11주차
OP AMP 회로 해석 및 설계

지난 시간에 배운 내용 정리

1. 가장 중요한 내용 3가지는?

- 트랜지스터 I-V 특성 곡선, Q point, load line
- CE, CB, CC 증폭기의 특성
- 트랜지스터 증폭기의 주파수 응답

면접시험

- S전자회사의 서류전형을 통과한 신전통군은 면접시험을 보러 갔습니다. 자기소개, 장래포부 등을 중심으로 준비하였는데 기술이사님이 갑자기 op amp 비반전 증폭기를 그리고 설명하라고 하십니다. 신전통군은 멘붕상태가 되었고 보기 좋게 낙방하였고 대학에서 무얼 배웠느냐는 핀잔까지 듣고 나왔습니다.

Op amp에서 꼭 알아야 할 것은?

- 다시 마음을 가다듬고 이번엔 L 전자에 면접을 준비하여야 하는데 시간을 많지 않습니다. 여러분은 어떻게 시작하시겠습니까?

문제해결

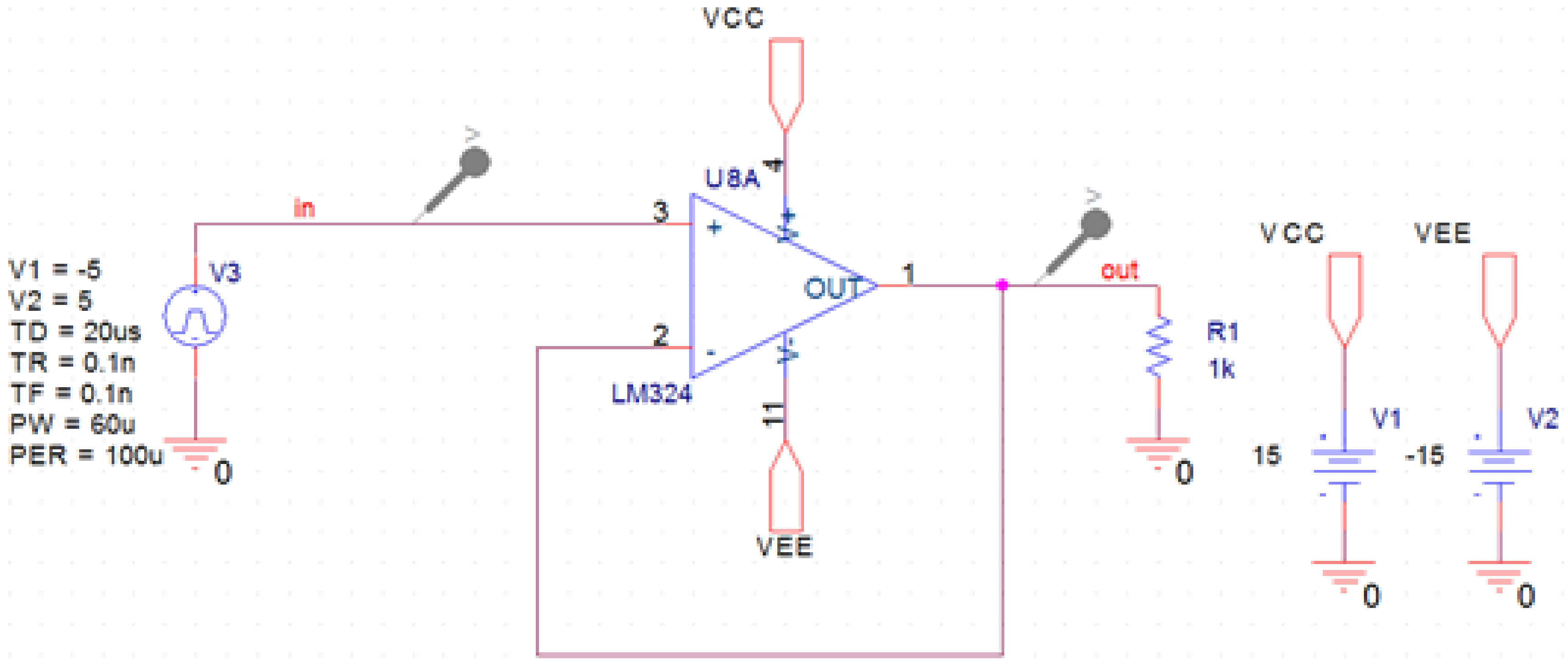
- 꼭 알아야 할 것은?

