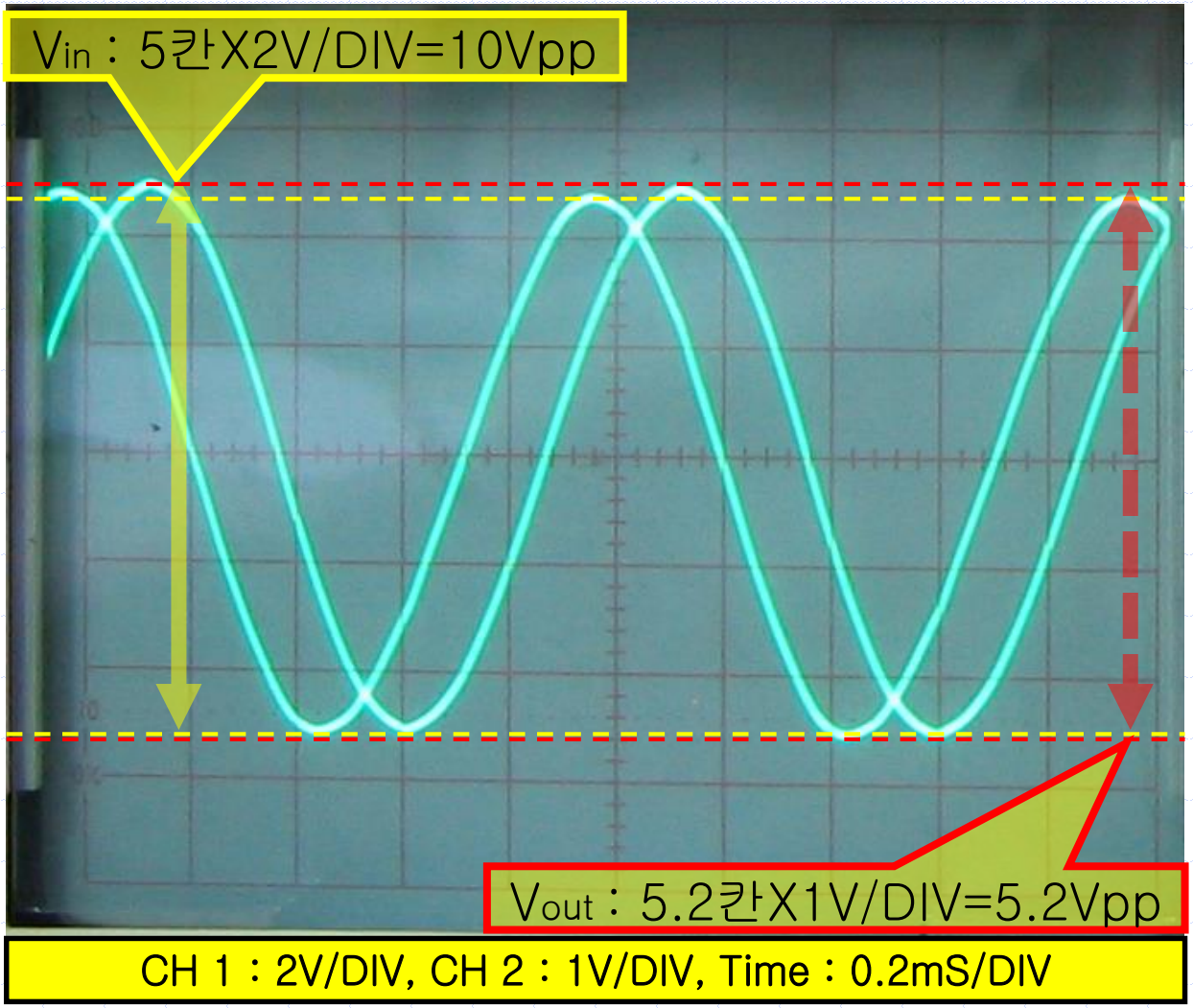
14-4. 주파수에 따른 전압

- ✓ 주파수 : 500Hz



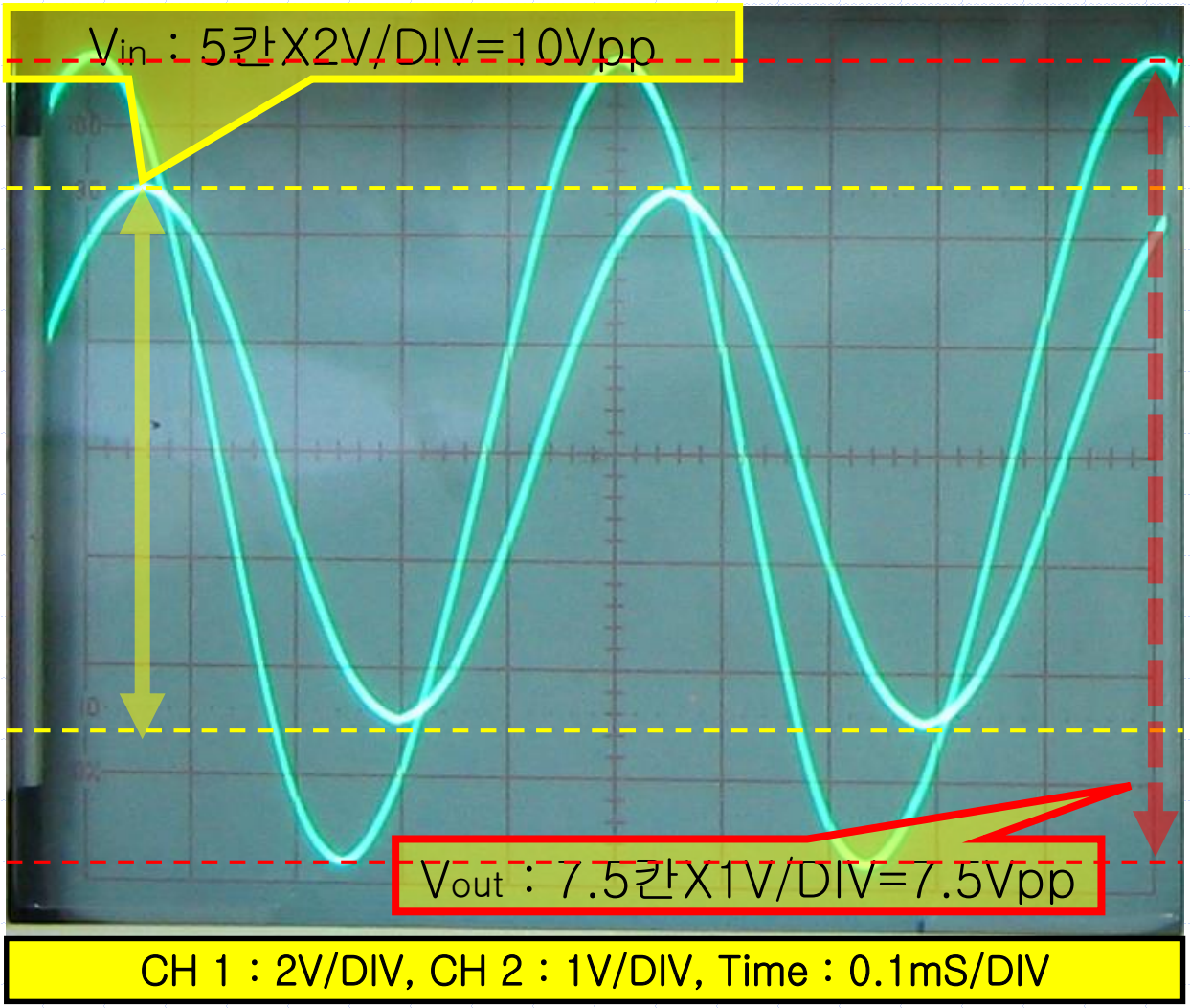
14-4. 주파수에 따른 전압

- ✓ 주파수 : 1kHz



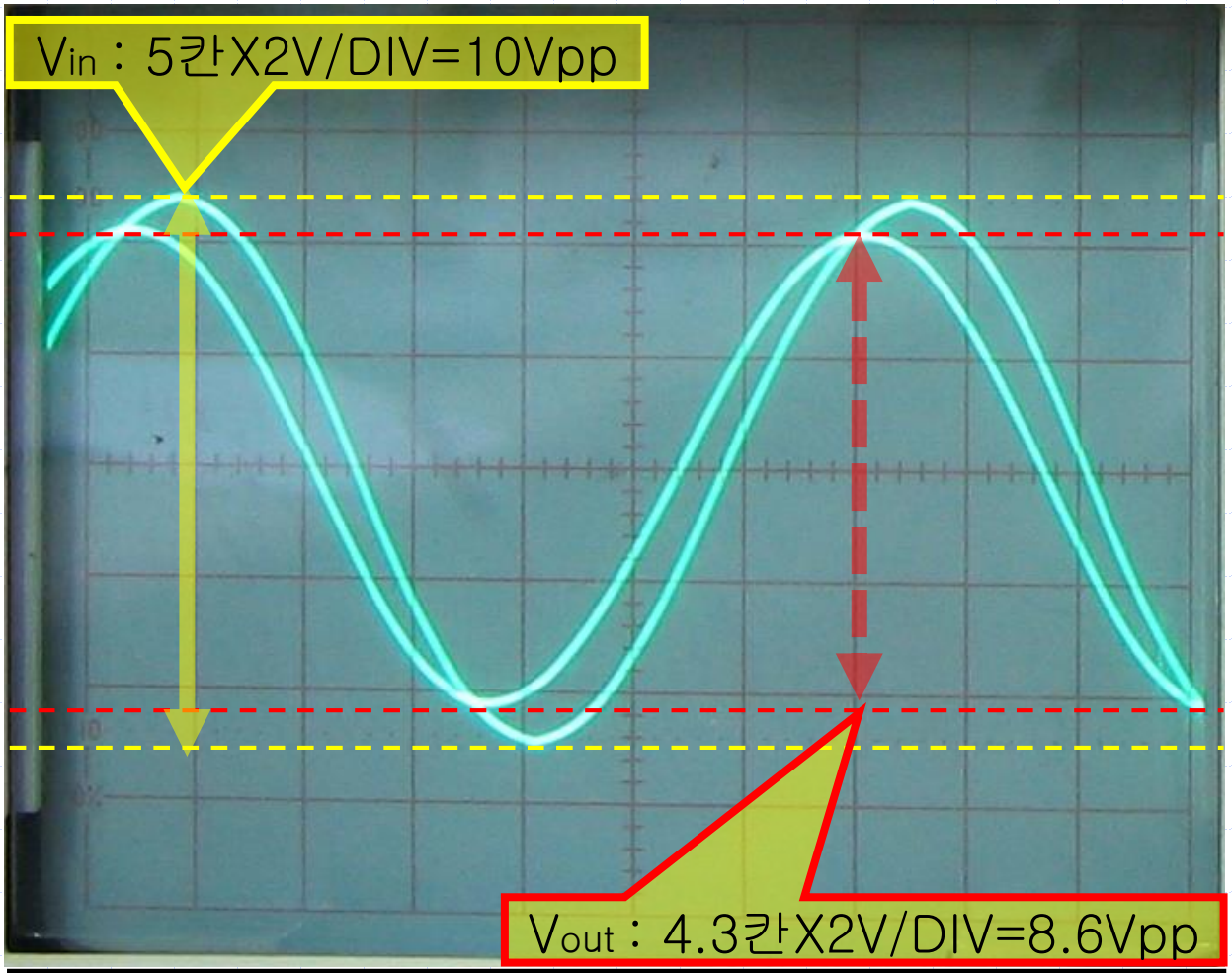
14-4. 주파수에 따른 전압

- ✓ 주파수 : 2kHz



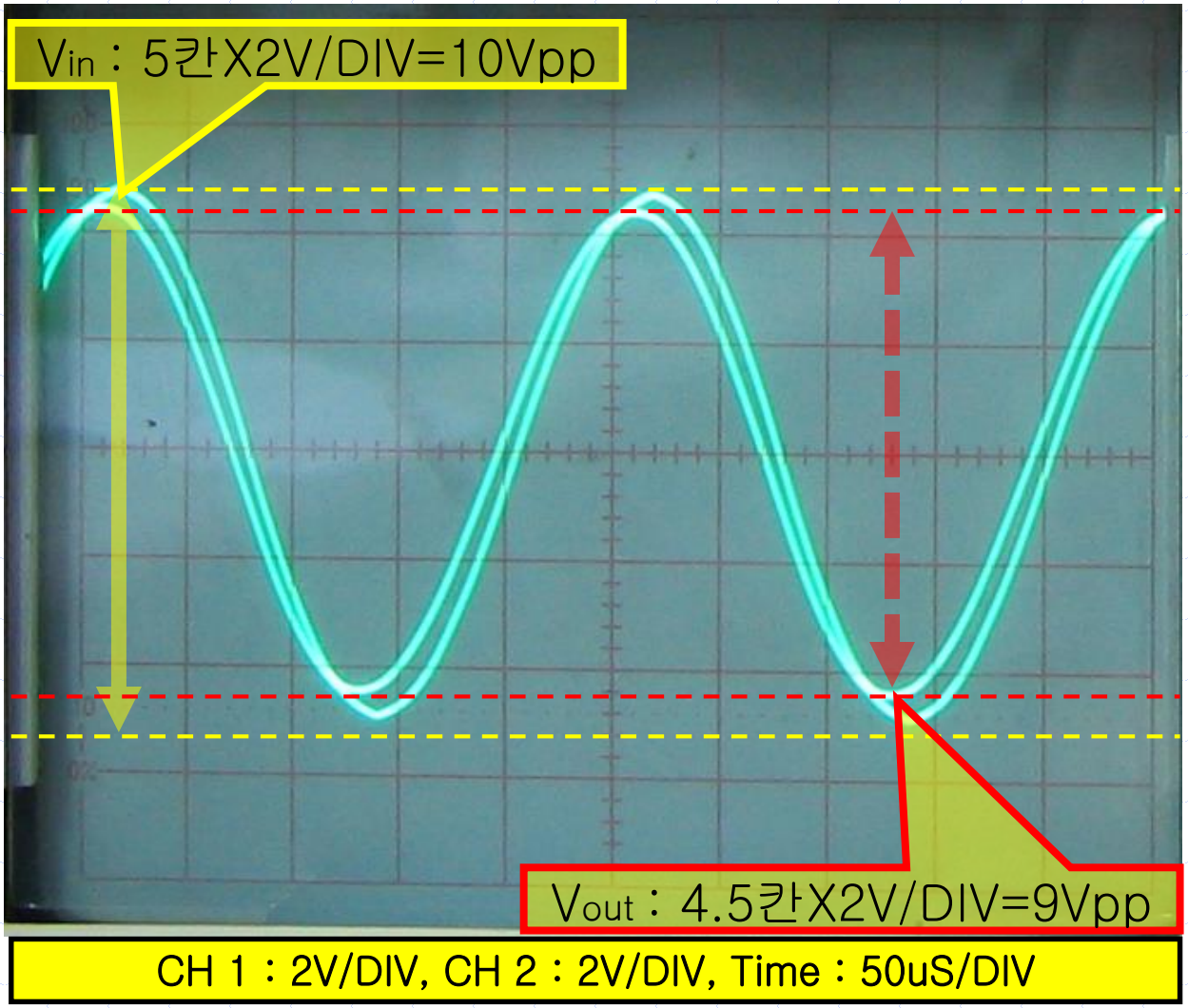
14-4. 주파수에 따른 전압

- ✓ 주파수 : 3kHz



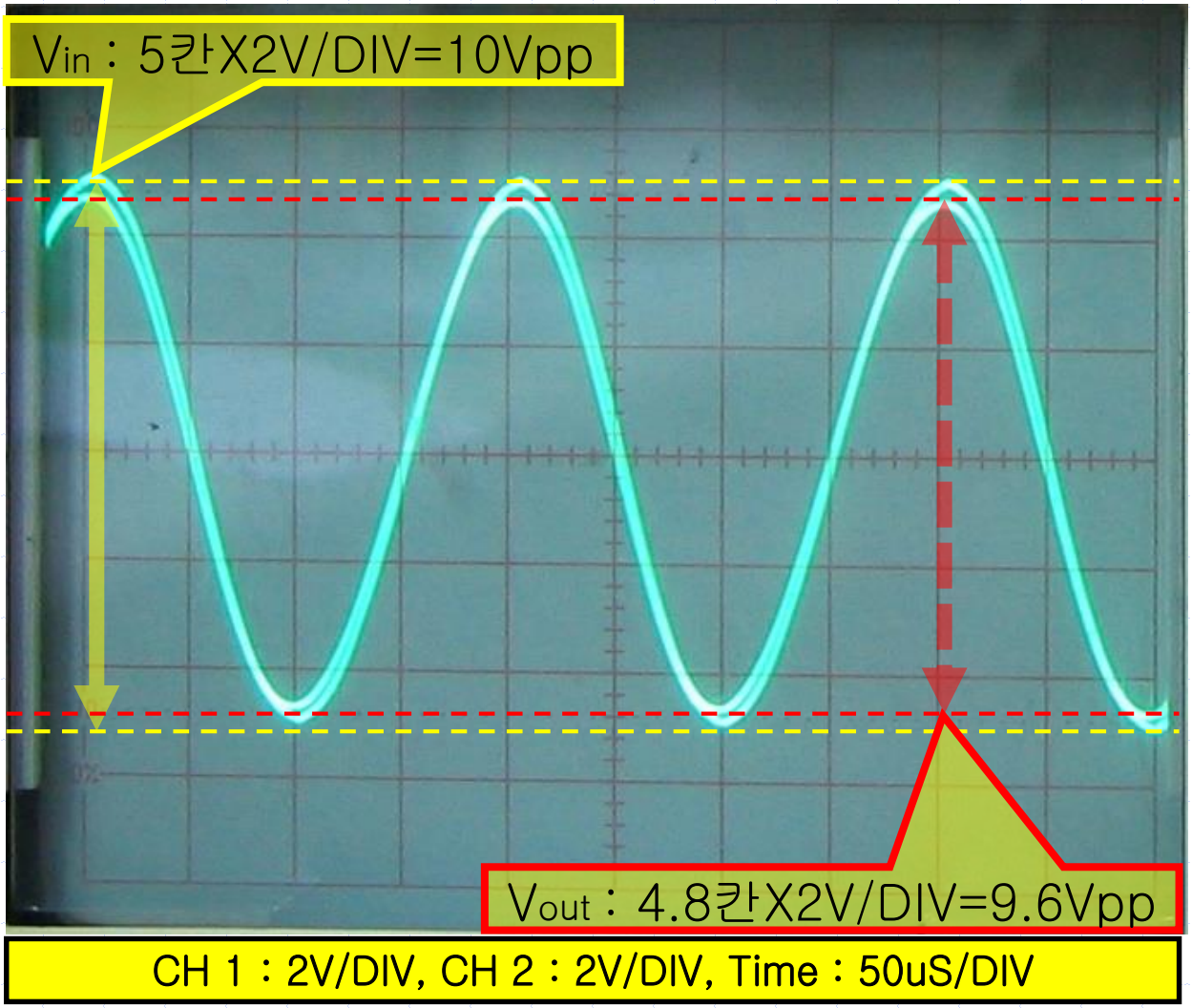
14-4. 주파수에 따른 전압

- ✓ 주파수 : 4kHz



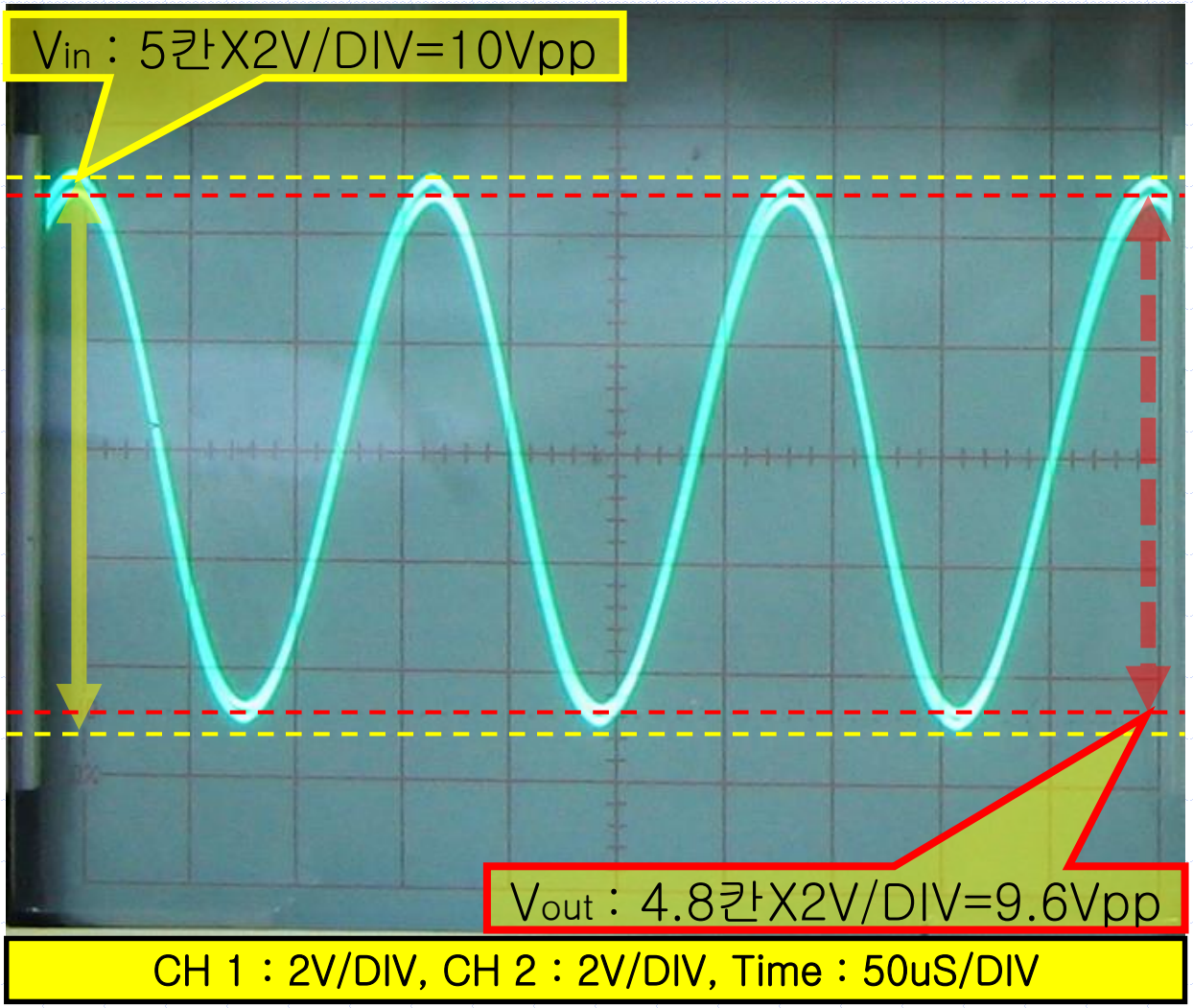
14-4. 주파수에 따른 전압

- ✓ 주파수 : 5kHz



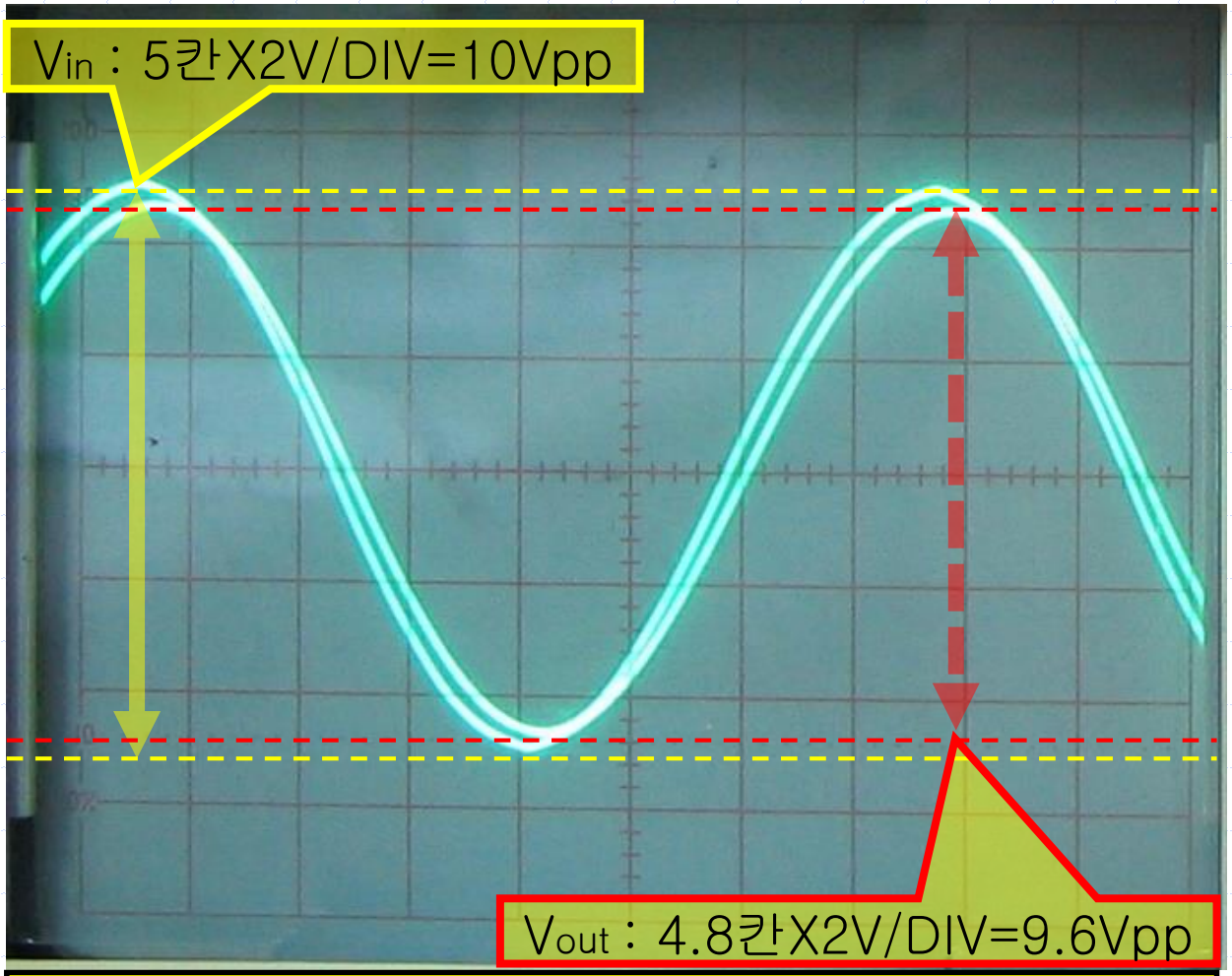
14-4. 주파수에 따른 전압

- ✓ 주파수 : 6kHz



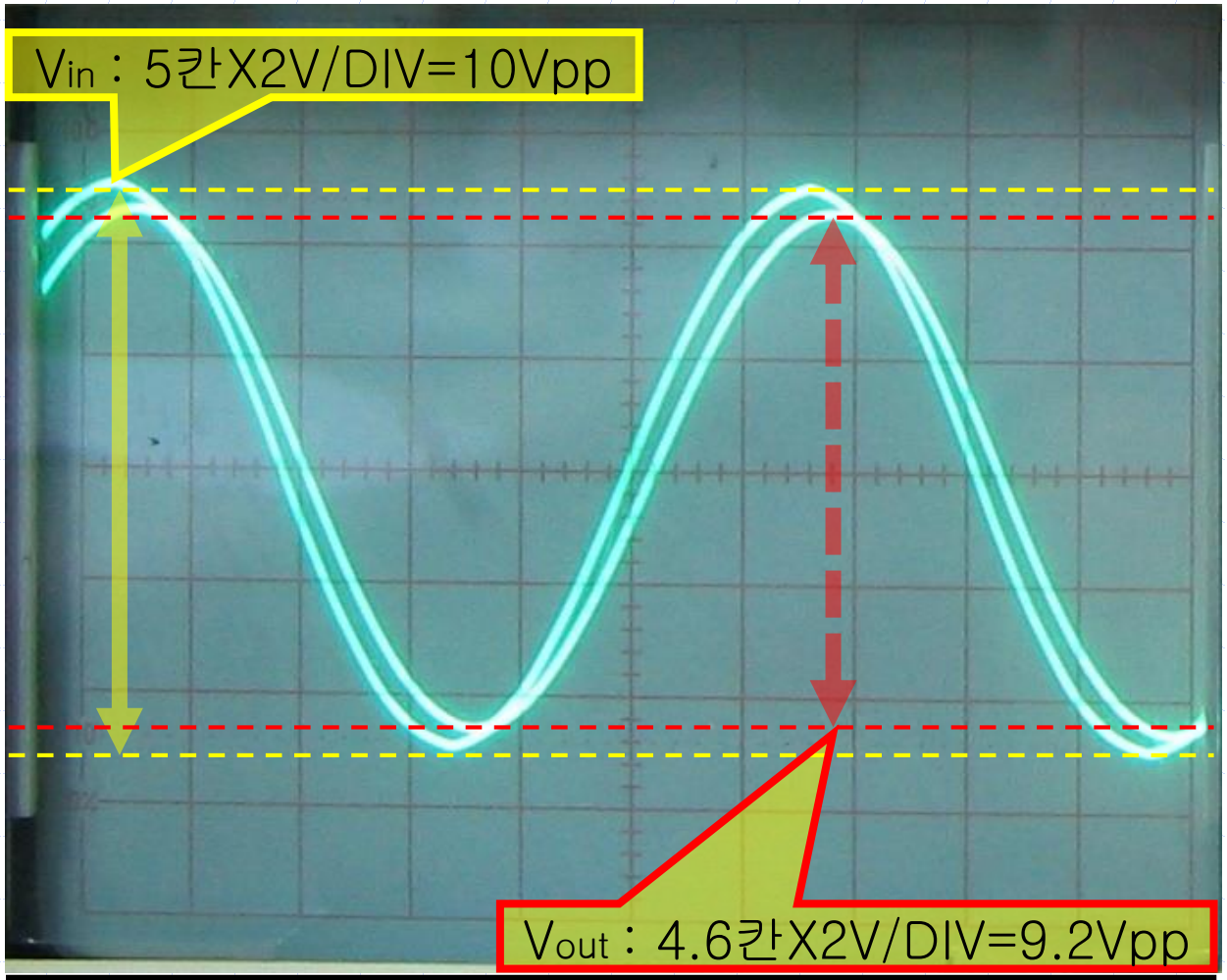
14-4. 주파수에 따른 전압

- ✓ 주파수 : 7kHz



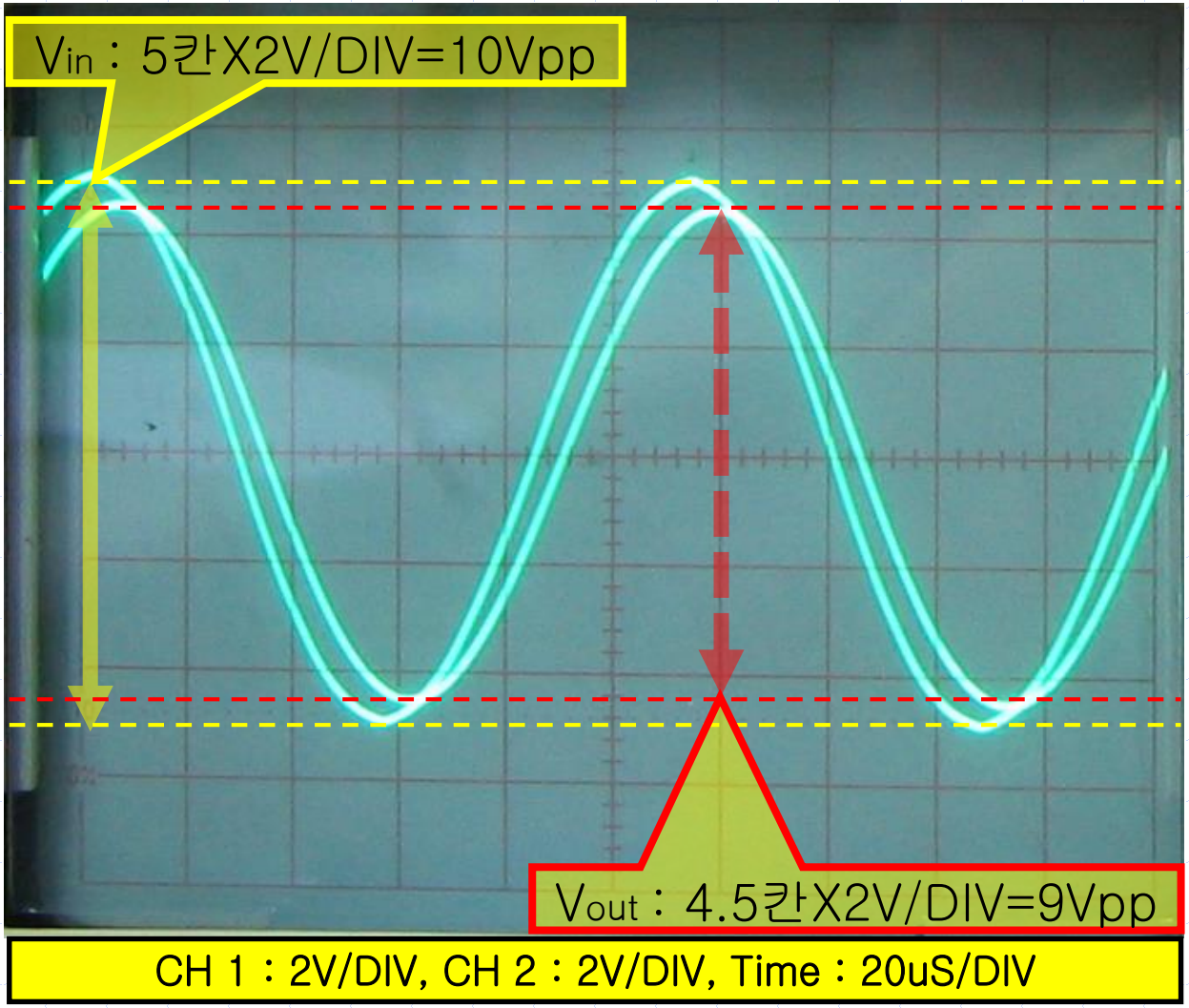
14-4. 주파수에 따른 전압

- ✓ 주파수 : 8kHz



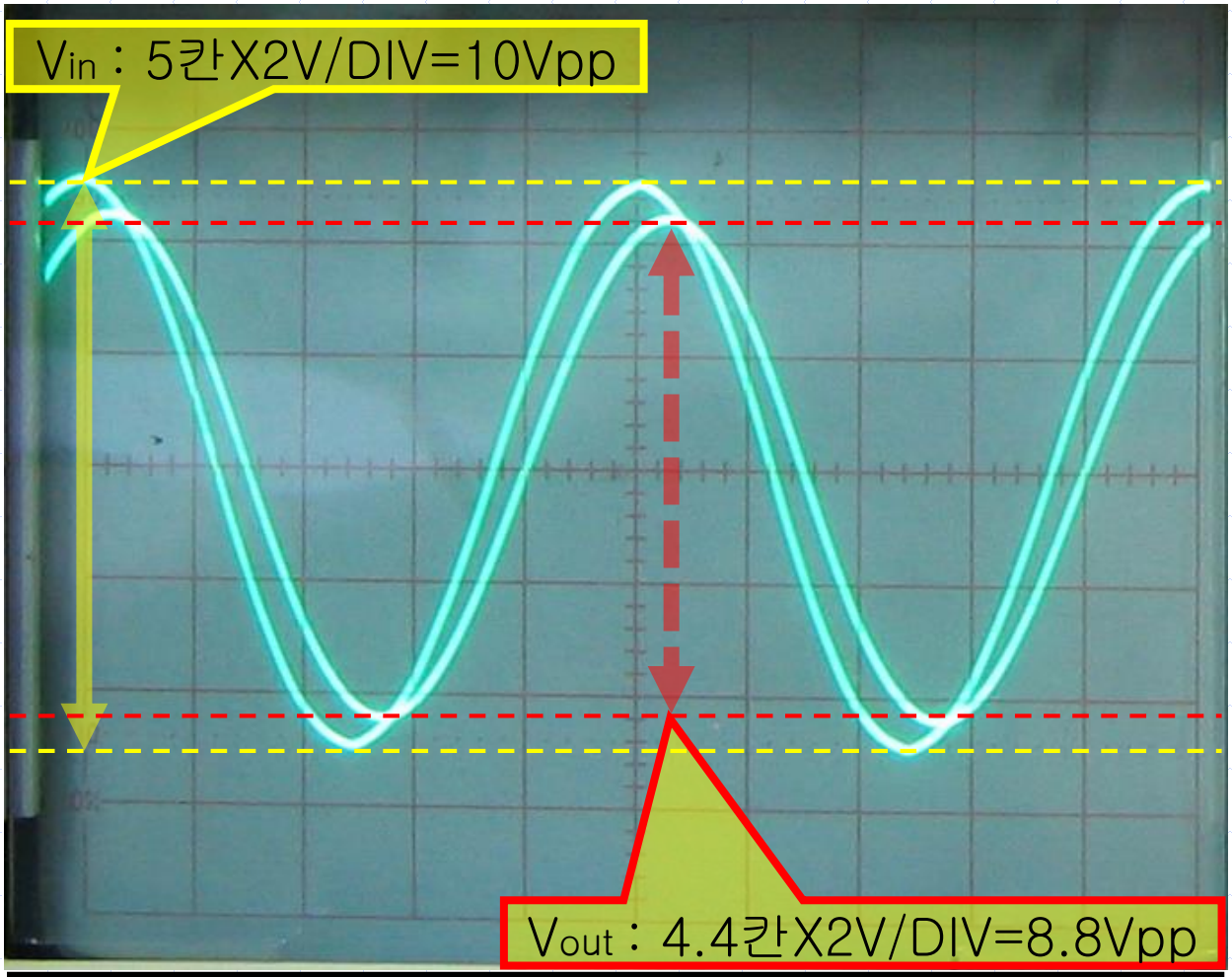
14-4. 주파수에 따른 전압

- ✓ 주파수 : 9kHz



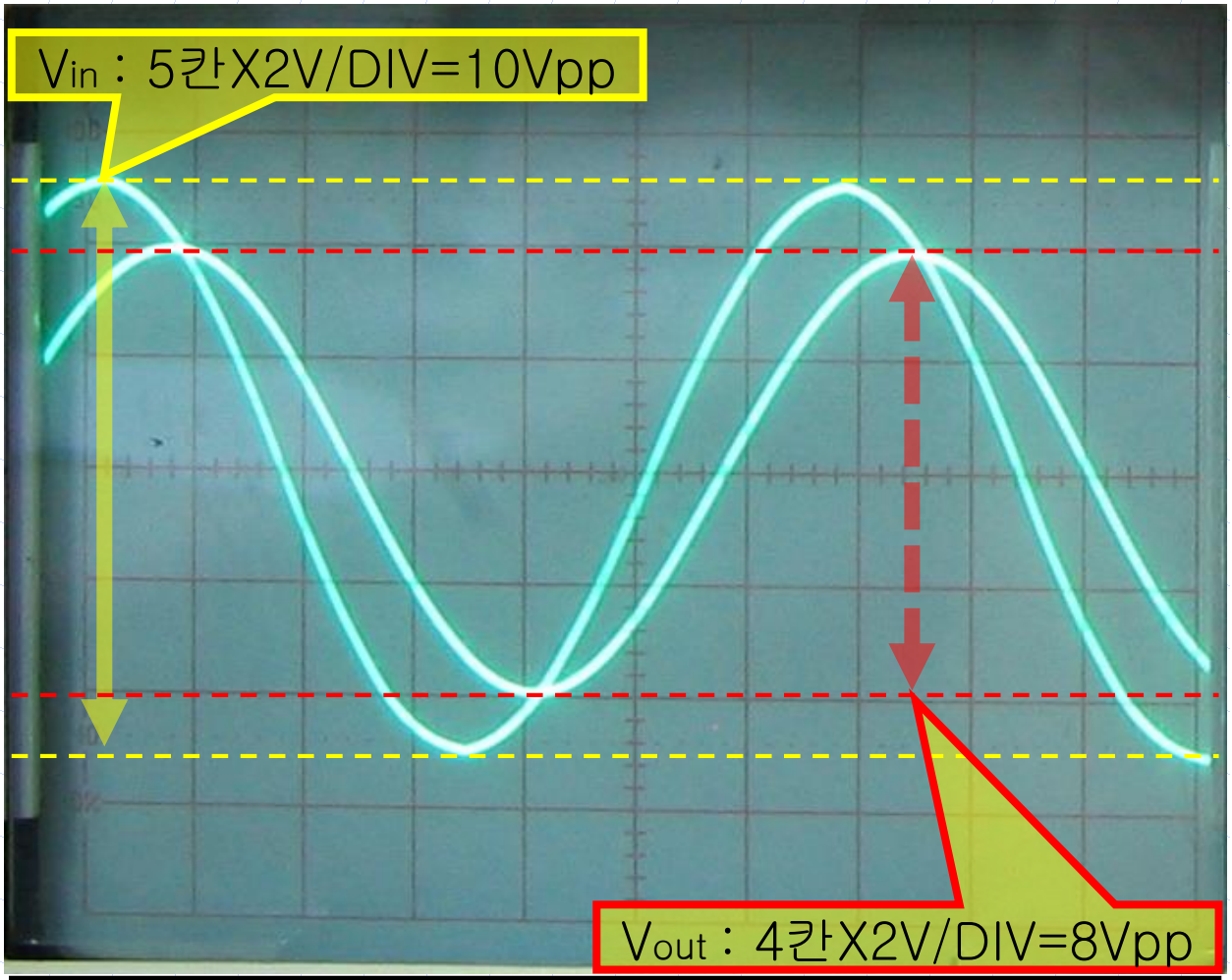
14-4. 주파수에 따른 전압

- ✓ 주파수 : 10kHz



14-4. 주파수에 따른 전압

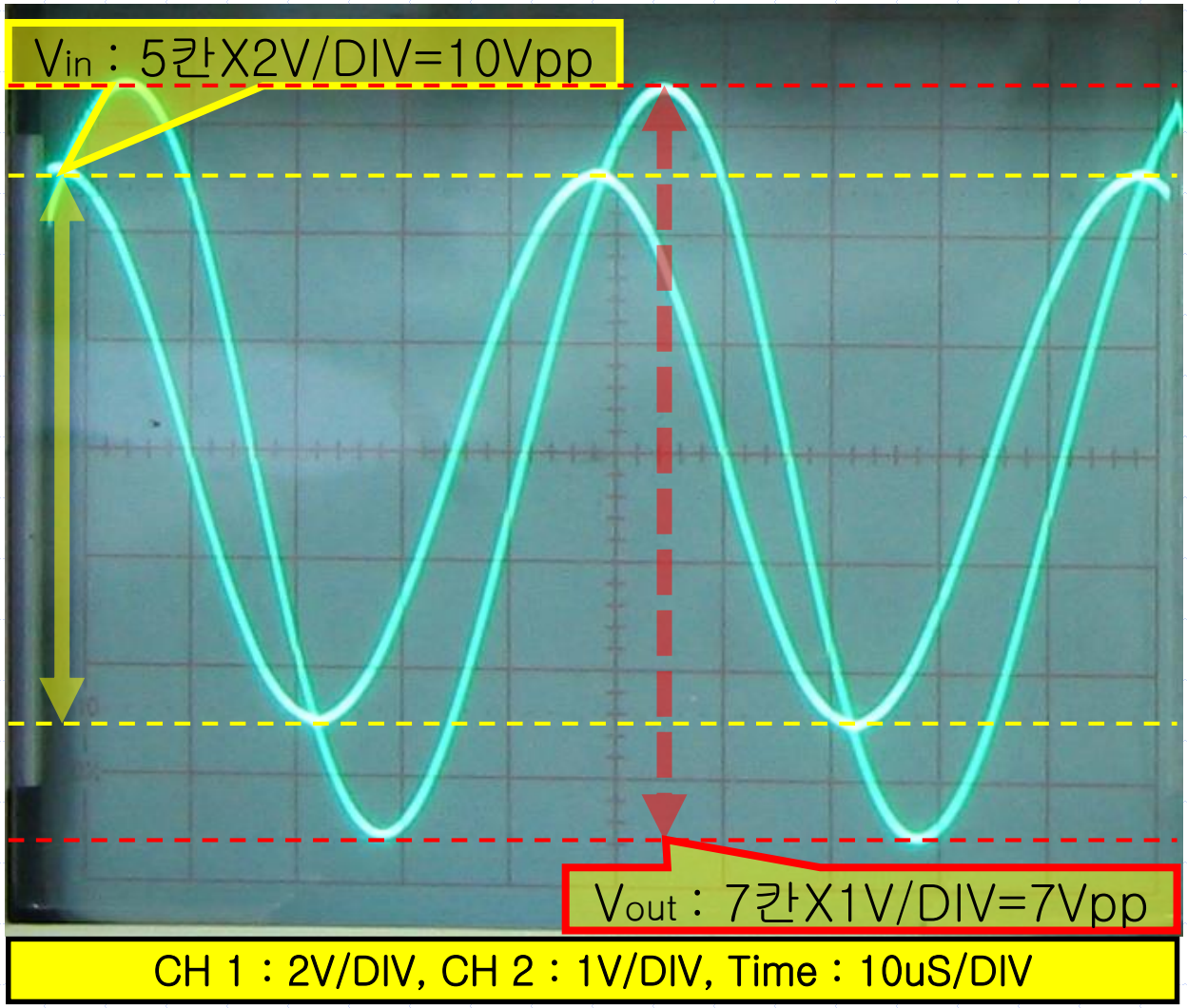
- ✓ 주파수 : 15kHz



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

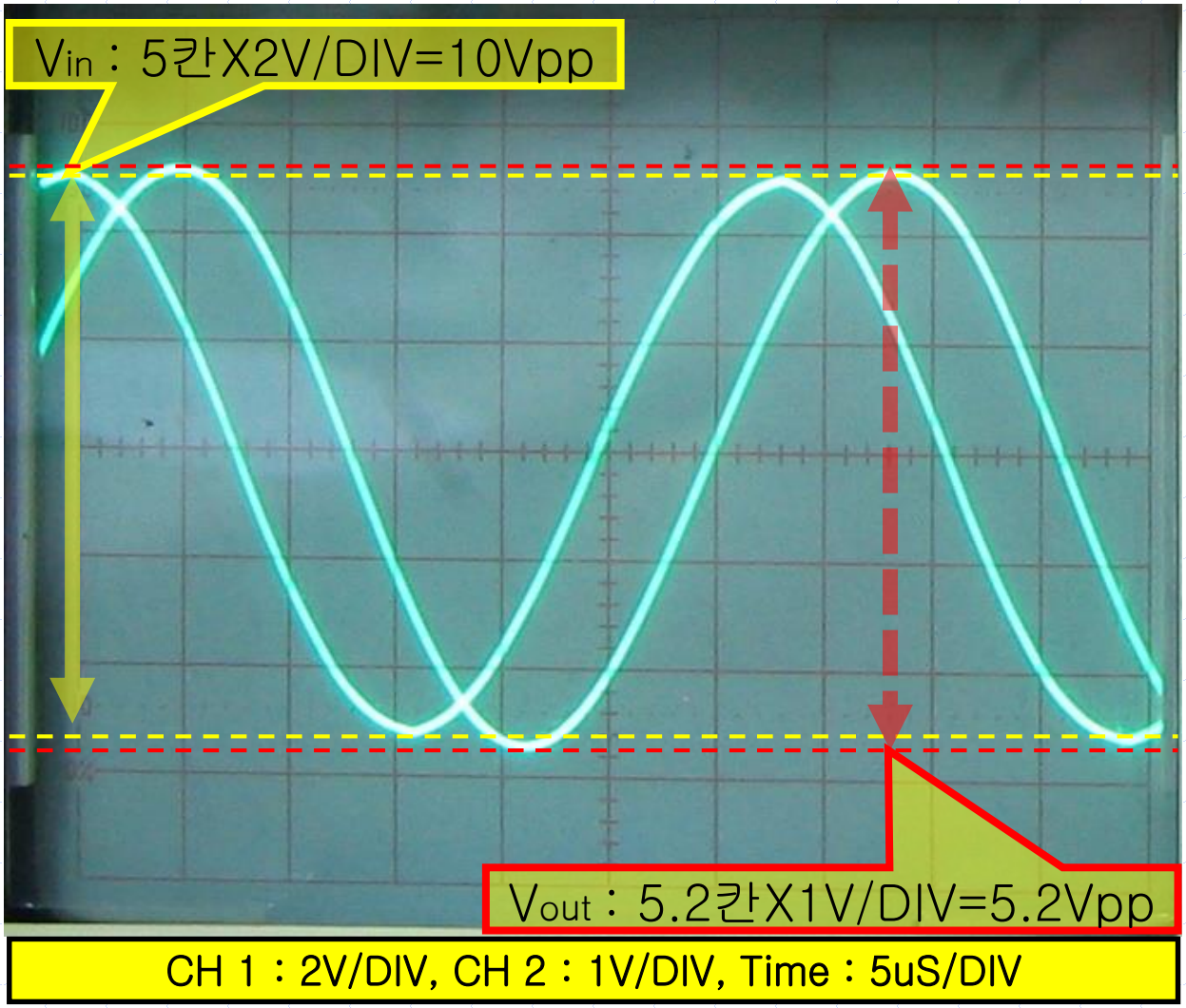
14-4. 주파수에 따른 전압

- ✓ 주파수 : 20kHz



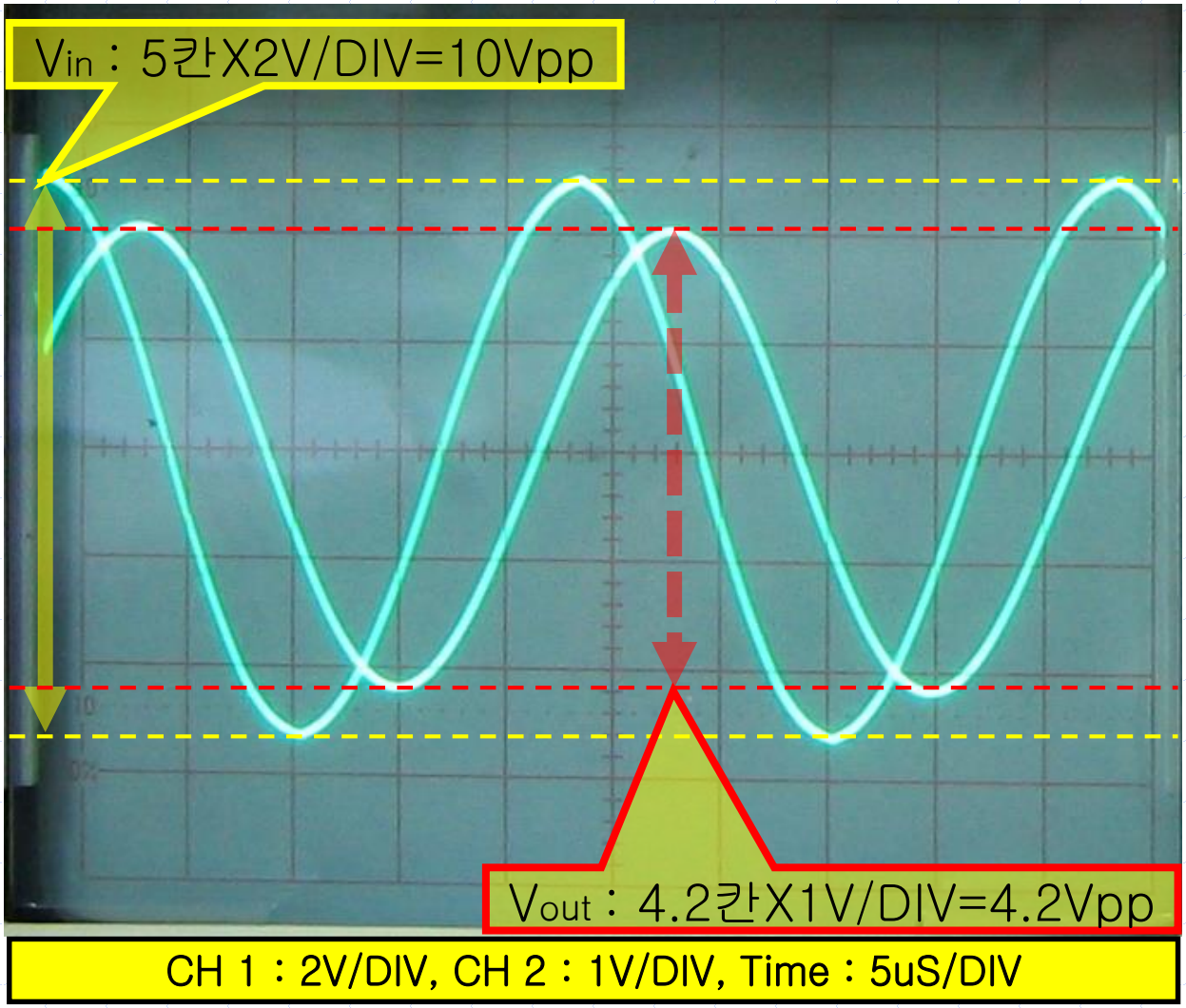
14-4. 주파수에 따른 전압

- ✓ 주파수 : 30kHz



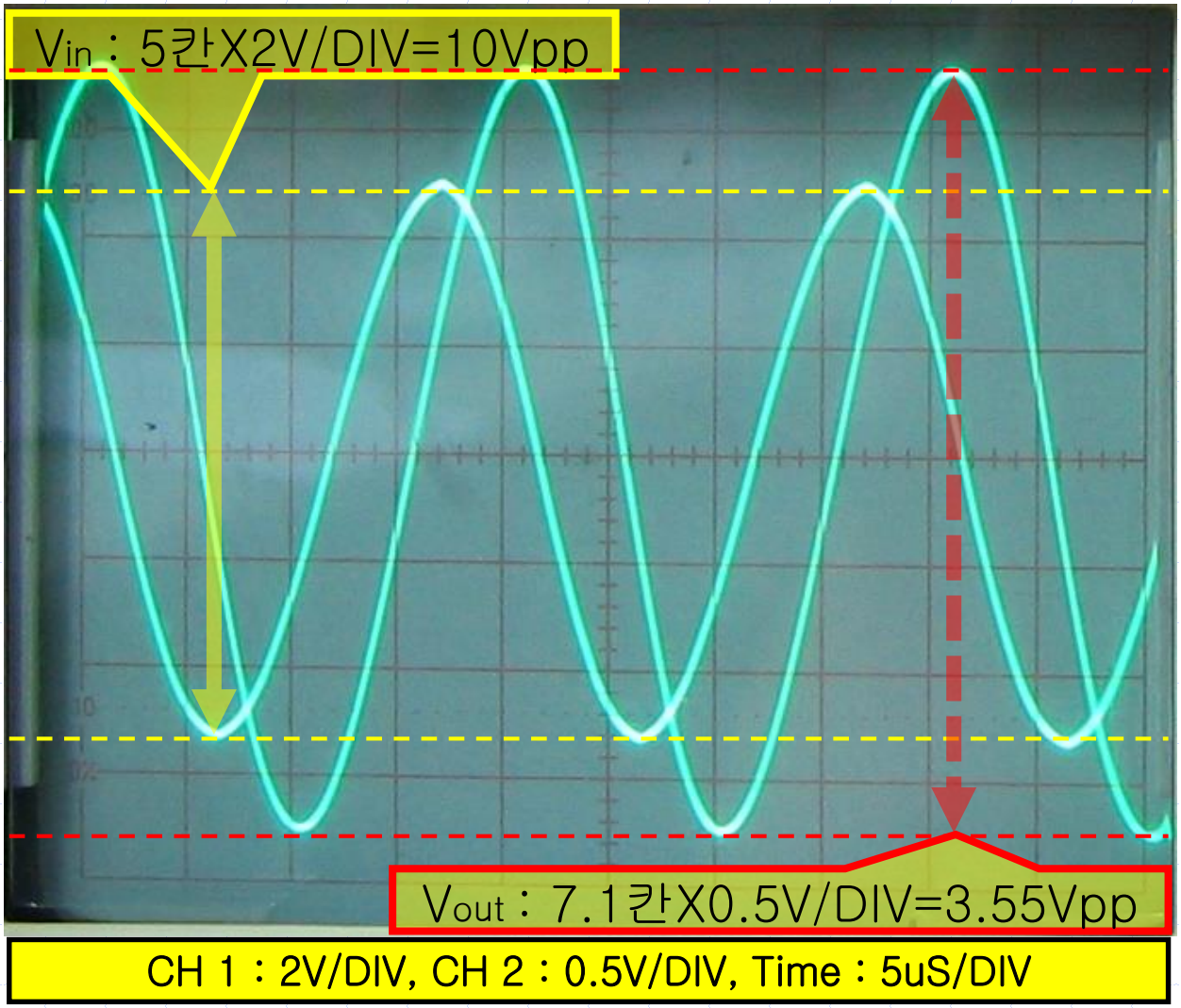
14-4. 주파수에 따른 전압

- ✓ 주파수 : 40kHz



14-4. 주파수에 따른 전압

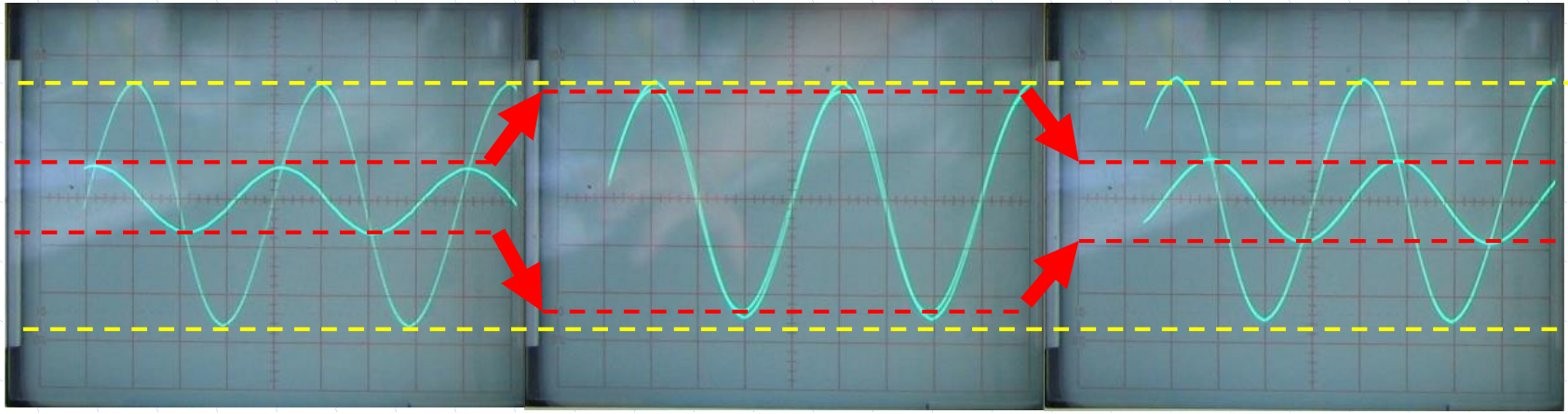
- ✓ 주파수 : 50kHz



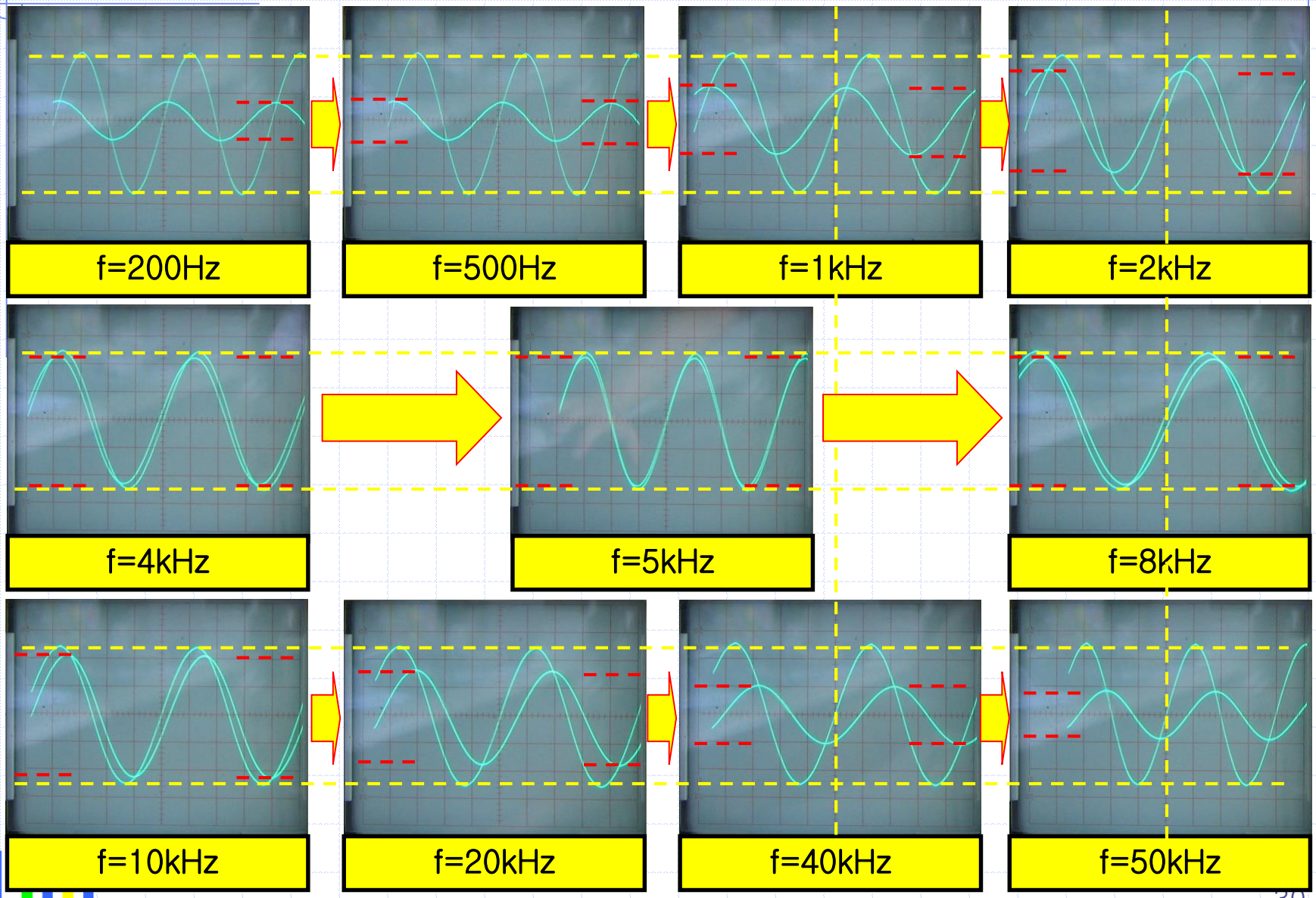
14-4. 주파수에 따른 전압

Frequency (Hz)	이 론				실 험			
	Vin (Vpp)	Vout (Vpp)	전압 이득	전압 이득 (dB)	Vin (Vpp)	Vout (Vpp)	전압 이득	전압 이득 (dB)
200	10	1.25	0.125	-18.06	10	1.26	0.126	-17.99
500	10	3.02	0.302	-10.40	10	2.9	0.29	-10.75
1,000	10	5.47	0.547	-5.24	10	5.2	0.52	-5.68
2,000	10	8.31	0.831	-1.61	10	7.5	0.75	-2.50