- 여러분이 면접관이라면 대학교를 졸업한 학생에게 어떤 질문을 하겠습니까?

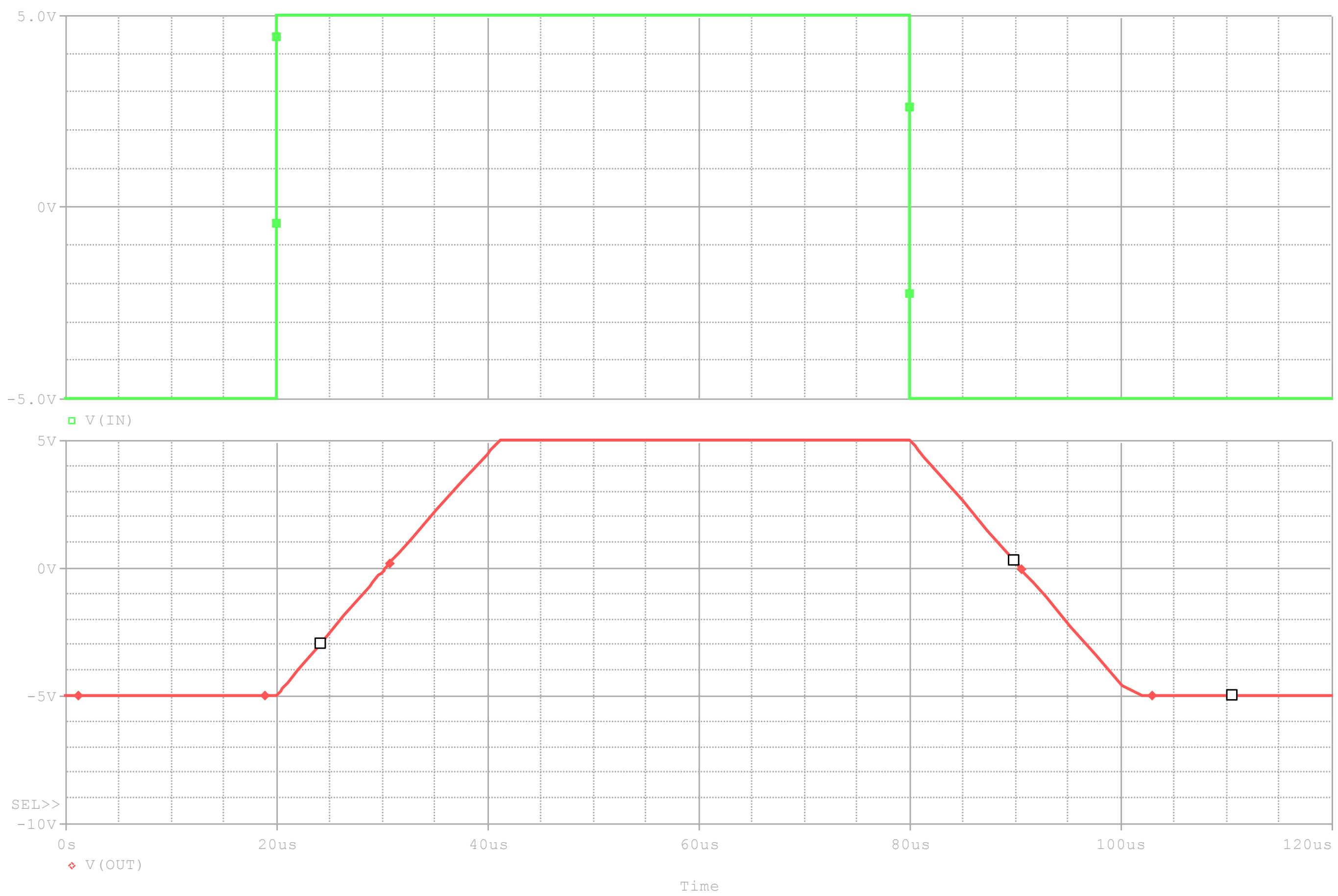
이번 주차 주요 내용

- Op amp의 slew rate
- 반전증폭기
- 비반전 증폭기
- 비교기
- 가산기
- 적분기

10.1 OP-AMP의 SLEW RATE

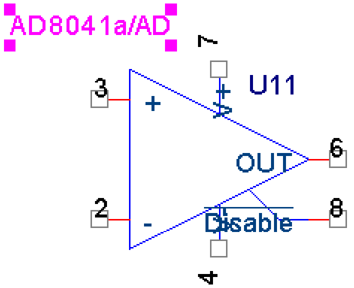


LM324



5.0V
0V
-5.0V
V(IN)
5V
0V
-5V
SEL>>
-10V
0s
20us
40us
60us
80us
100us
120us
V(OUT)
Time