3,000	10	9.46	0.946	-0.48	10	8.6	0.86	-1.31
4,000	10	9.89	0.989	-0.10	10	9	0.9	-0.92
5,000	10	9.99	0.999	-0.01	10	9.6	0.96	-0.35
6,000	10	9.94	0.994	-0.05	10	9.6	0.96	-0.35
7,000	10	9.78	0.978	-0.19	10	9.6	0.96	-0.35
8,000	10	9.57	0.957	-0.38	10	9.2	0.92	-0.72
9,000	10	9.32	0.932	-0.61	10	9	0.9	-0.92
10,000	10	9.05	0.905	-0.87	10	8.8	0.88	-1.11
15,000	10	7.67	0.767	-2.30	10	8	0.8	-1.94
20,000	10	6.47	0.647	-3.78	10	7	0.7	-3.10
30,000	10	4.79	0.479	-6.39	10	5.2	0.52	-5.68
40,000	10	3.75	0.375	-8.52	10	4.2	0.42	-7.54
50,000	10	3.06	0.306	-10.29	10	3.55	0.355	-9.00

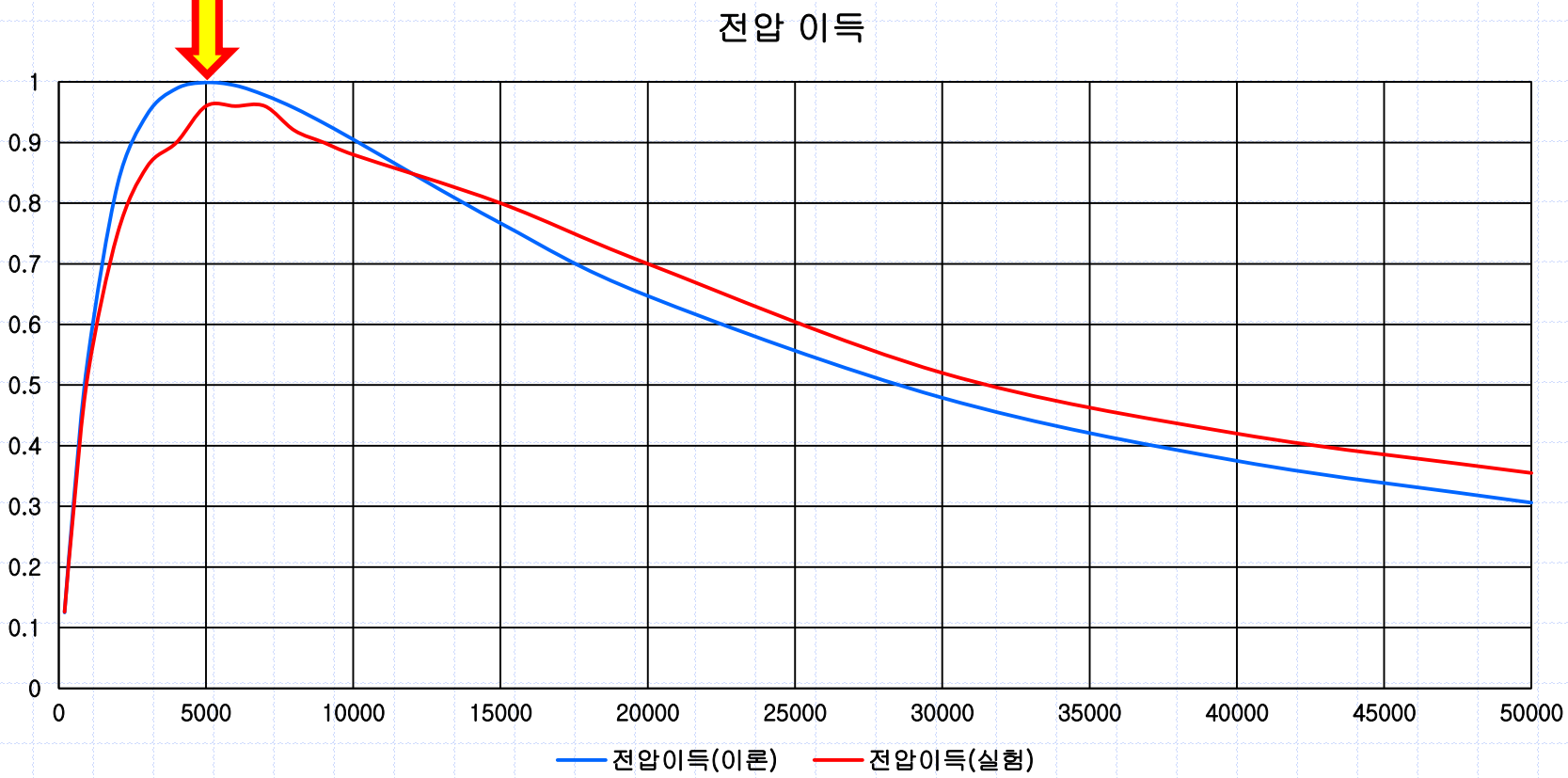
14-4. 주파수에 따른 전압



14-4. 주파수에 따른 전압

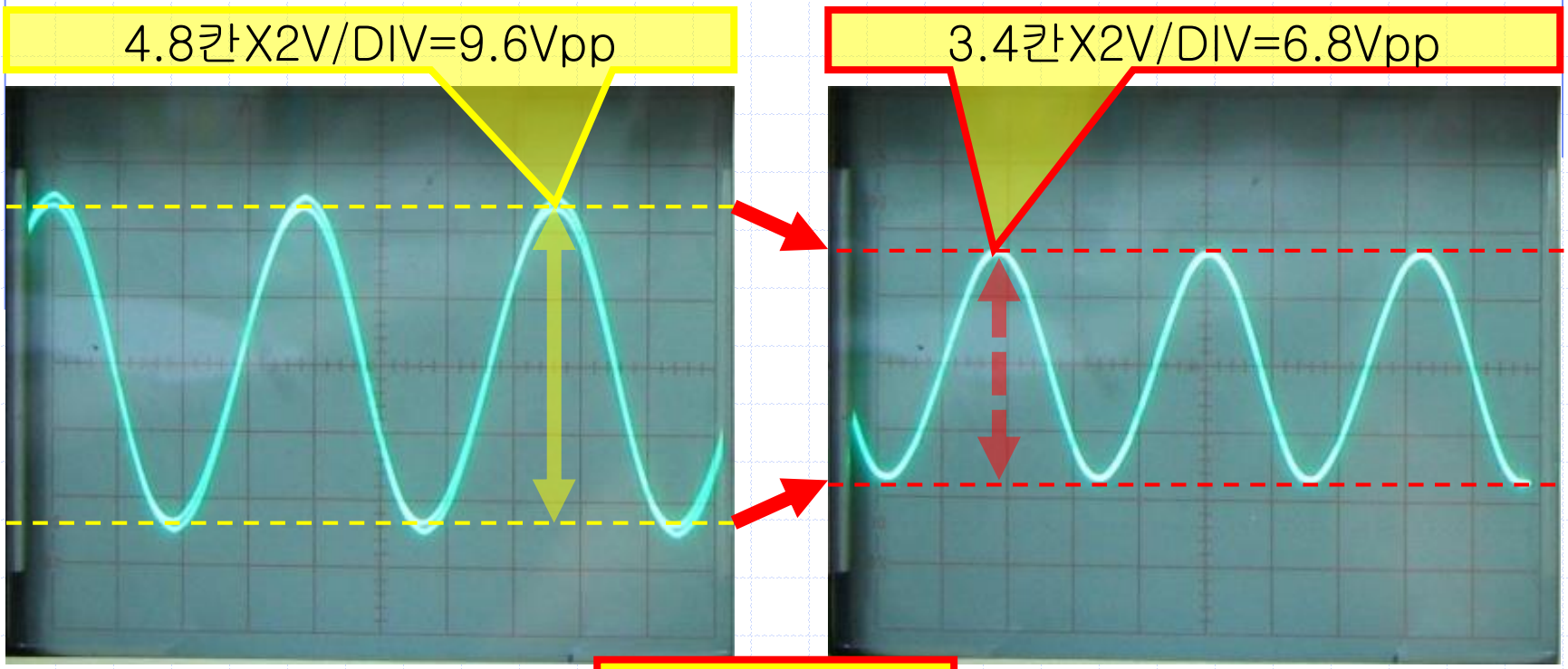


14-5. 공진 주파수



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

14-6. 대역폭 측정



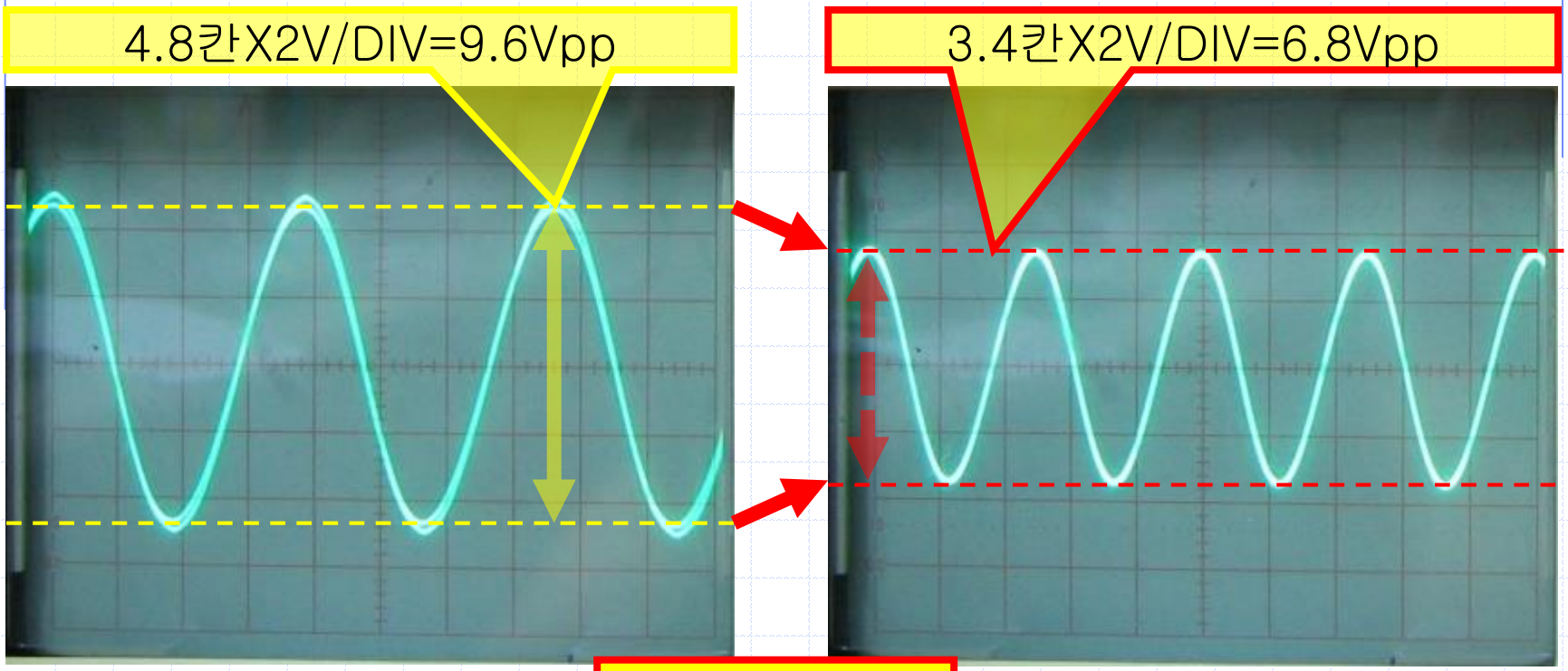
공진주파수 : 5.032kHz

0.707 (3dB)

하한주파수: 1.55kHz

CH 1 : 2V/DIV, CH 2 : 0.5V/DIV, Time : 5uS/DIV

14-6. 대역폭 측정



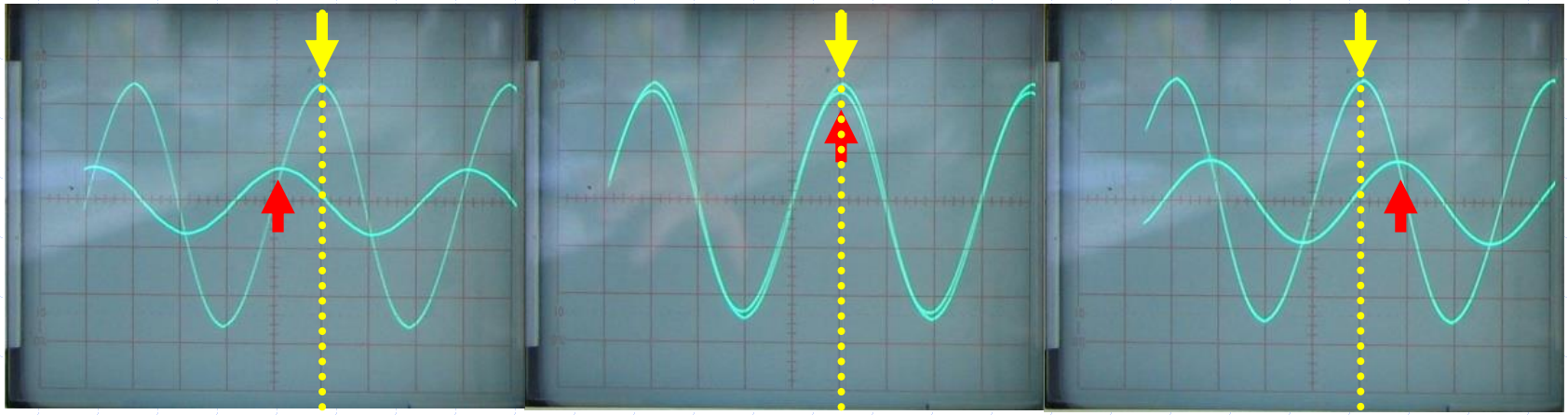
공진주파수 : 5.032kHz

0.707 (3dB)

상한주파수: 20.05kHz

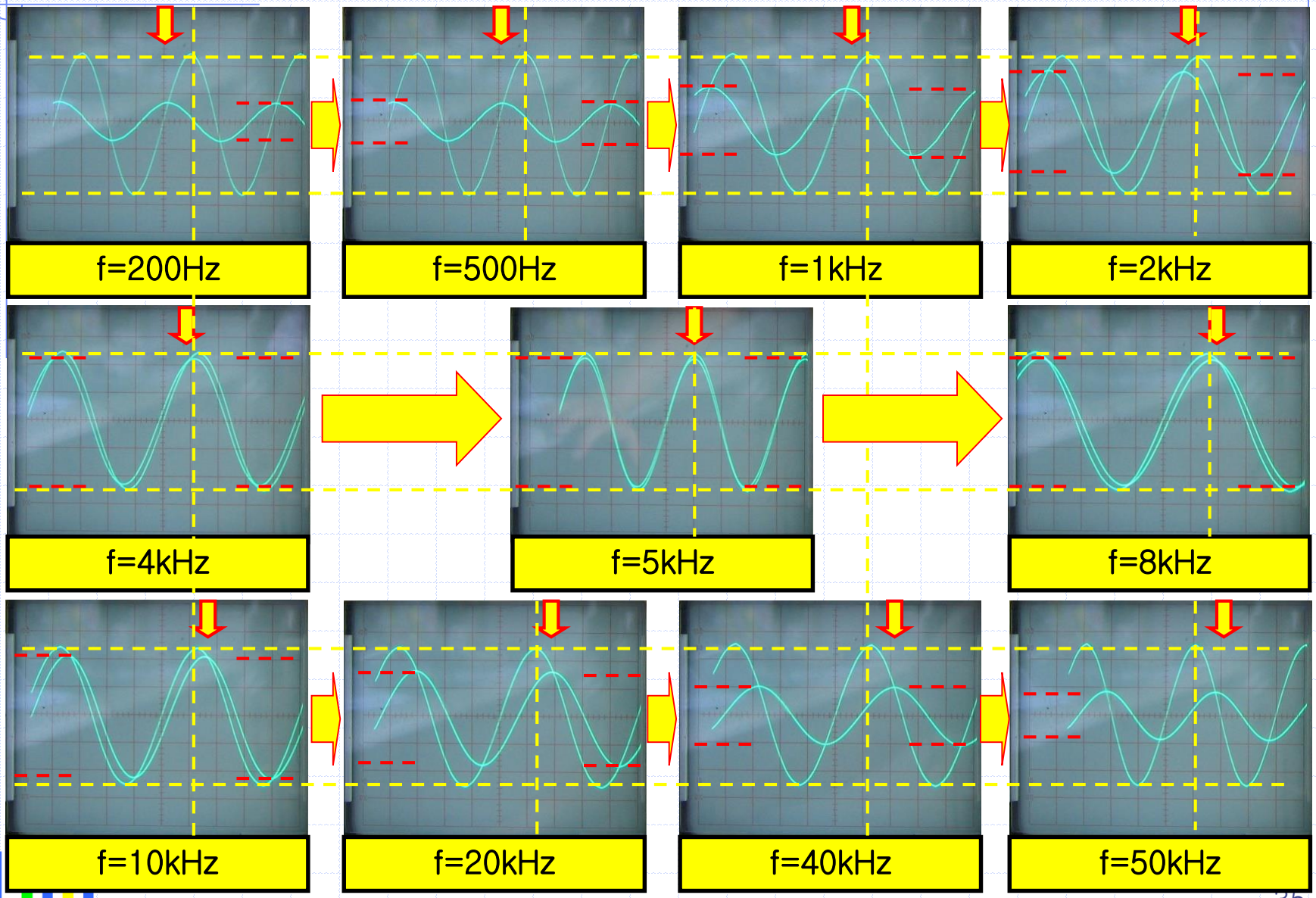
CH 1 : 2V/DIV, CH 2 : 0.5V/DIV, Time : 5uS/DIV

14-7. 주파수에 따른 위상 변화

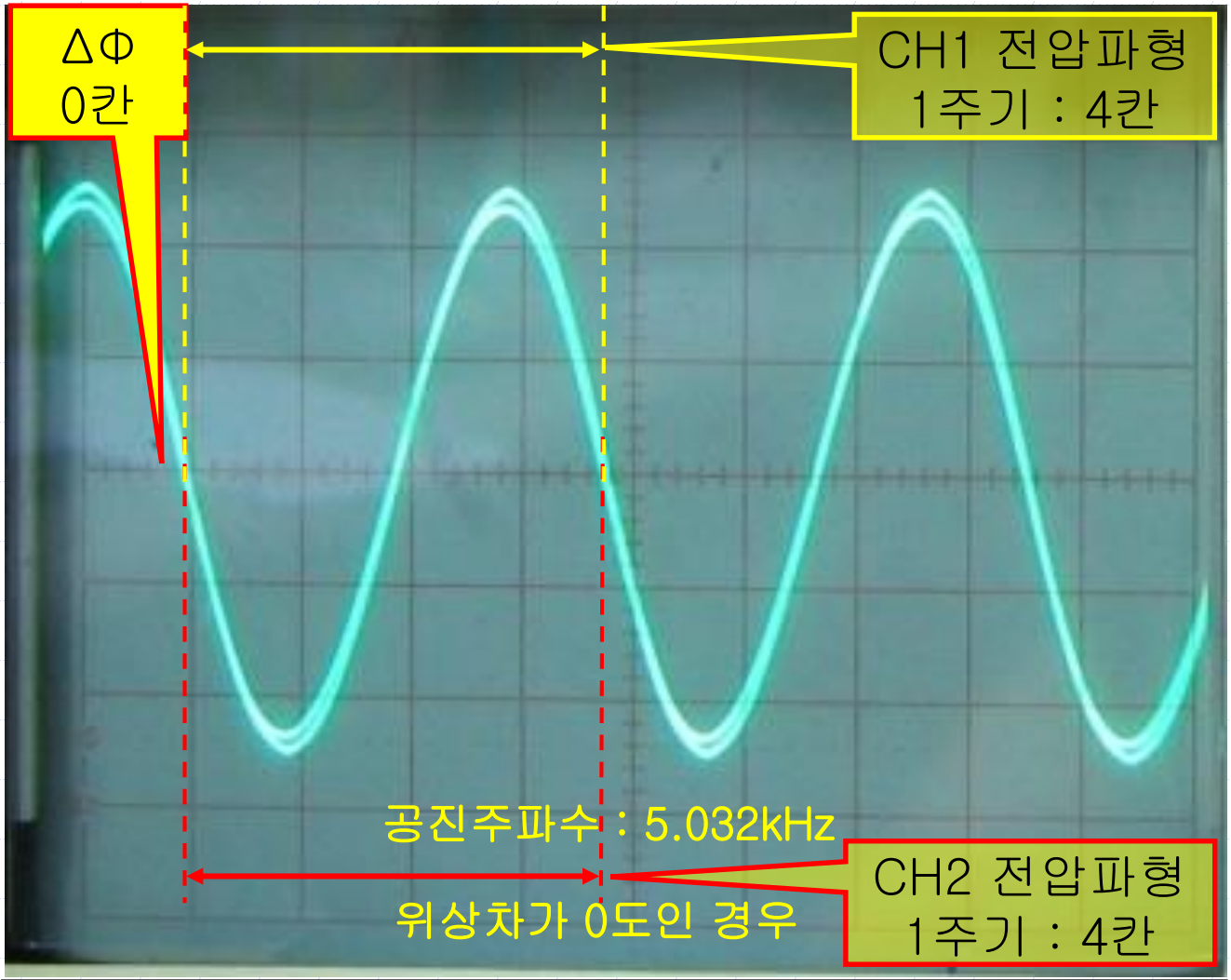


f=200Hz	f=5kHz	f=50kHz

14-7. 주파수에 따른 위상 변화

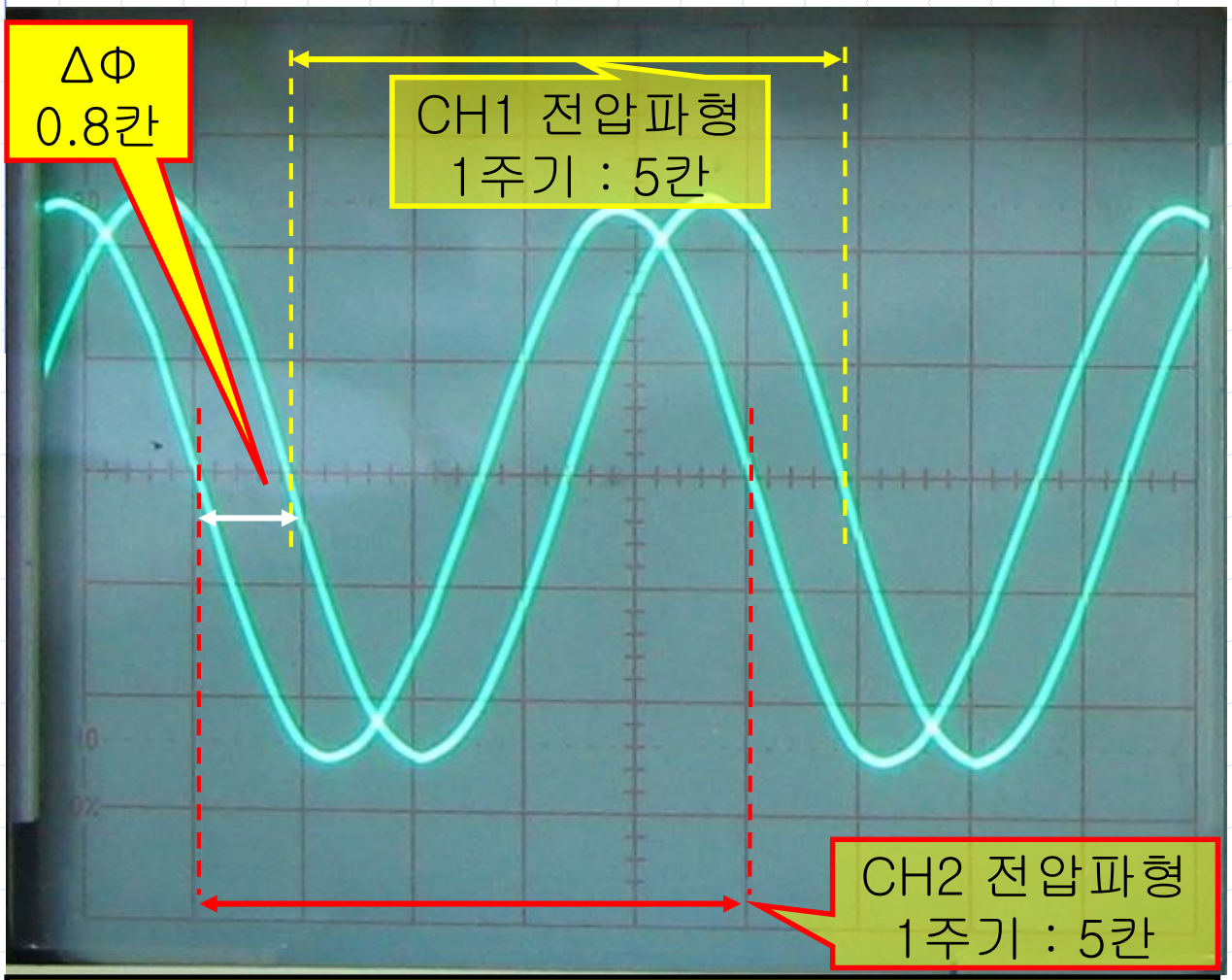


14-7. 주파수에 따른 위상 변화



14-7. 주파수에 따른 위상 변화

✓ 위상차를 측정하라. (주파수 : 1kHz)



$1T = 5칸 \times 0.2mSec$
$= 1mSec$

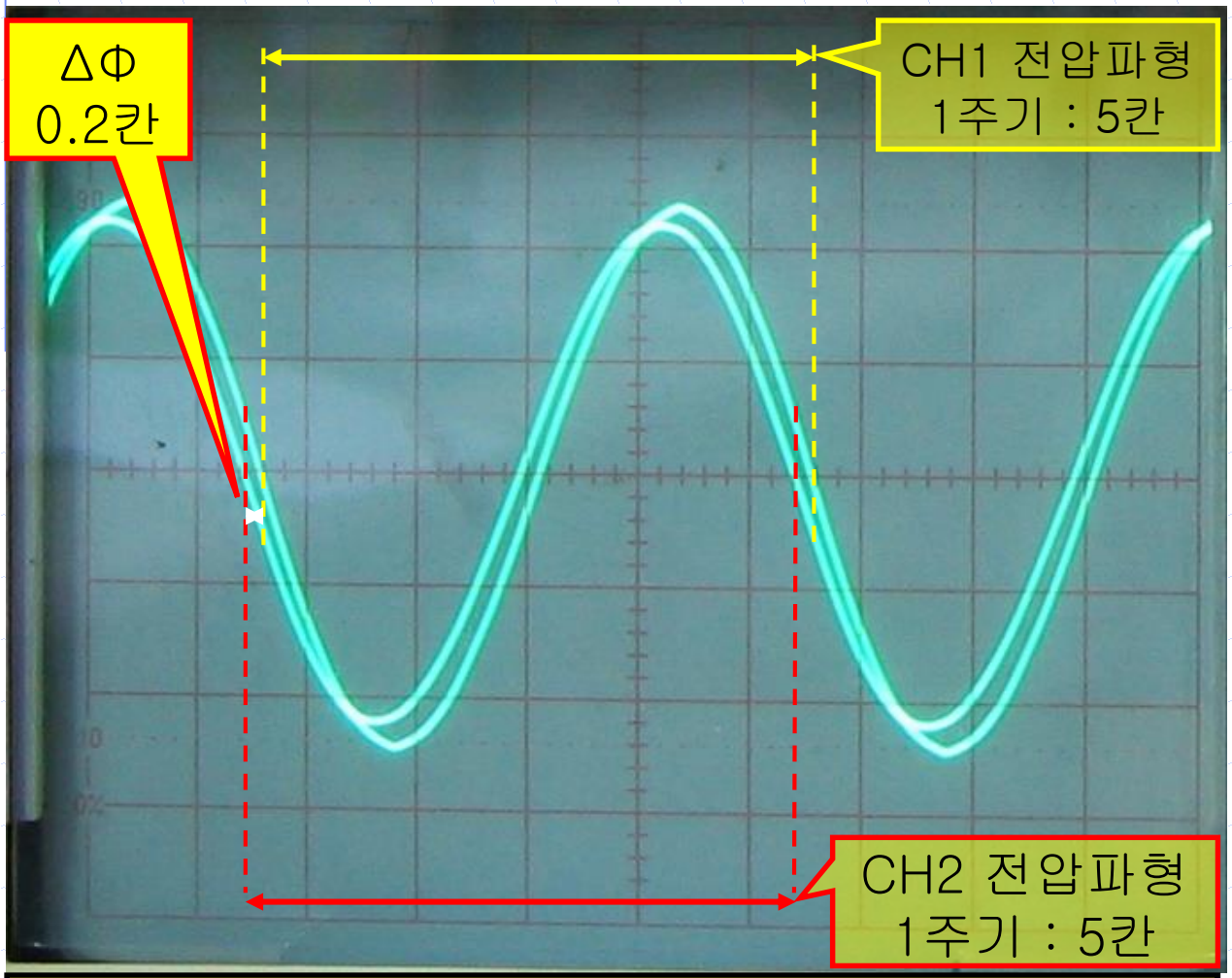
$\Delta t = 0.8칸 \times 0.2mSec$
$= 0.16mSec$

$1mSec : 0.16mSec$
$= 360° : \Delta\theta$

$\Delta\theta = +57.6°$

14-7. 주파수에 따른 위상 변화

✓ 위상차를 측정하라. (주파수 : 4kHz)



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

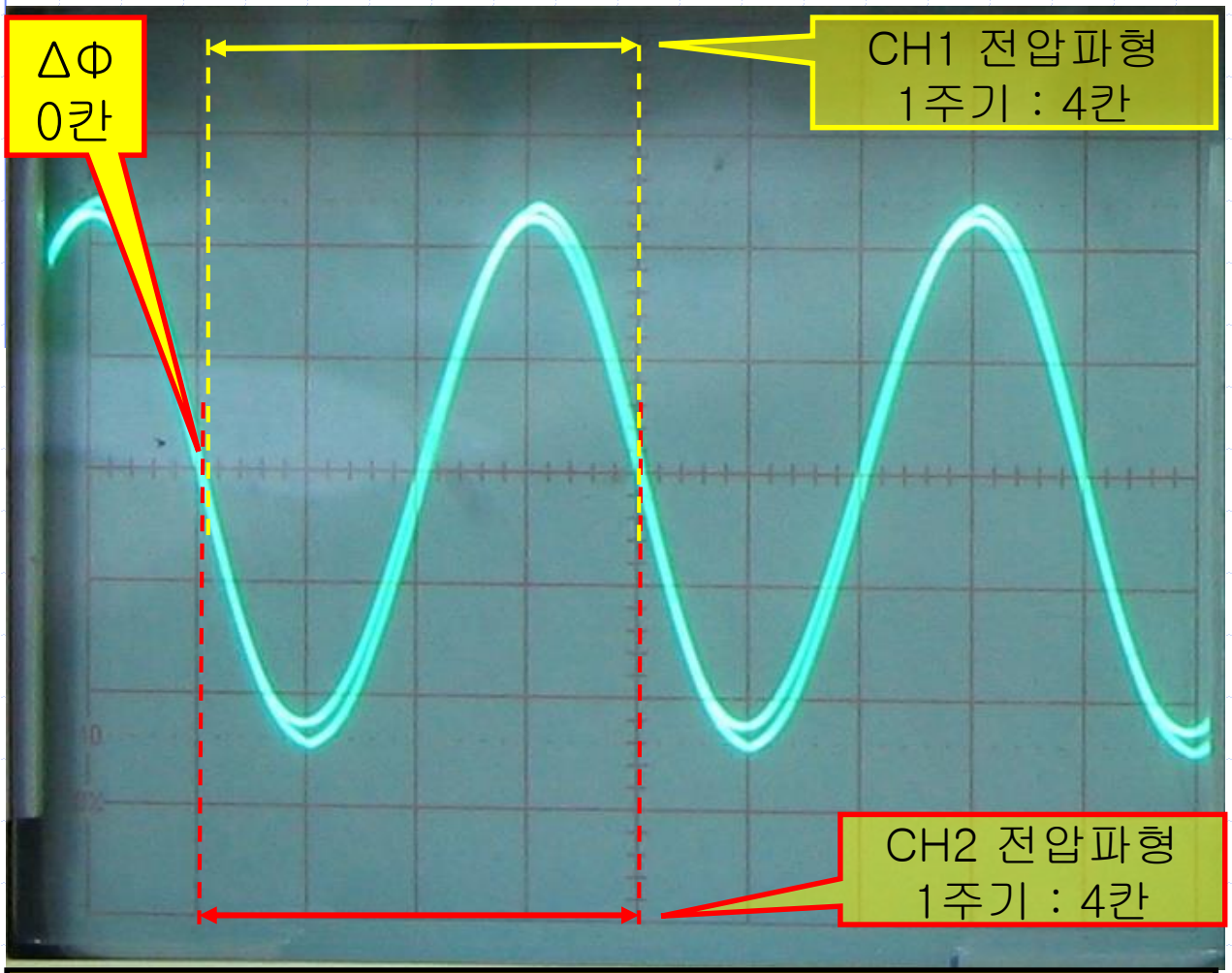
$\Delta t = 0.2칸 \times 50\mu Sec$
$= 10\mu Sec$