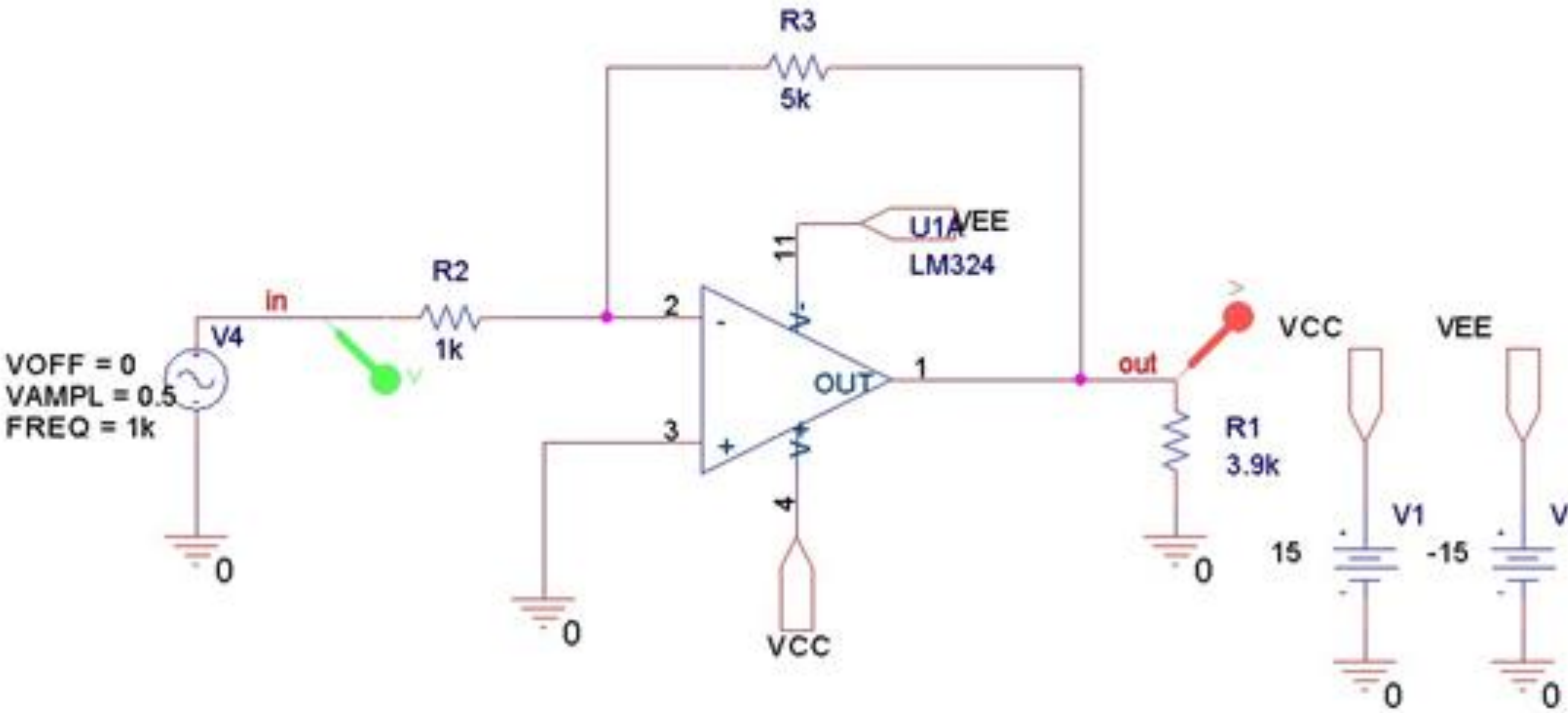
AD8041



AD8041a/AD
U11
3
2
7
4
6
8
+
-
V+
OUT
Disable

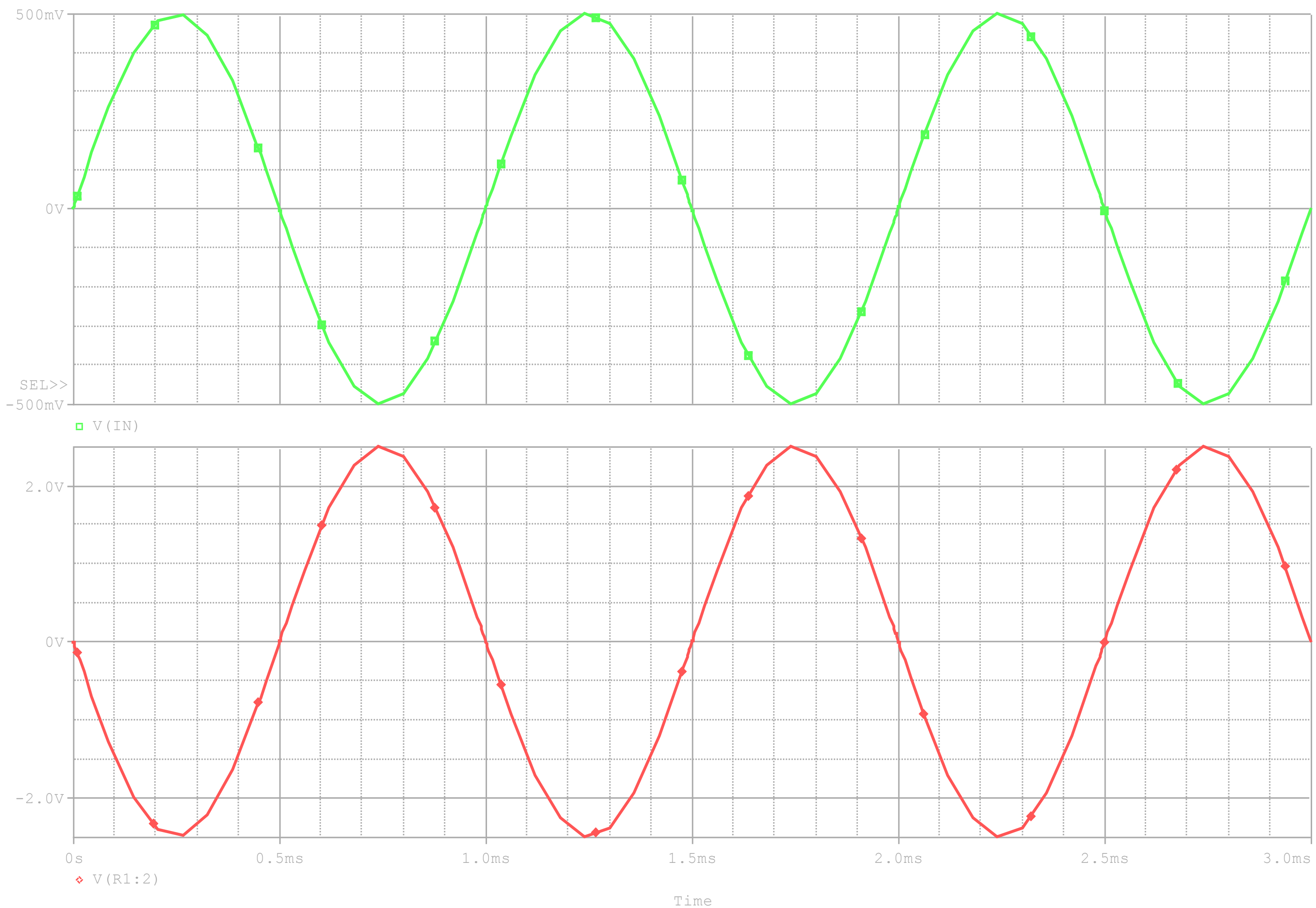
5.0V
0V
-5.0V
V(IN)
10V
0V
SEL>>
-10V
19.990us
19.992us
19.994us
19.996us
19.998us
20.000us
20.002us
20.004us
20.006us
20.008us 20.010us
V(OUT)
Time