$250\mu Sec : 10\mu Sec$
$= 360° : \Delta\theta$

$\Delta\theta = +14.4°$

14-7. 주파수에 따른 위상 변화

✓ 위상차를 측정하라. (주파수 : 5kHz)



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

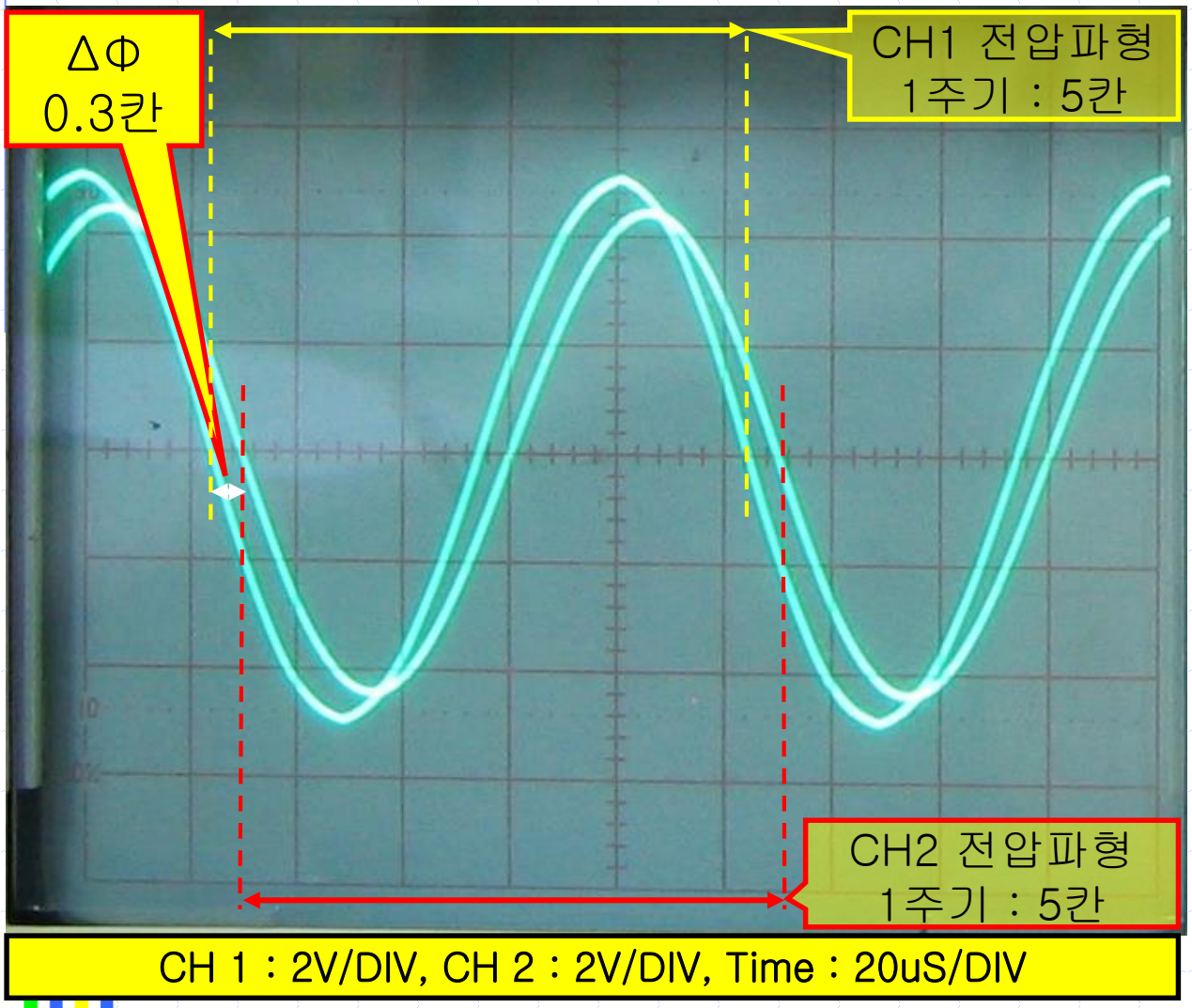
$\Delta t = 0칸 \times 50\mu Sec$
$= 0\mu Sec$

$200\mu Sec : 0\mu Sec$
$= 360° : \Delta\theta$

$\Delta\theta = 0°$

14-7. 주파수에 따른 위상 변화

✓ 위상차를 측정하라. (주파수 : 10kHz)



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

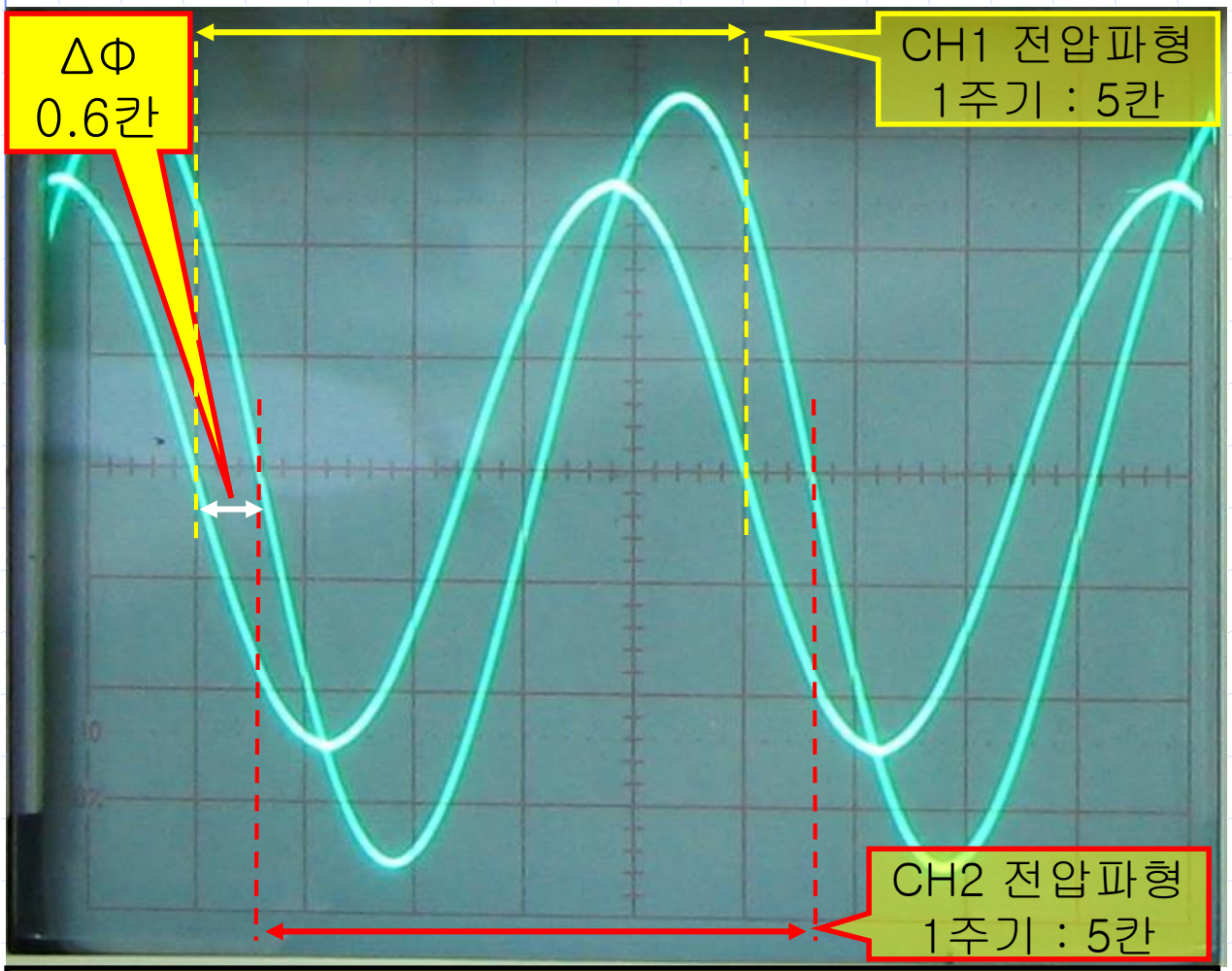
$\Delta t = 0.3칸 \times 20\mu Sec$
$= 6\mu Sec$

$100\mu Sec : 6\mu Sec$
$= 360° : \Delta\theta$

$\Delta\theta = -21.6°$

14-7. 주파수에 따른 위상 변화

✓ 위상차를 측정하라. (주파수 : 20kHz)



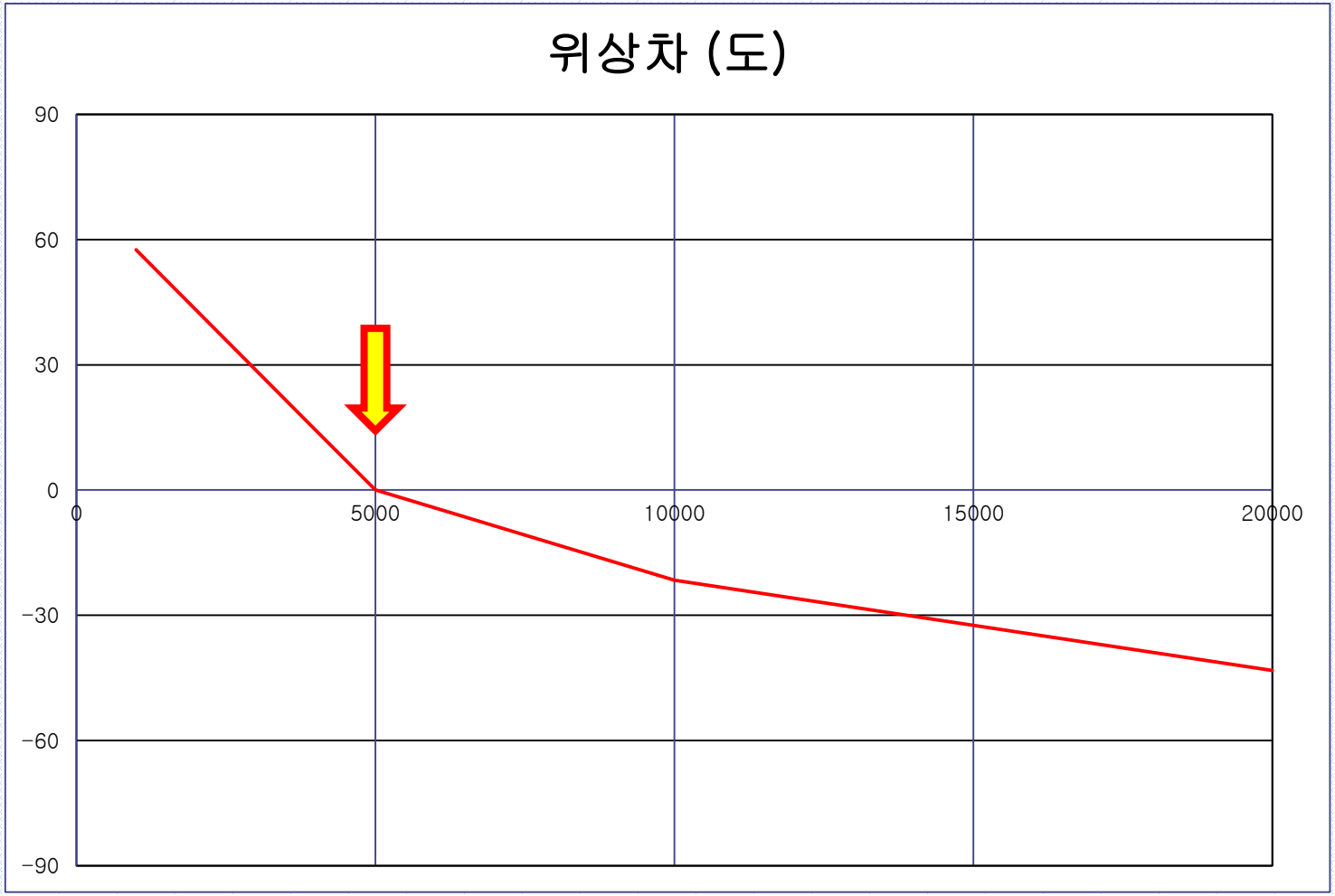
$1T = 5칸 \times 10\mu Sec$
$= 50\mu Sec$

$\Delta t = 0.6칸 \times 10\mu Sec$
$= 6\mu Sec$

$50\mu Sec : 6\mu Sec$
$= 360° : \Delta\theta$

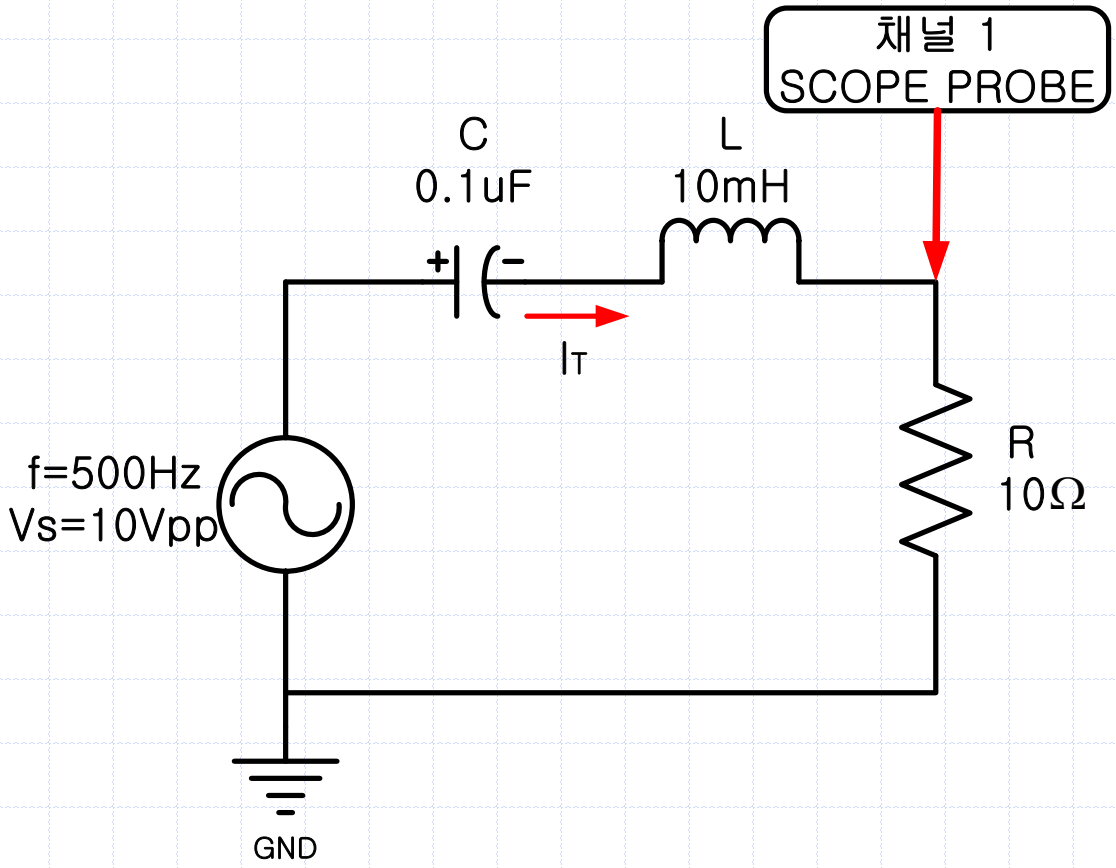
$\Delta\theta = -43.2°$

14-7. 주파수에 따른 위상 변화



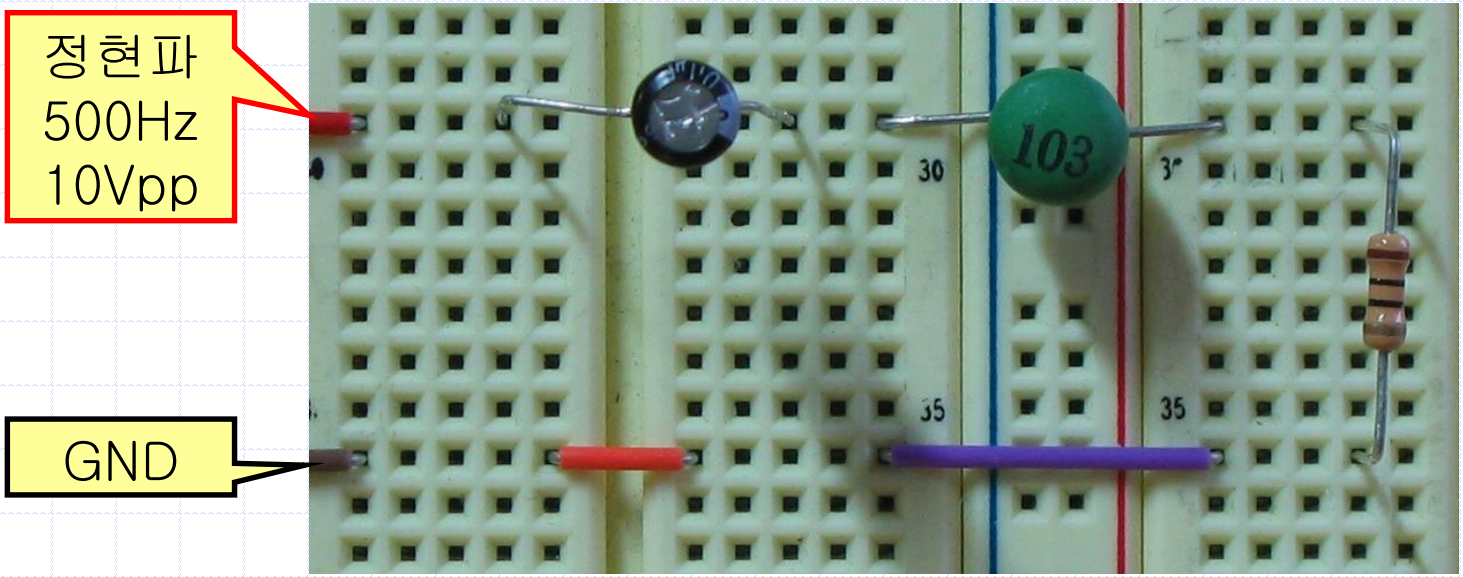
14-8. 주파수에 따른 전류 및 임피던스

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

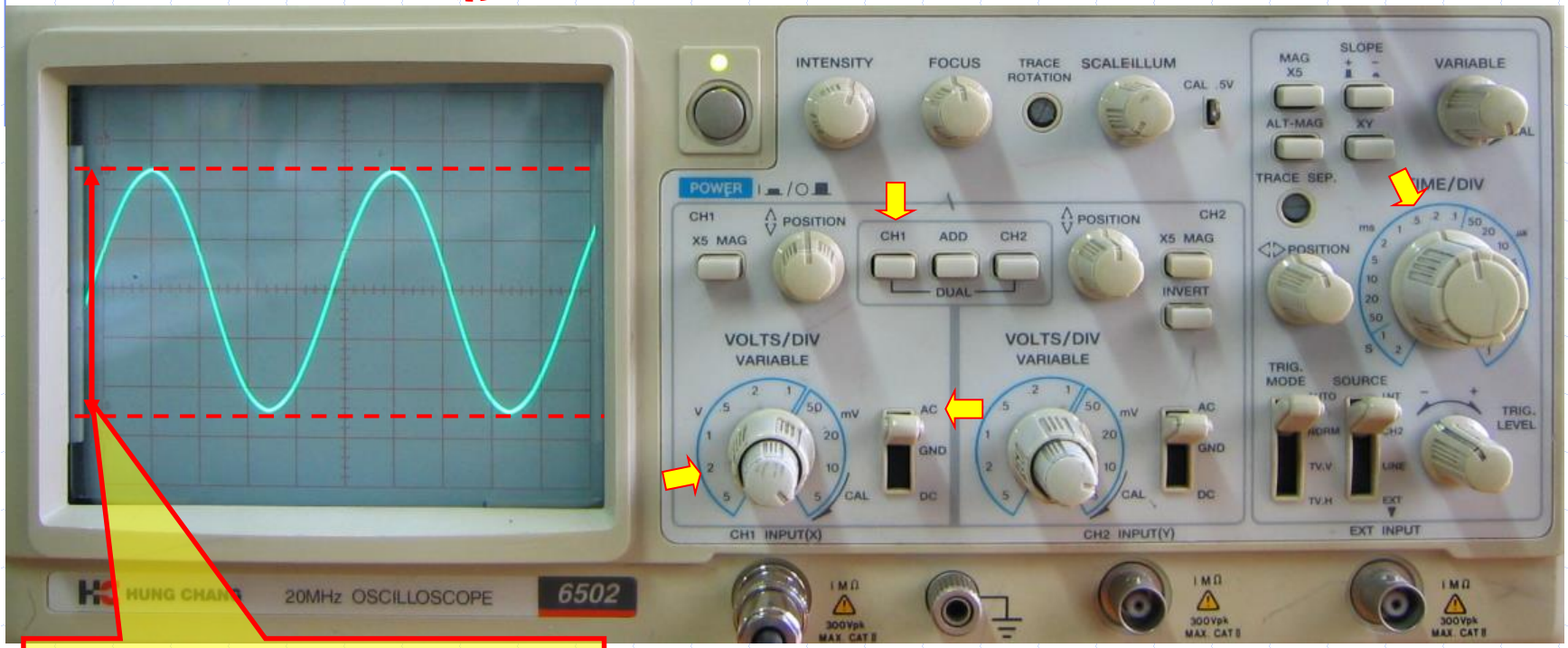


14-8. 주파수에 따른 전류 및 임피던스

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

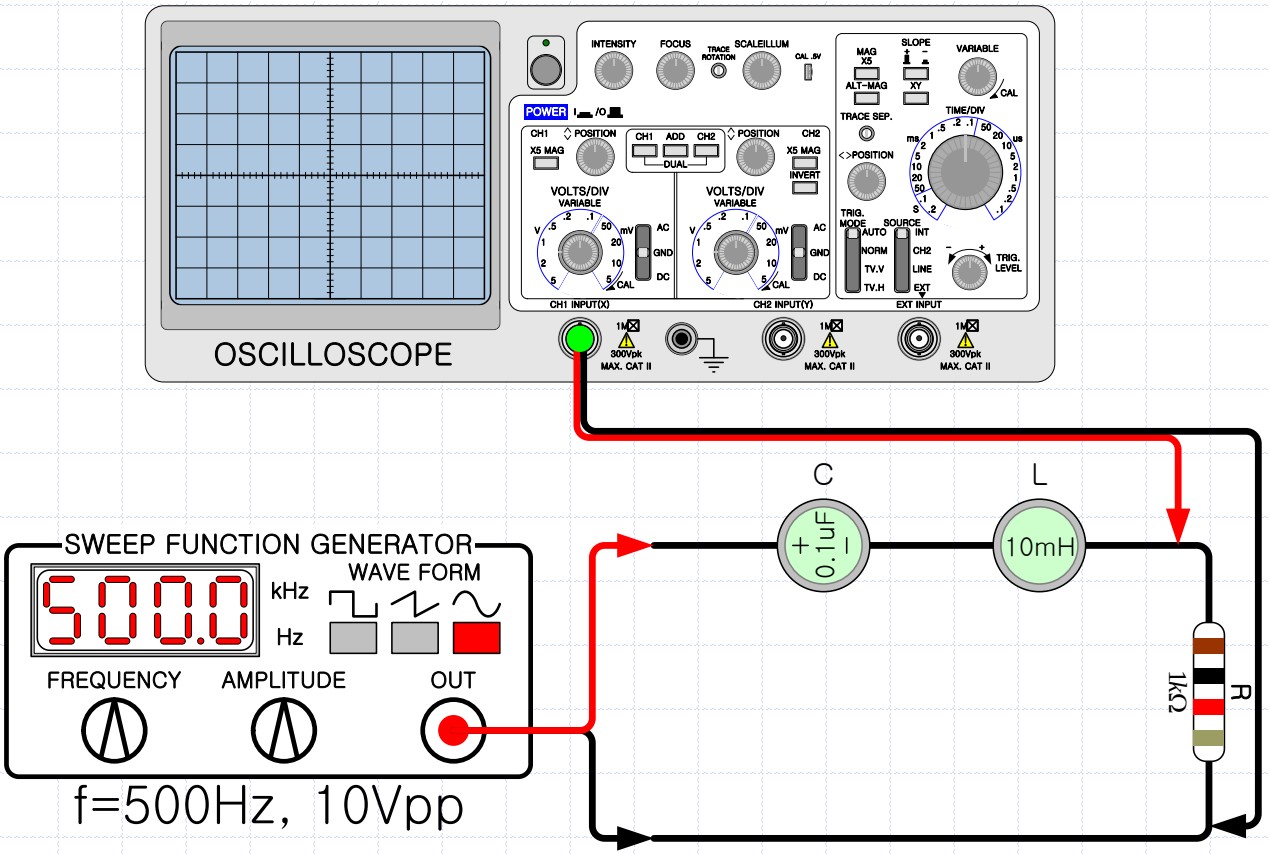


14-8. 주파수에 따른 전류 및 임피던스



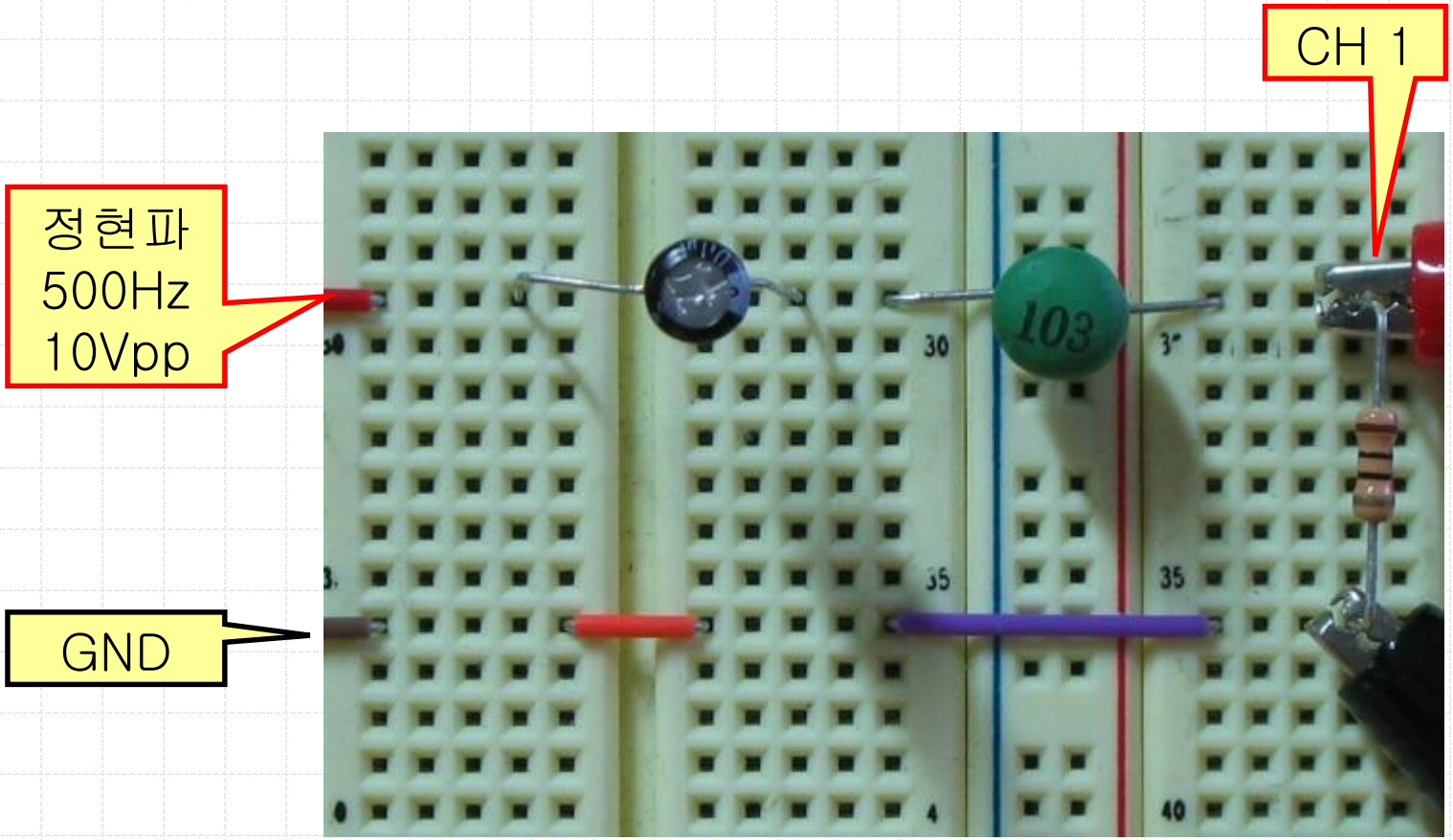
14-8. 주파수에 따른 전류 및 임피던스

- 오실로스코프의 CH 1 을 이용하여 저항 양단의 출력 전압 (Vout) 을 측정한다.



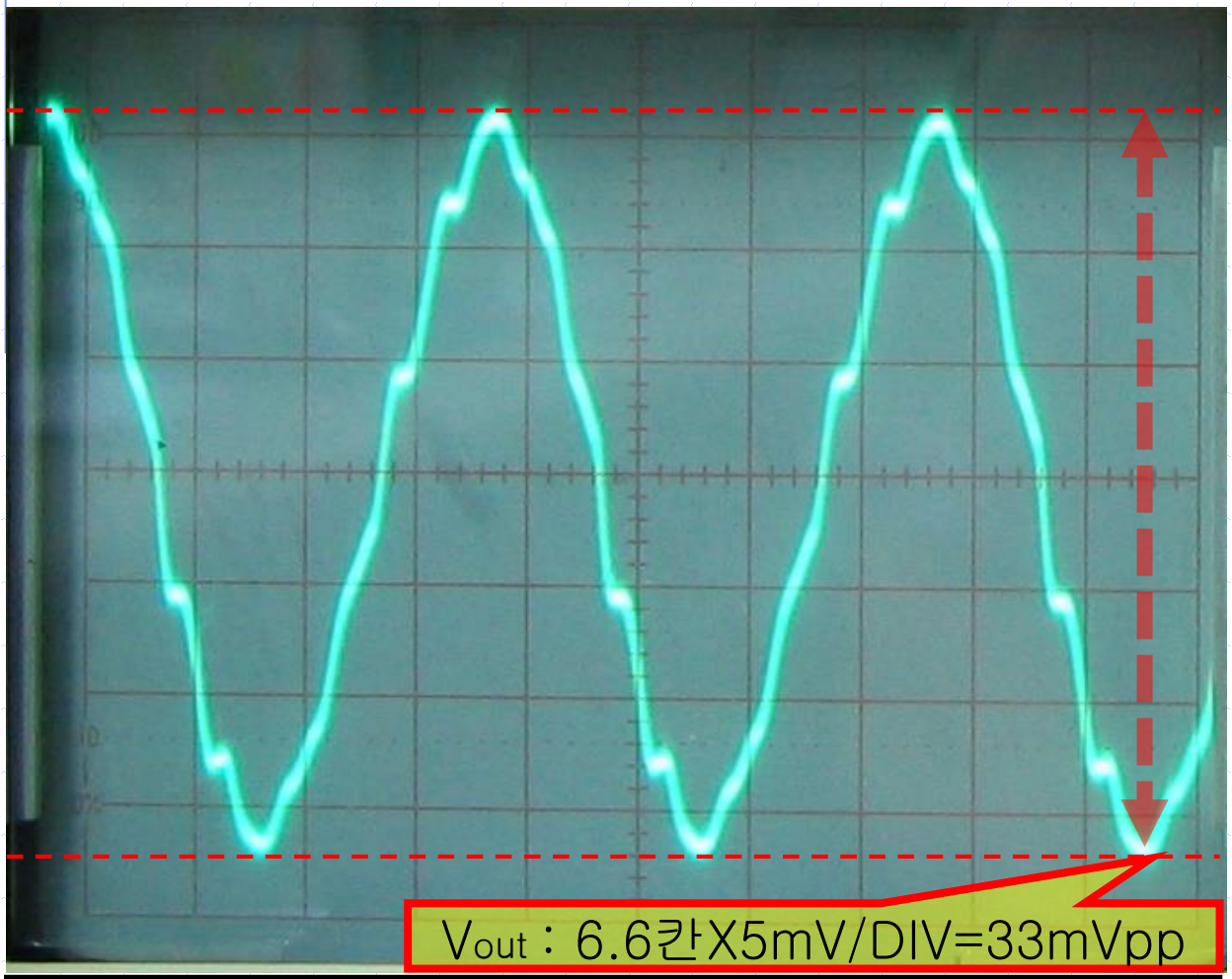
14-8. 주파수에 따른 전류 및 임피던스

- ✓ 주파수 : 500Hz



14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 500Hz

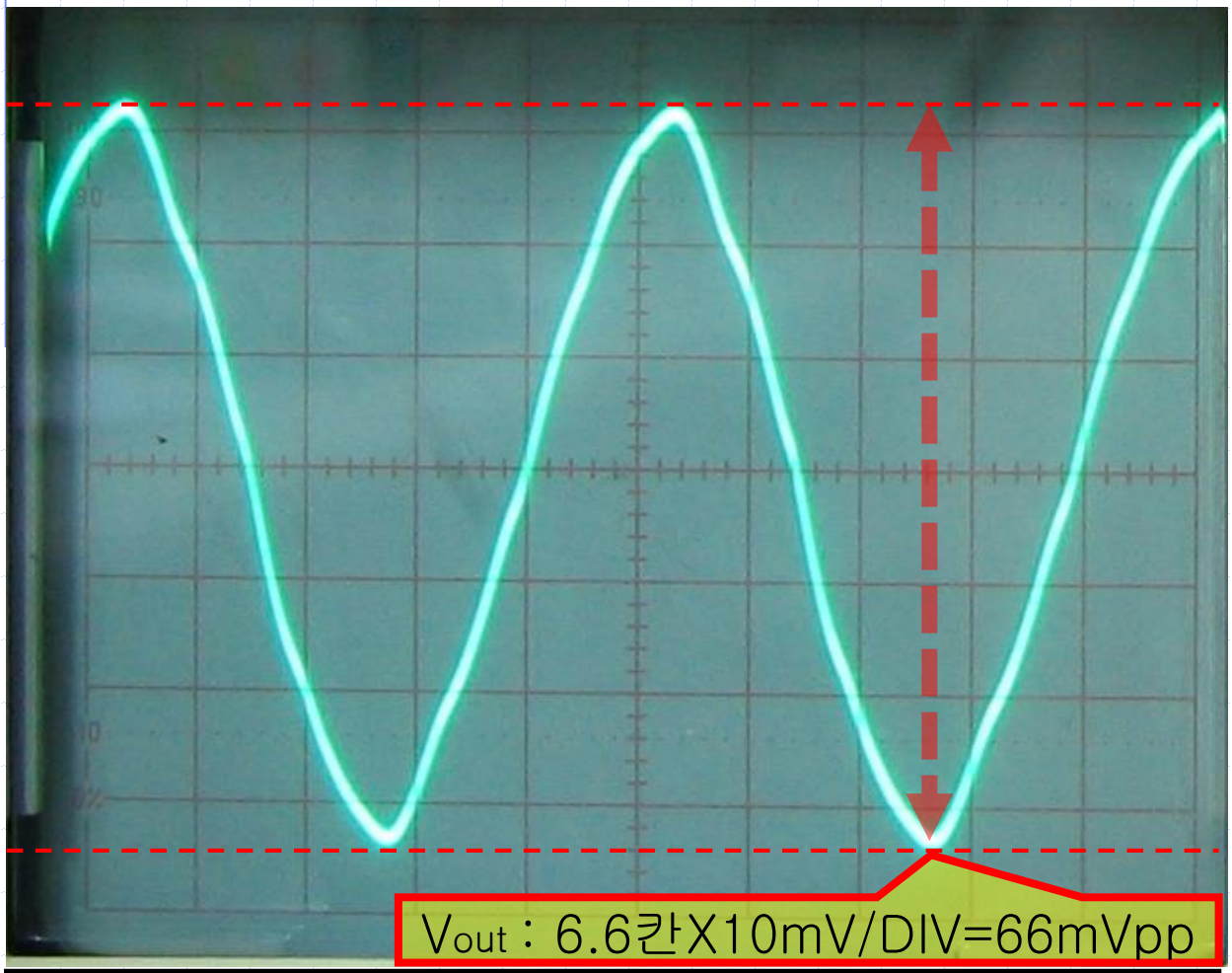


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{33mV_{PP}}{10\Omega} = 3.3mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{3.3mA_{PP}} = 3030.3\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 1kHz

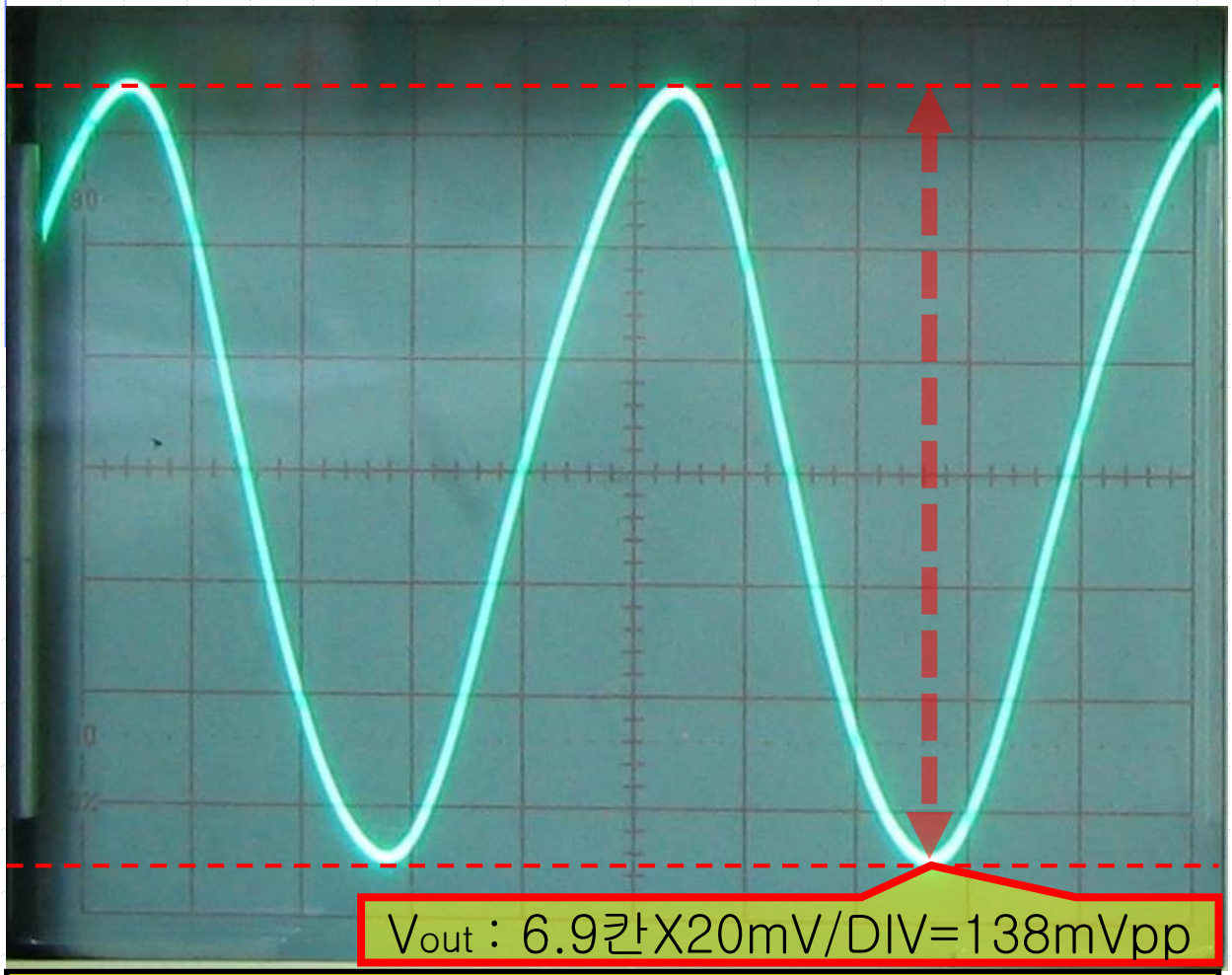


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{66mV_{PP}}{10\Omega} = 6.6mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{6.6mA_{PP}} = 1515.2\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 2kHz

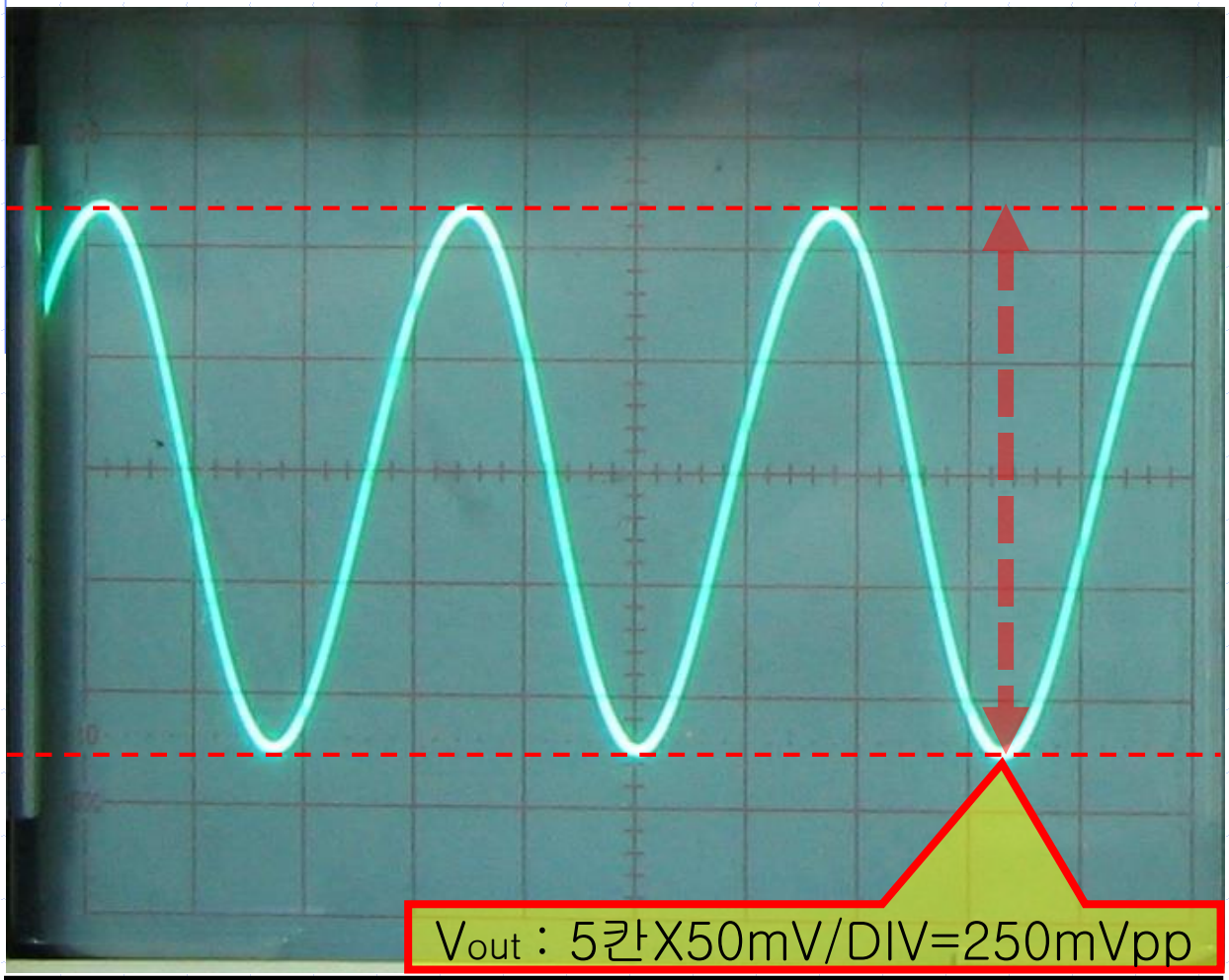


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{138mV_{PP}}{10\Omega} = 13.8mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{13.8mA_{PP}} = 724.6\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 3kHz

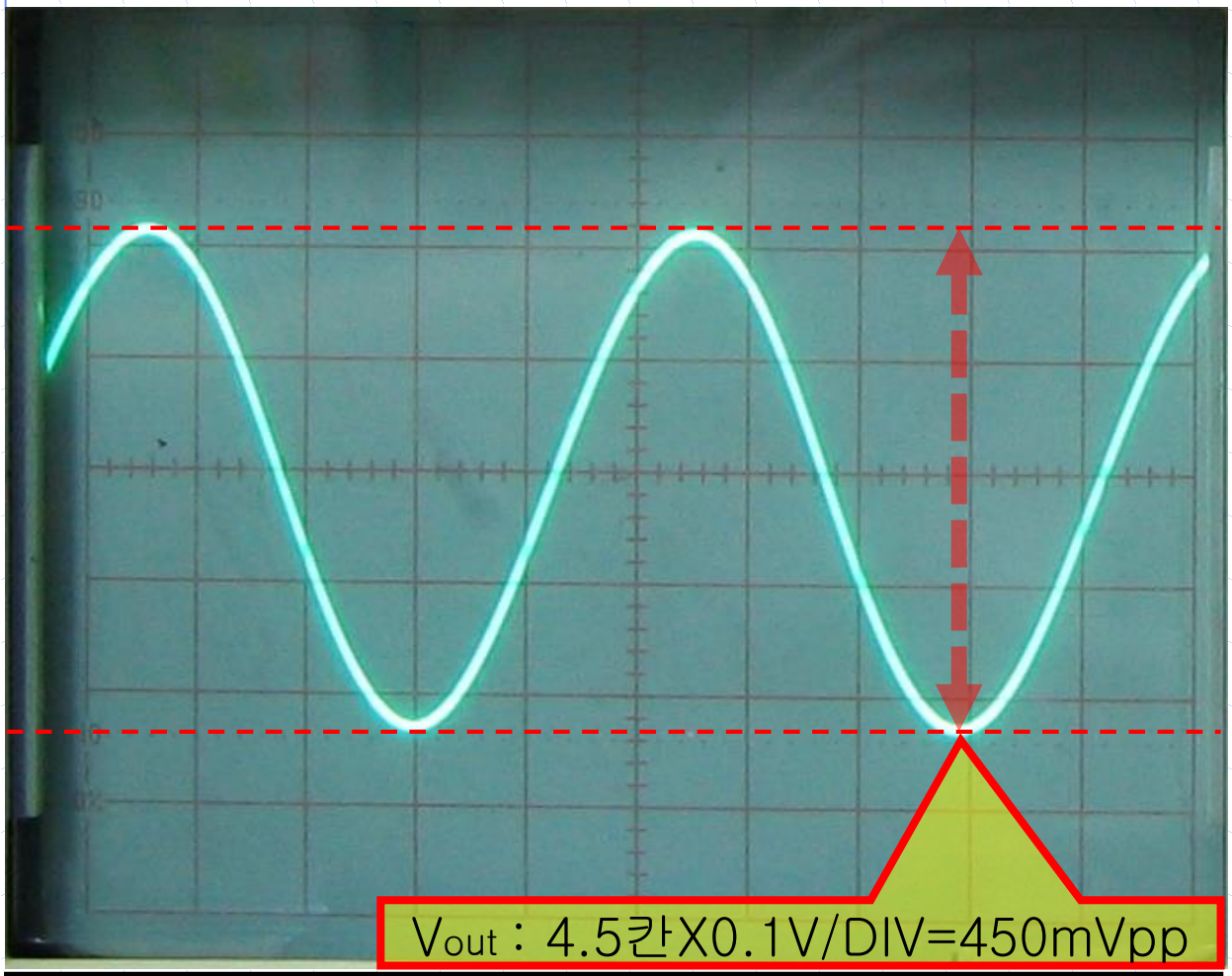


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{250mV_{PP}}{10\Omega} = 25mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{25mA_{PP}} = 400\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 4kHz