10.2 반전 증폭기

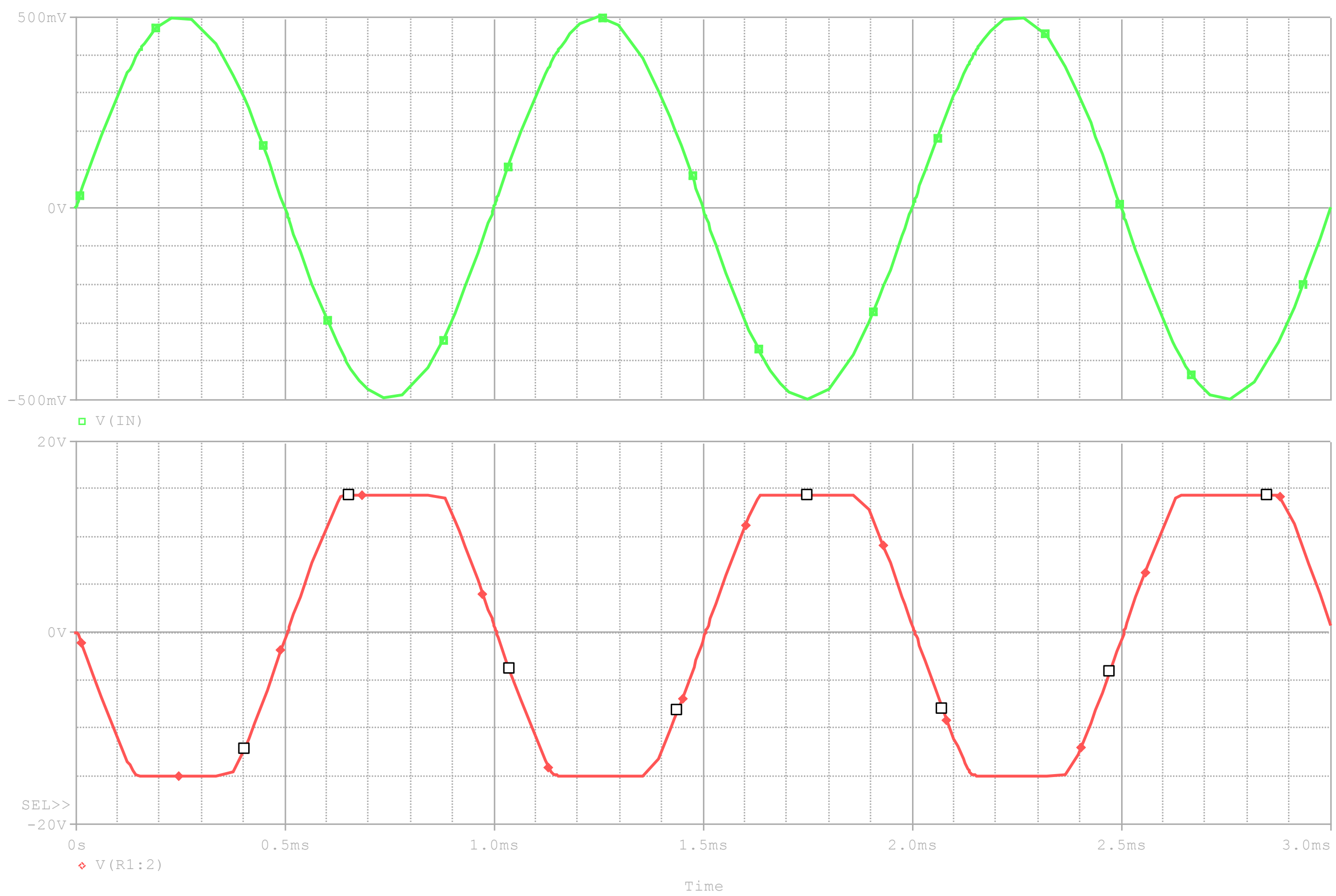


R3
5k
U1A
VEE
LM324
11
R2
1k
in
2
V4
VOFF = 0
VAMPL = 0.5
FREQ = 1k
OUT
1
out
3
4
VCC
VEE
R1
3.9k
V1
V2
15
-15
0