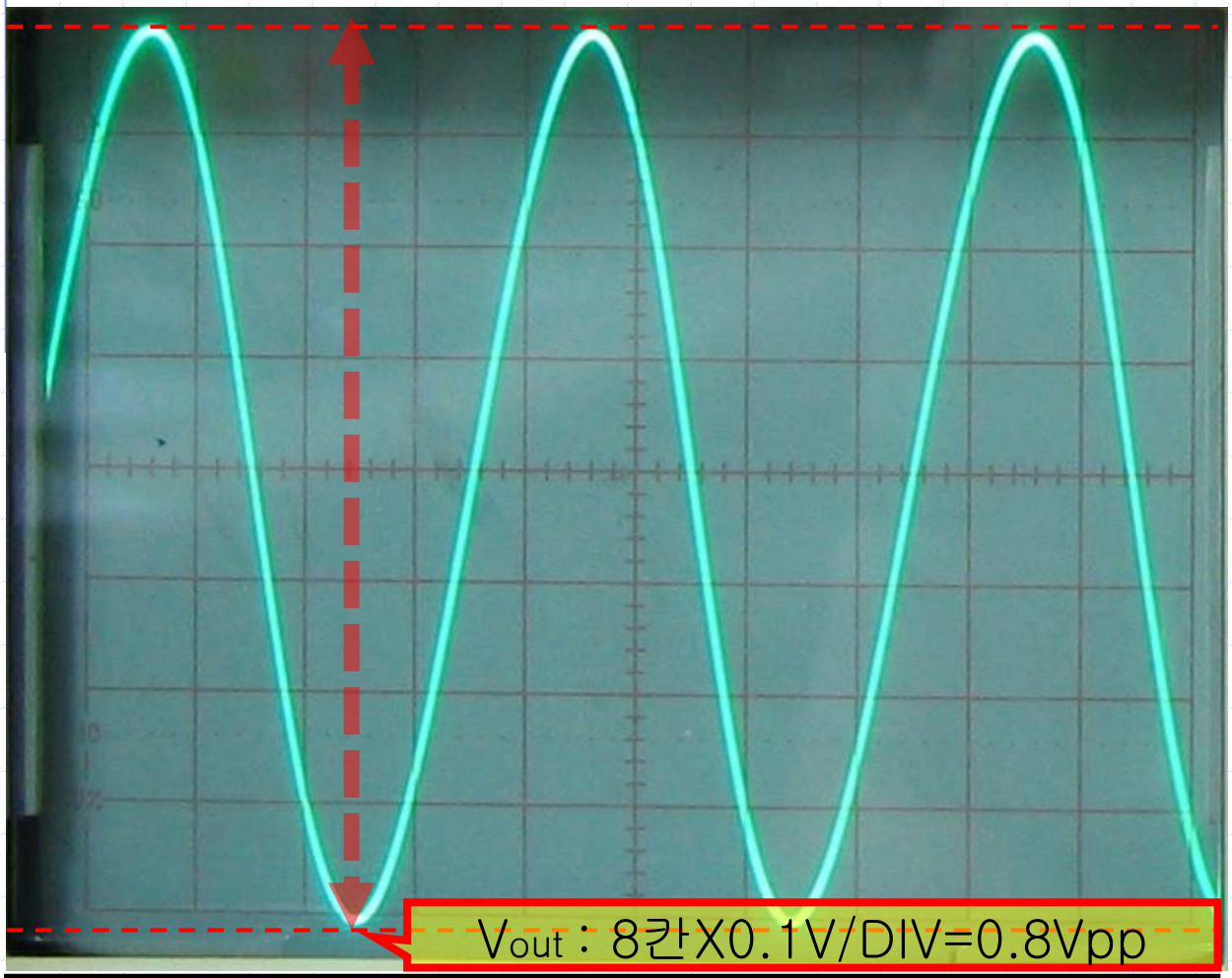


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{450mV_{PP}}{10\Omega} = 45mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{45mA_{PP}} = 222.2\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 5kHz



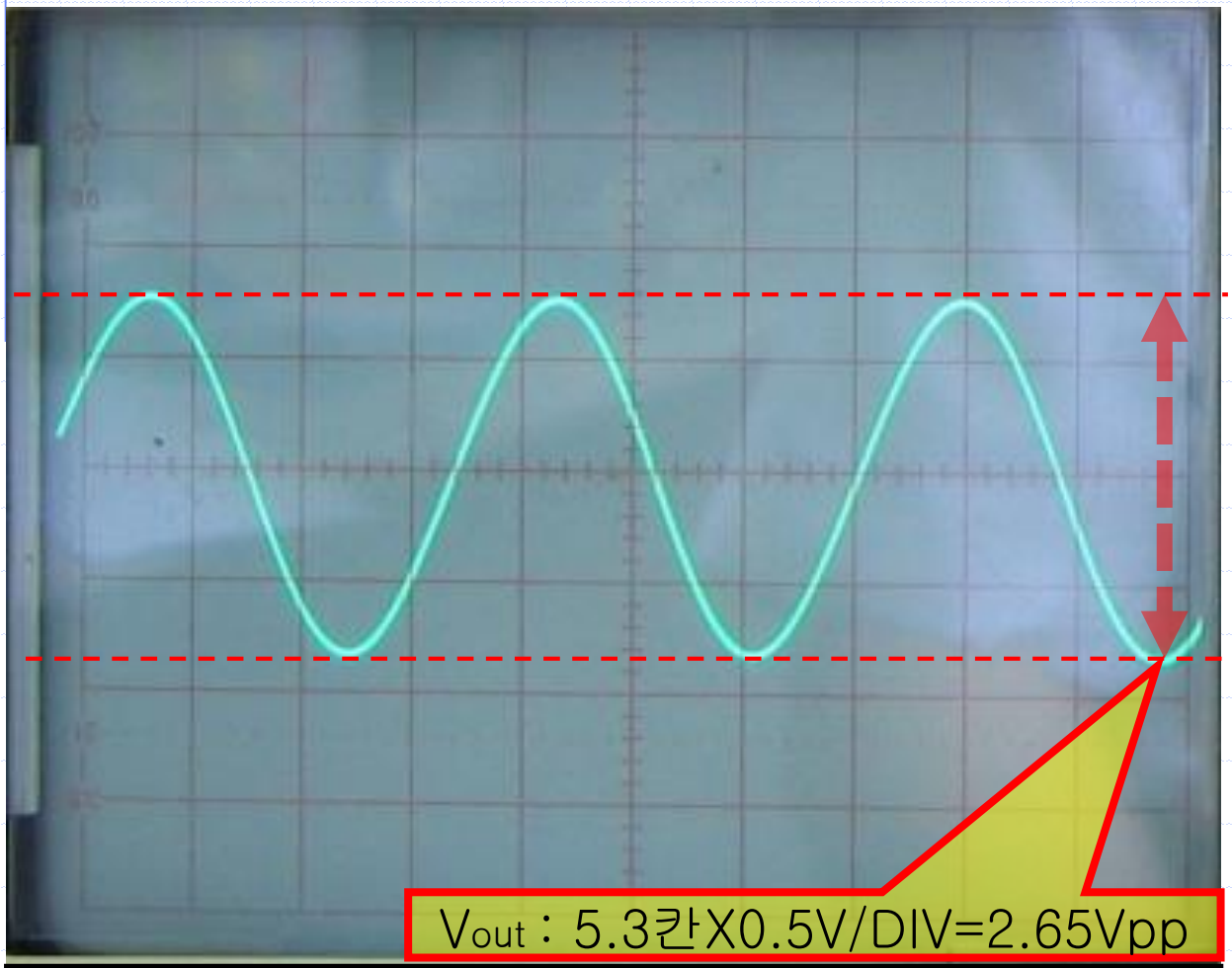
CH 1 : 0.1V/DIV, Time : 50uS/DIV

$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{0.8V_{PP}}{10\Omega} = 80mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{80mA_{PP}} = 127.8\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 공진주파수(5.032kHz)

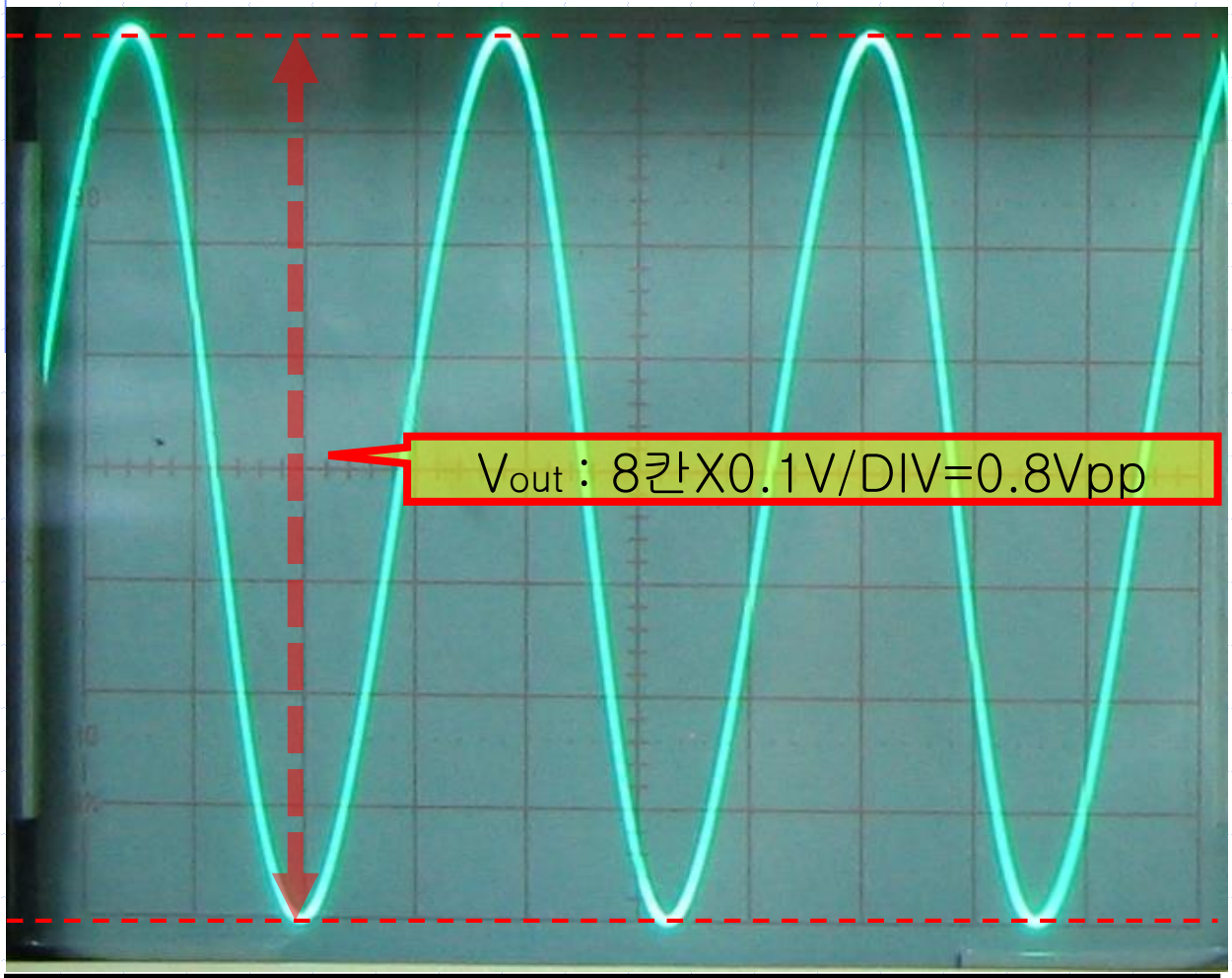


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{2.65V_{PP}}{10\Omega} = 265mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{80mA_{PP}} = 37.7\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 6kHz



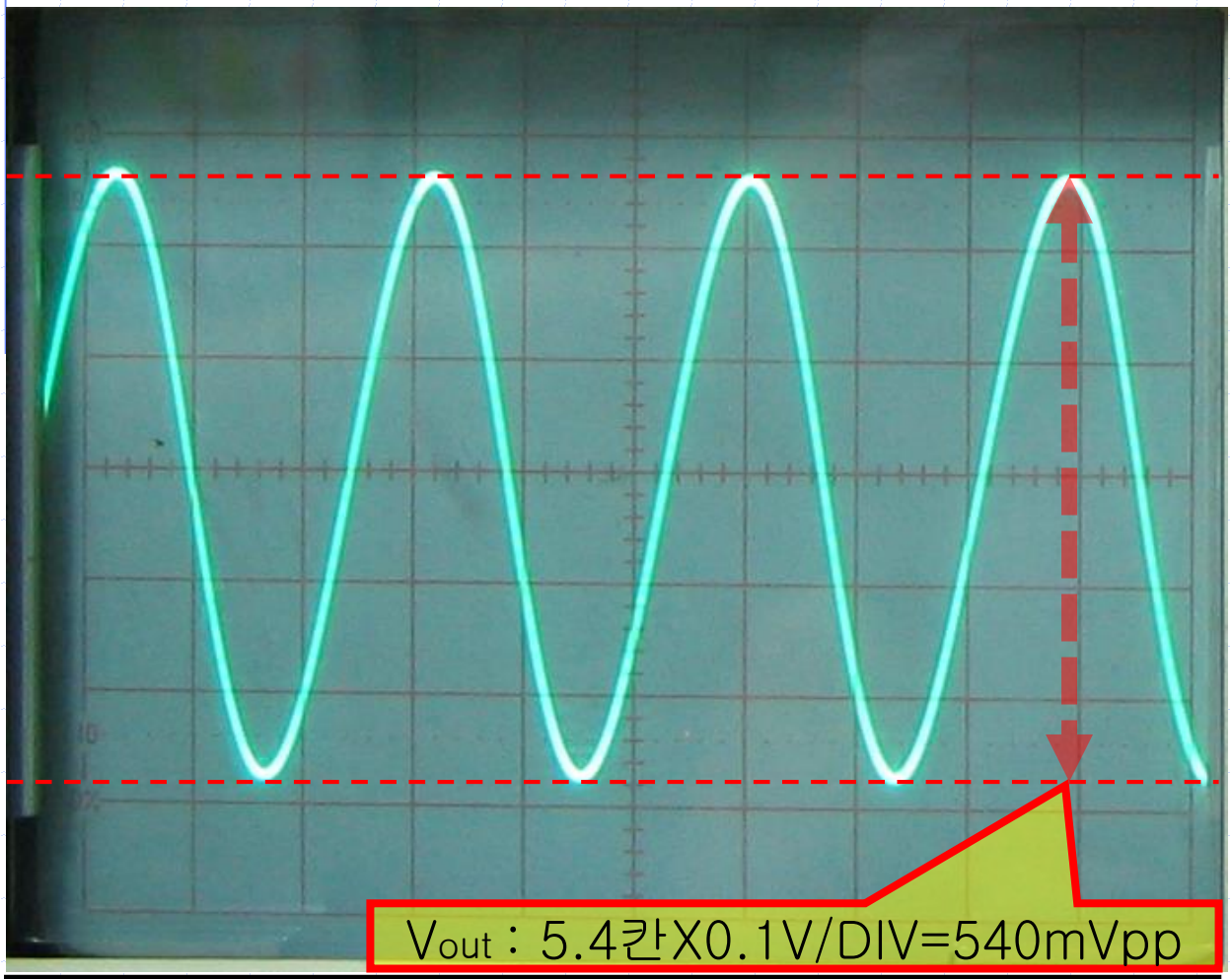
CH 1 : 0.1V/DIV, Time : 50uS/DIV

$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{0.8V_{PP}}{10\Omega} = 80mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{80mA_{PP}} = 127.8\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 7kHz



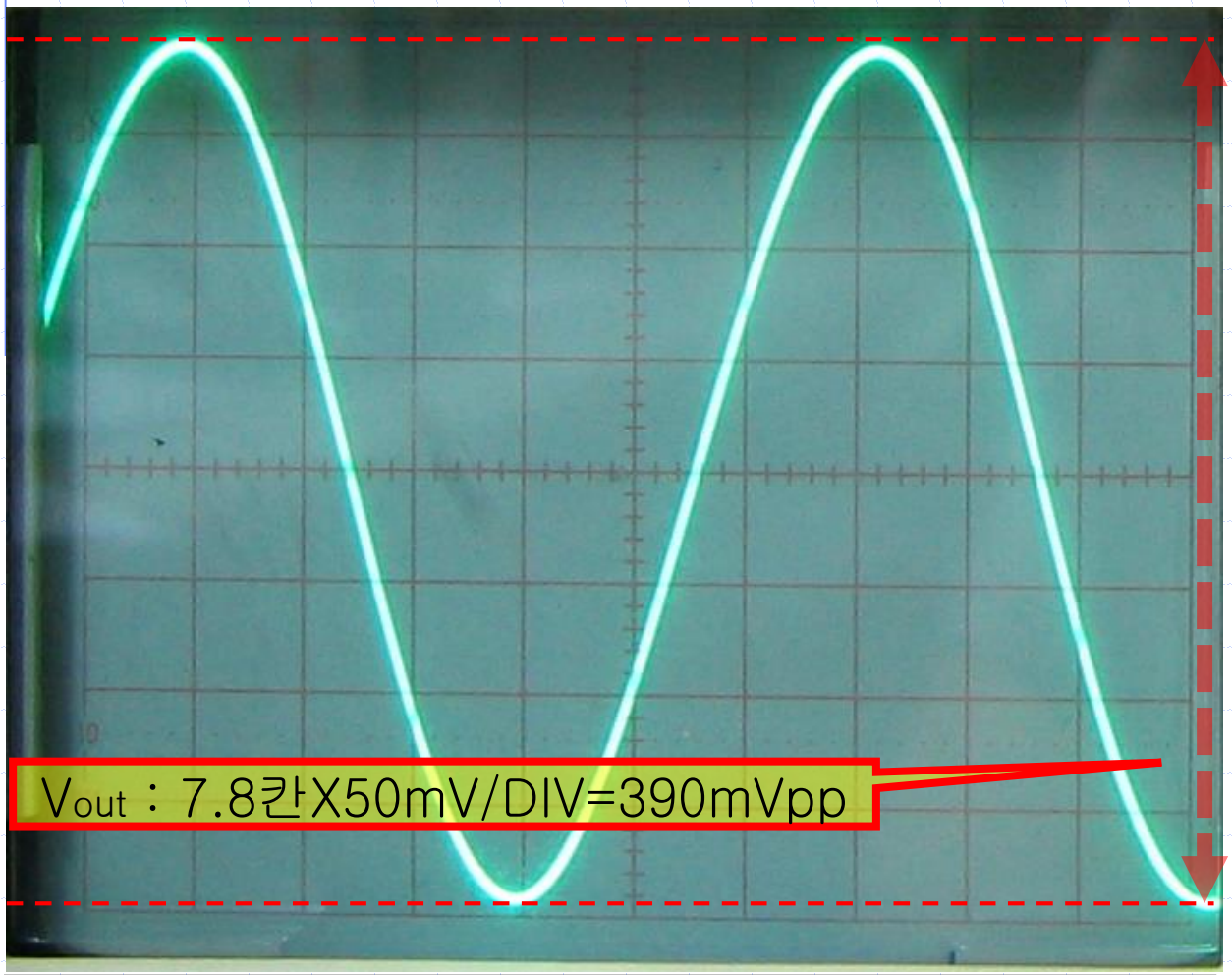
CH 1 : 0.1V/DIV, Time : 50uS/DIV

$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{540mV_{PP}}{10\Omega} = 54mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{54mA_{PP}} = 185.2\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 8kHz



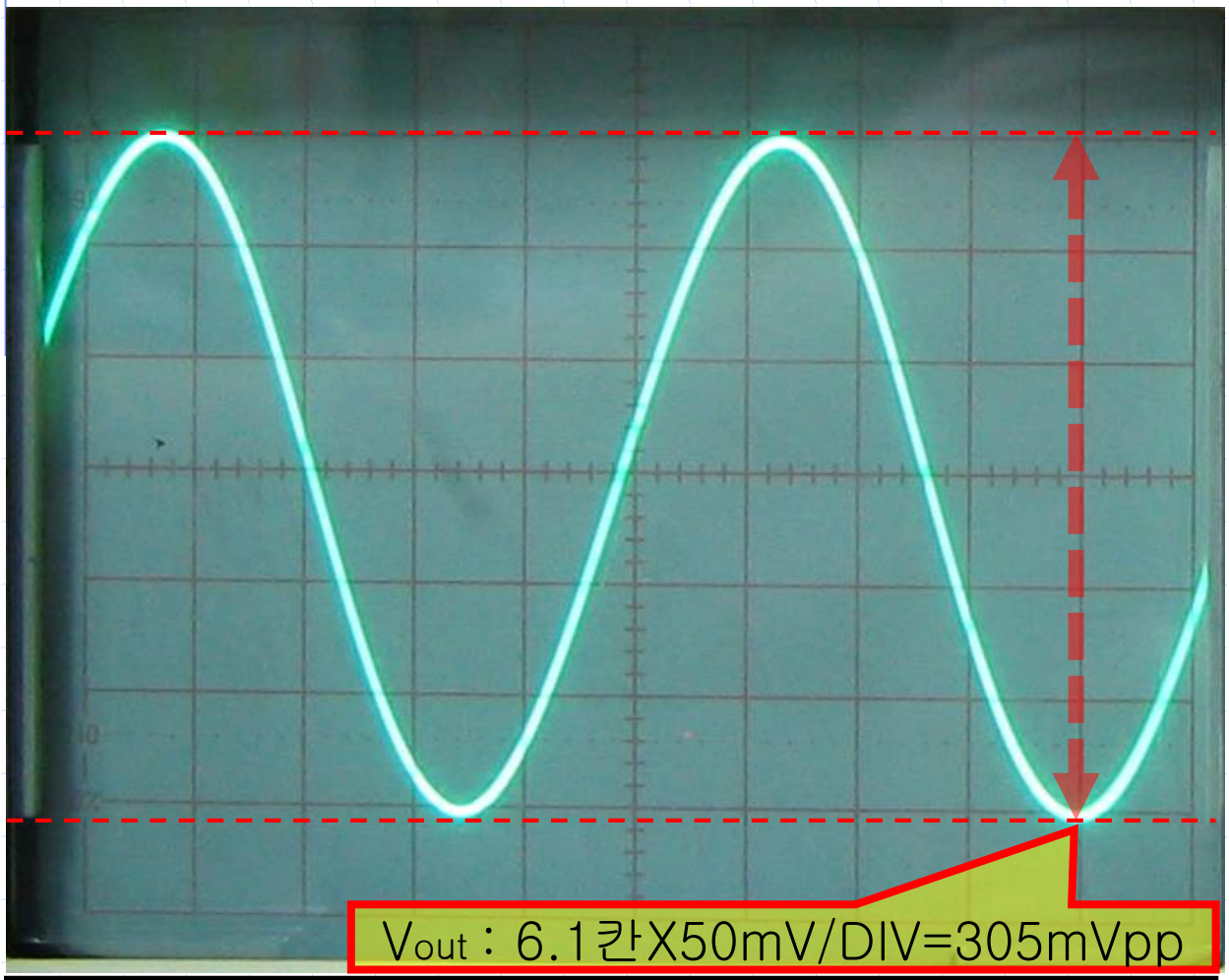
CH 1 : 50mV/DIV, Time : 20uS/DIV

$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{390mV_{PP}}{10\Omega} = 39mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{39mA_{PP}} = 256.4\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 9kHz