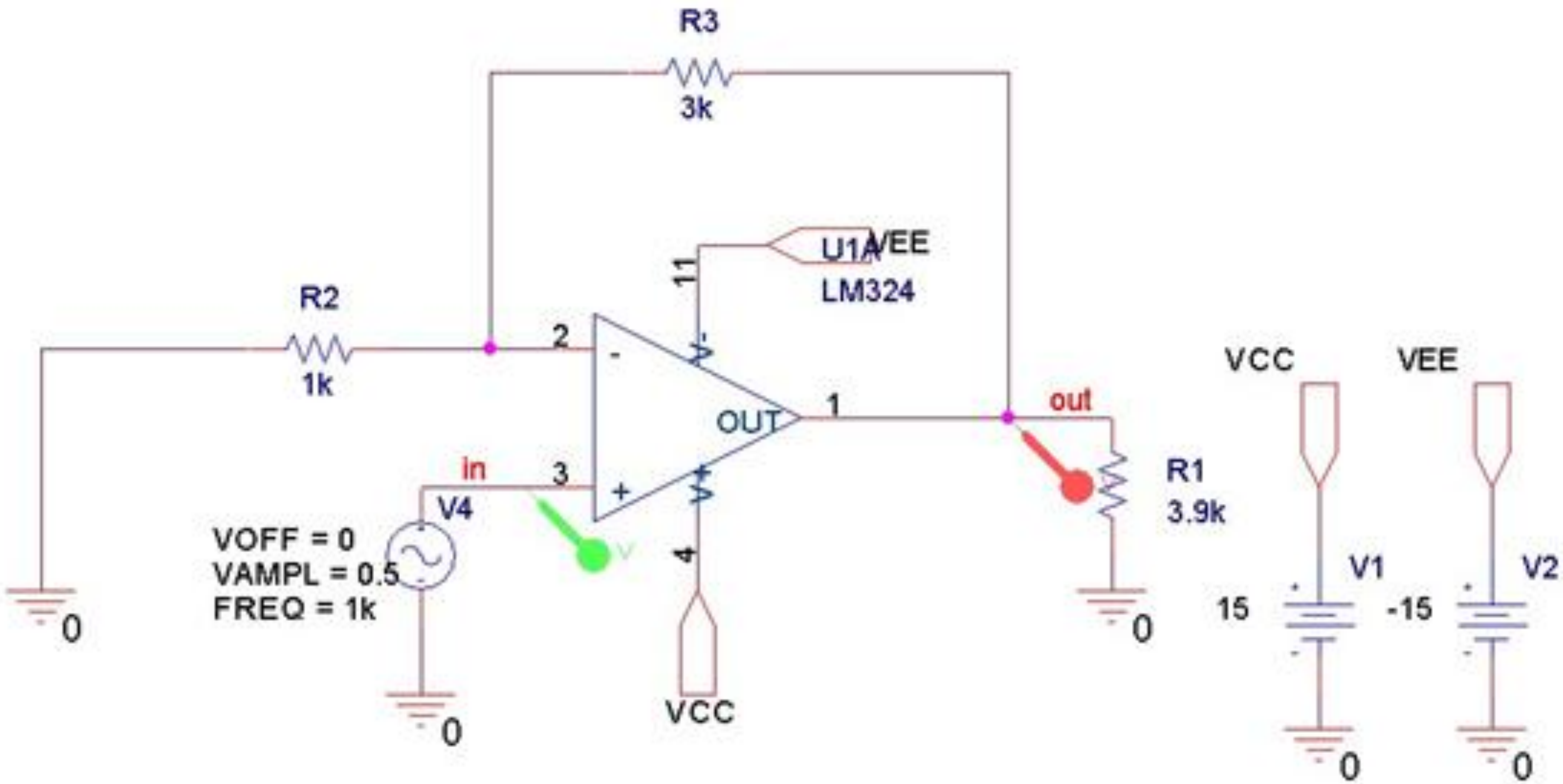
R3=5k Av= -Rout/Rin = Vout/Vin = -2.5/0.5 = -5