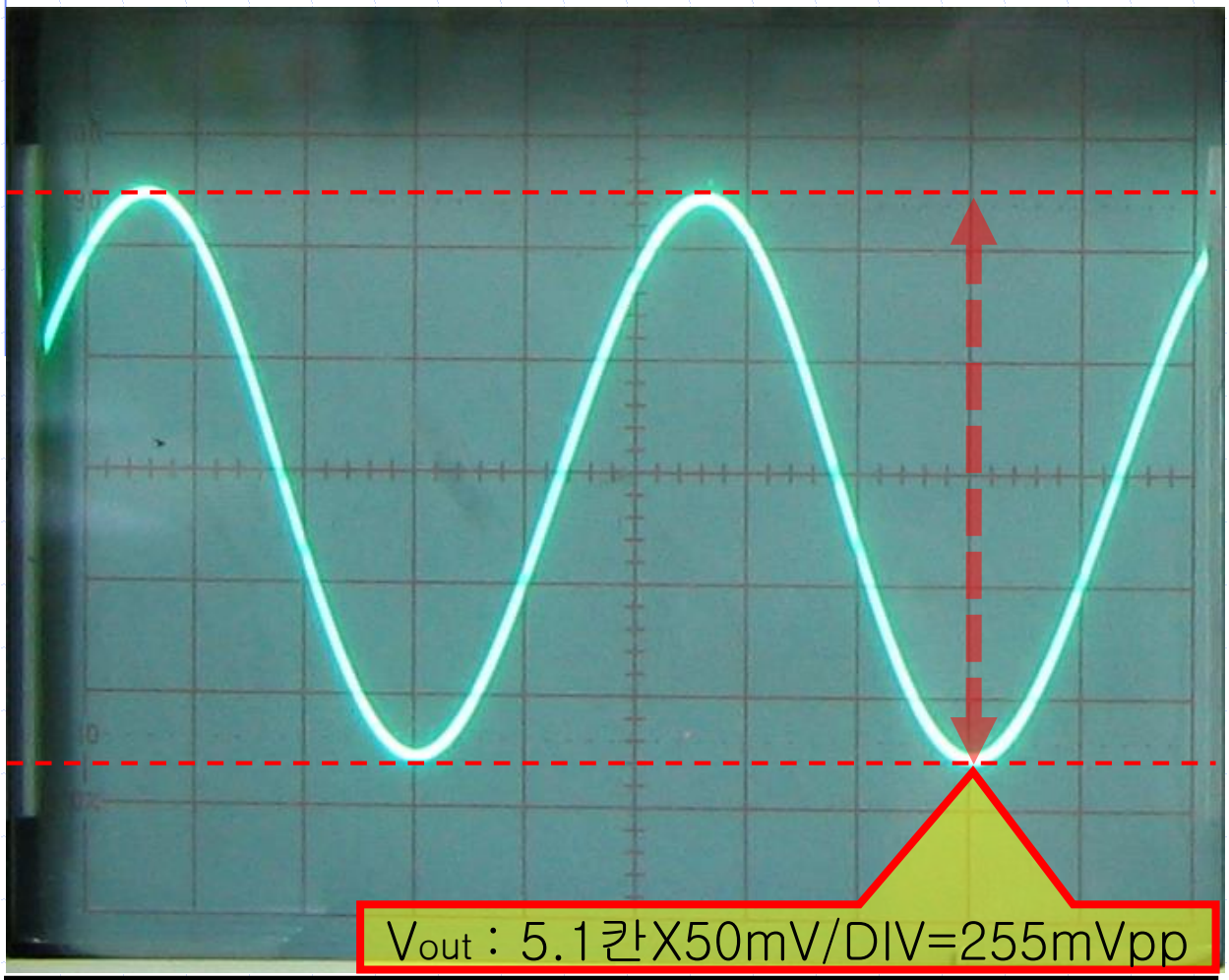


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{305mV_{PP}}{10\Omega} = 30.5mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{30.5mA_{PP}} = 327.9\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 10kHz

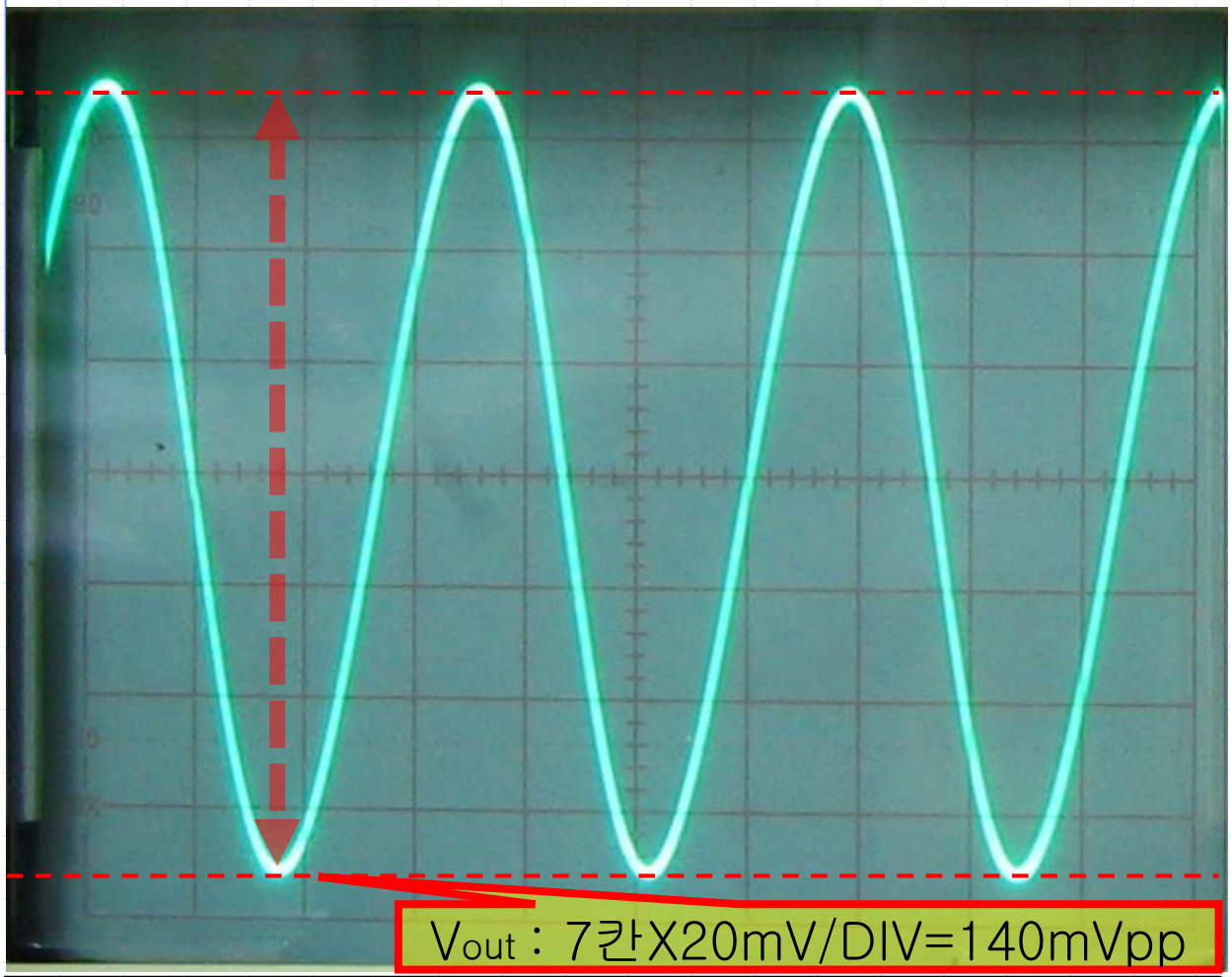


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{255mV_{PP}}{10\Omega} = 25.5mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{25.5mA_{PP}} = 392.2\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 15kHz

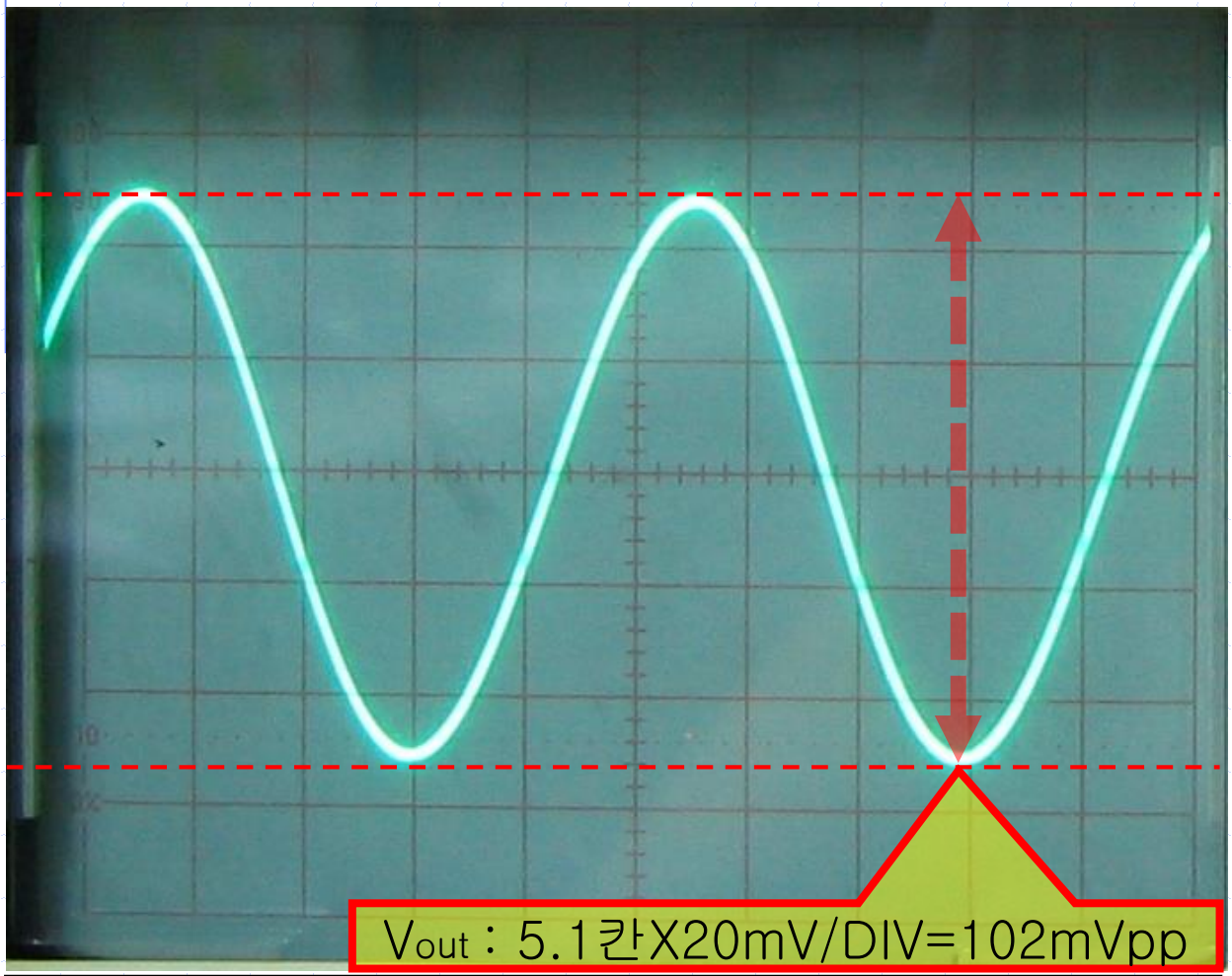


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{140mV_{PP}}{10\Omega} = 14mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{14mA_{PP}} = 714.3\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 20kHz

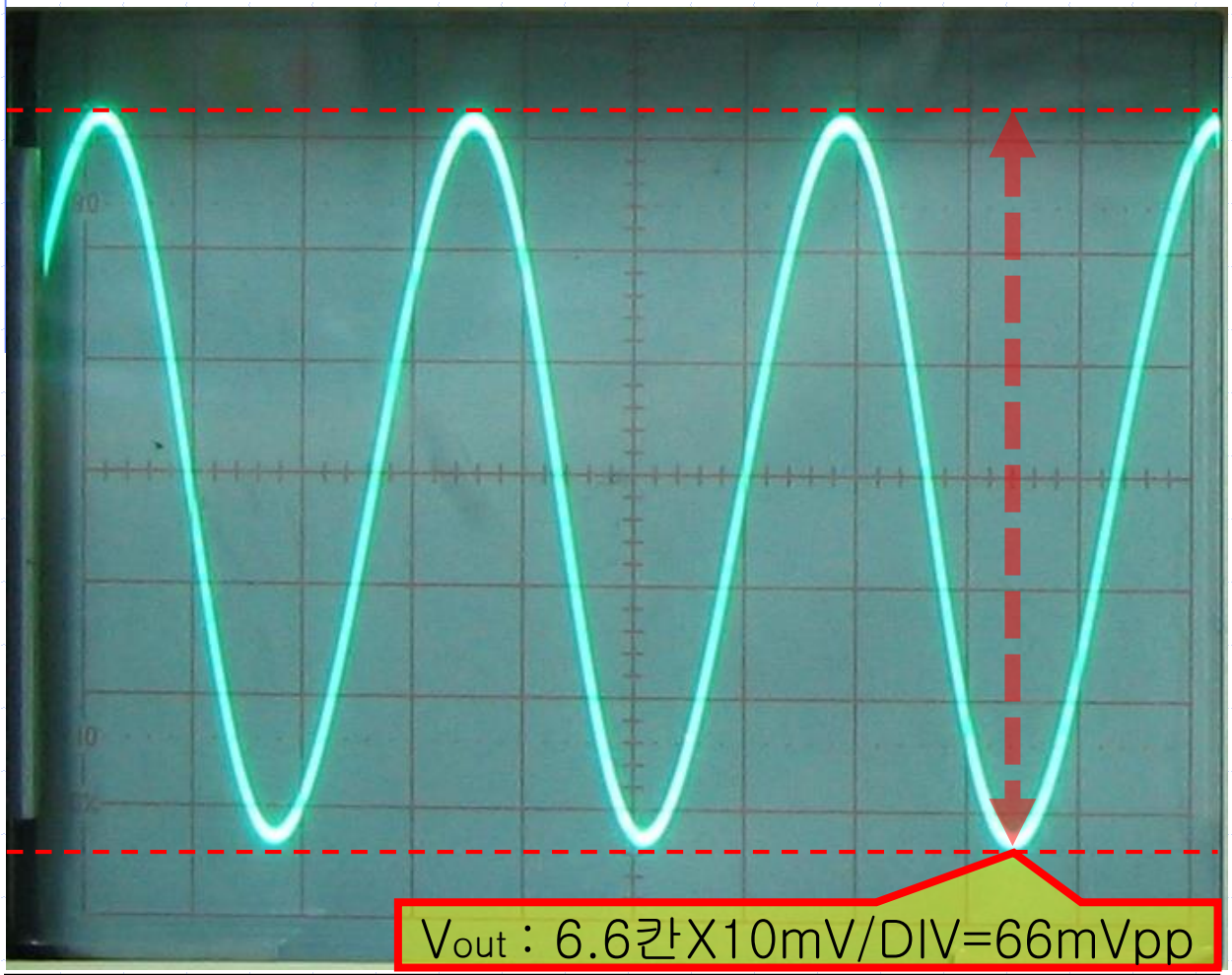


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{102mV_{PP}}{10\Omega} = 10.2mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{10.2mA_{PP}} = 980.4\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 30kHz

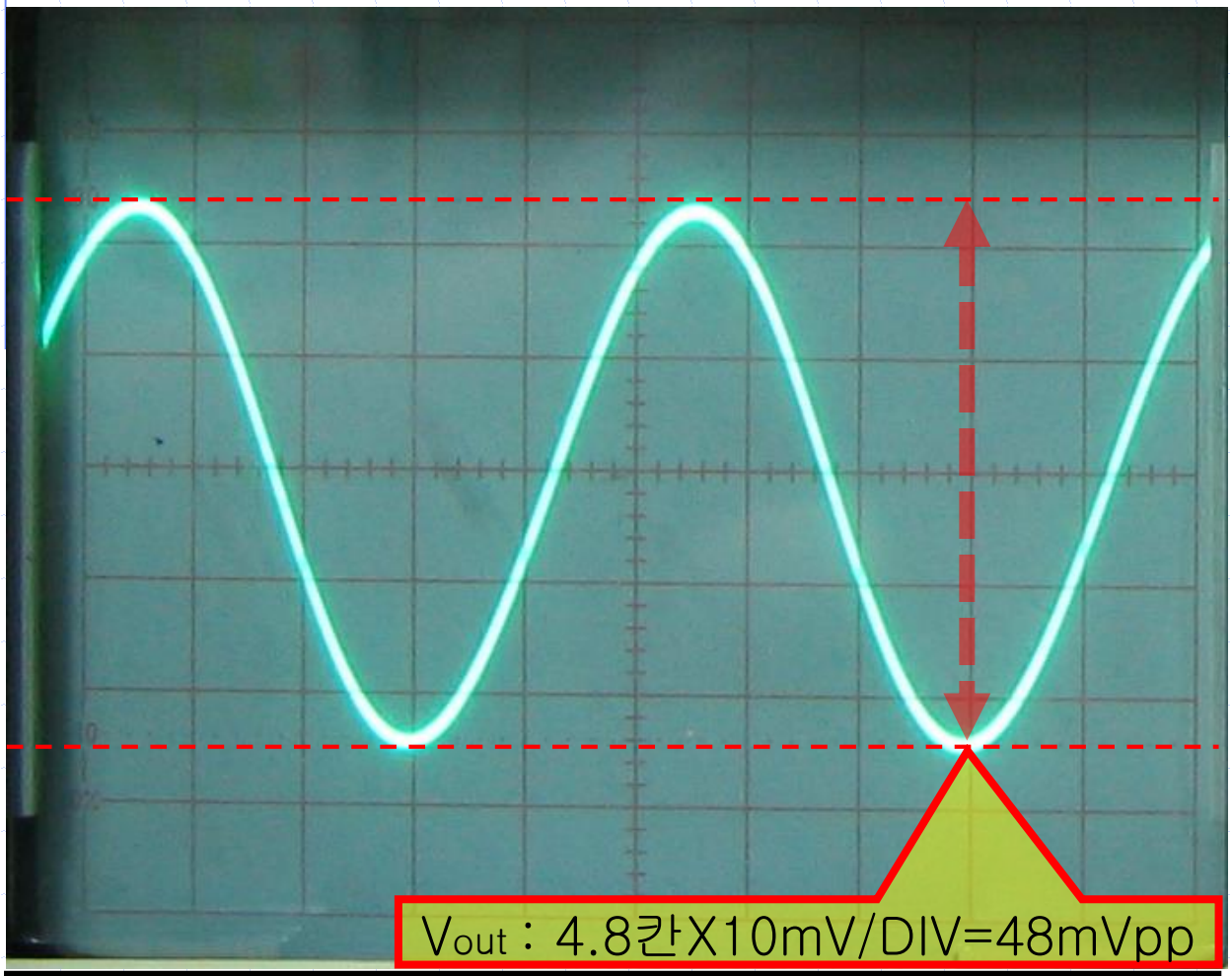


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{66mV_{PP}}{10\Omega} = 6.6mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{6.6mA_{PP}} = 1515.1\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 40kHz

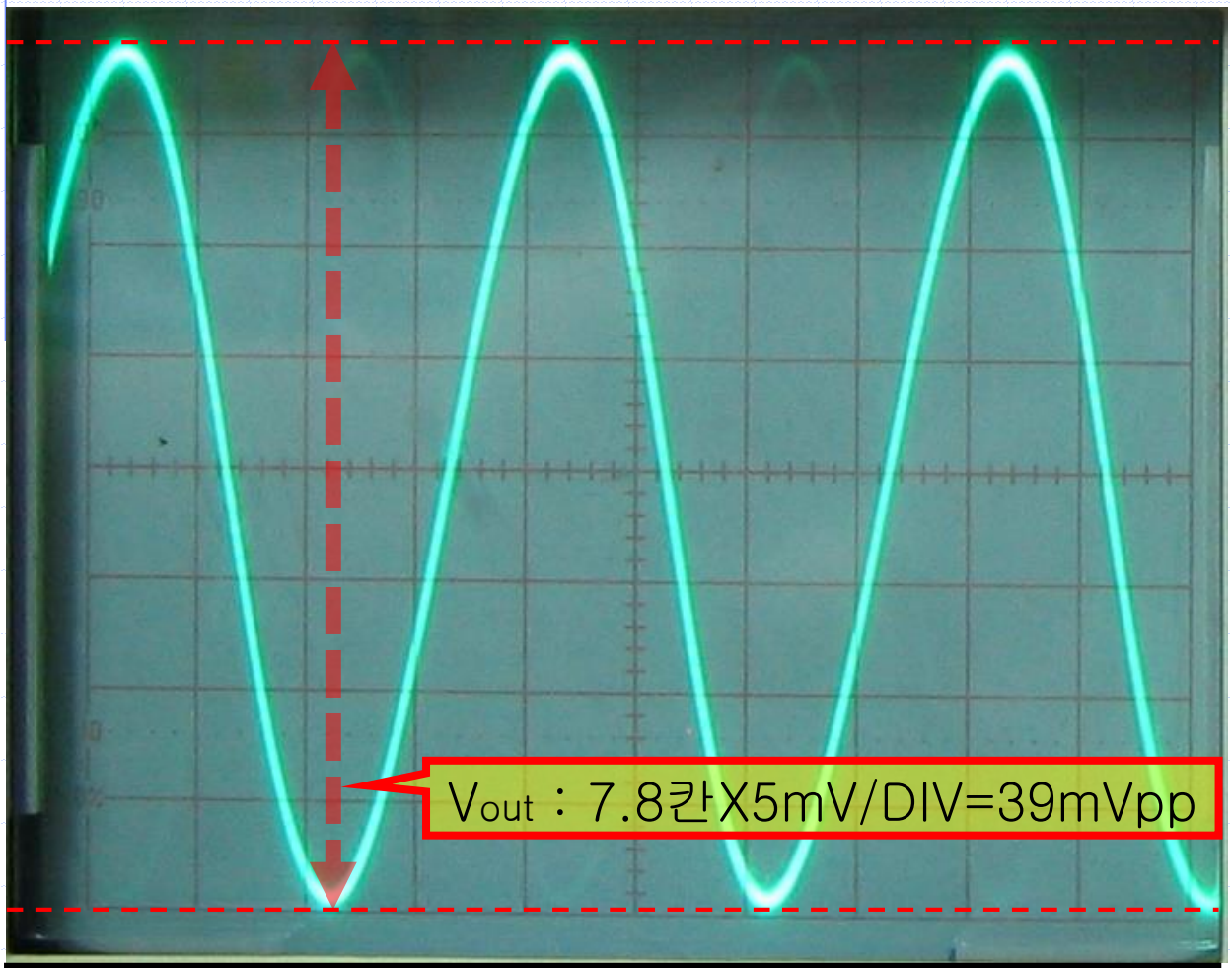


$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{48mV_{PP}}{10\Omega} = 4.8mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{4.8mA_{PP}} = 2083.3\Omega$$

14-8. 주파수에 따른 전류 및 임피던스

✓ 주파수 : 50kHz



$$I_T = \frac{V_{10\Omega}}{10\Omega} = \frac{39mV_{PP}}{10\Omega} = 3.9mA_{PP}$$

$$|Z| = \frac{V_S}{I_T} = \frac{10V_{PP}}{3.9mA_{PP}} = 2564.1\Omega$$

14-8. 주파수에 따른 전류 및 임피던스