R3 =40k

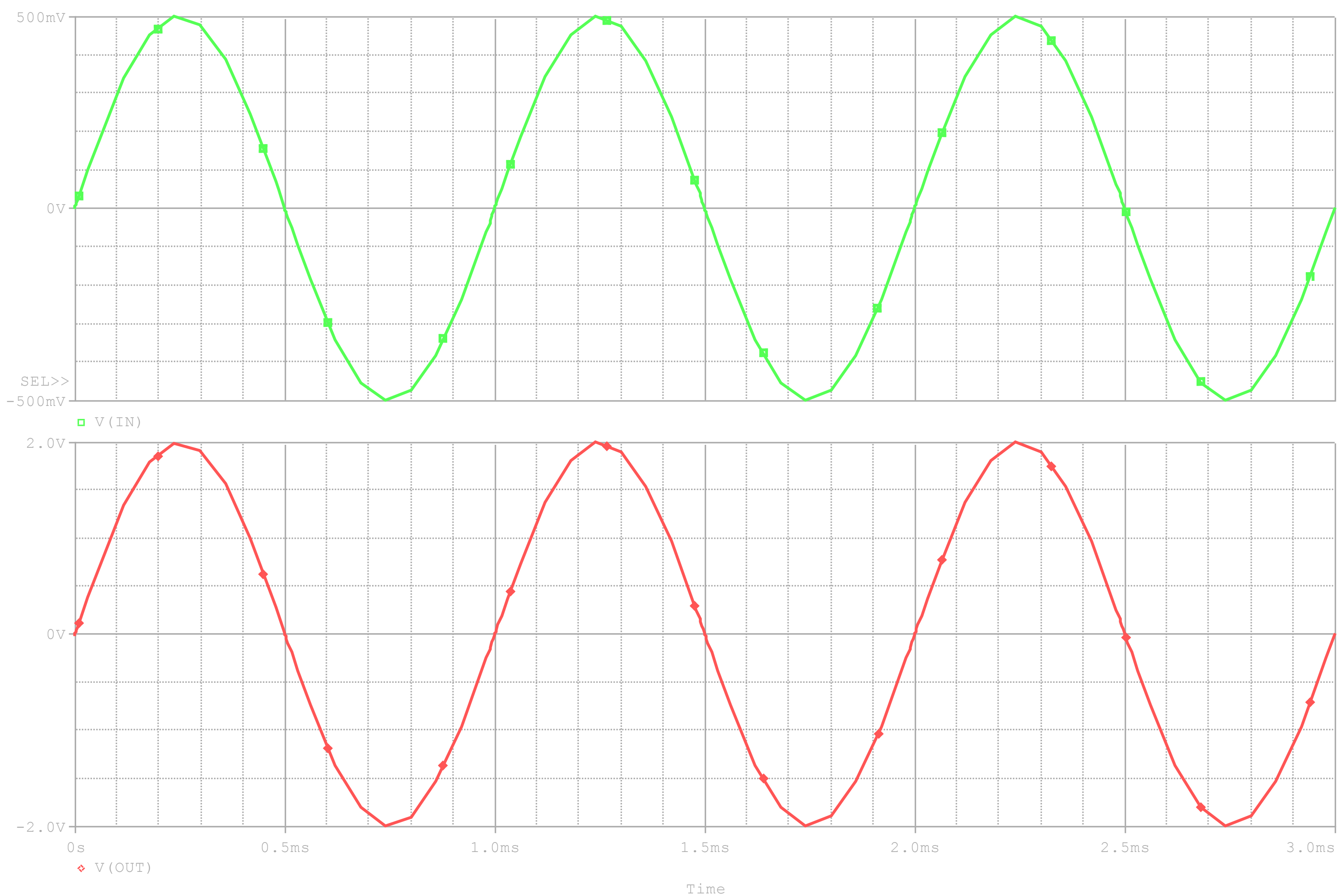

500mV
0V
-500mV
V(IN)
20V
0V
SEL>>
-20V
0s
0.5ms
1.0ms
1.5ms
2.0ms
2.5ms
3.0ms
V(R1:2)
Time

10-3 비반전증폭기

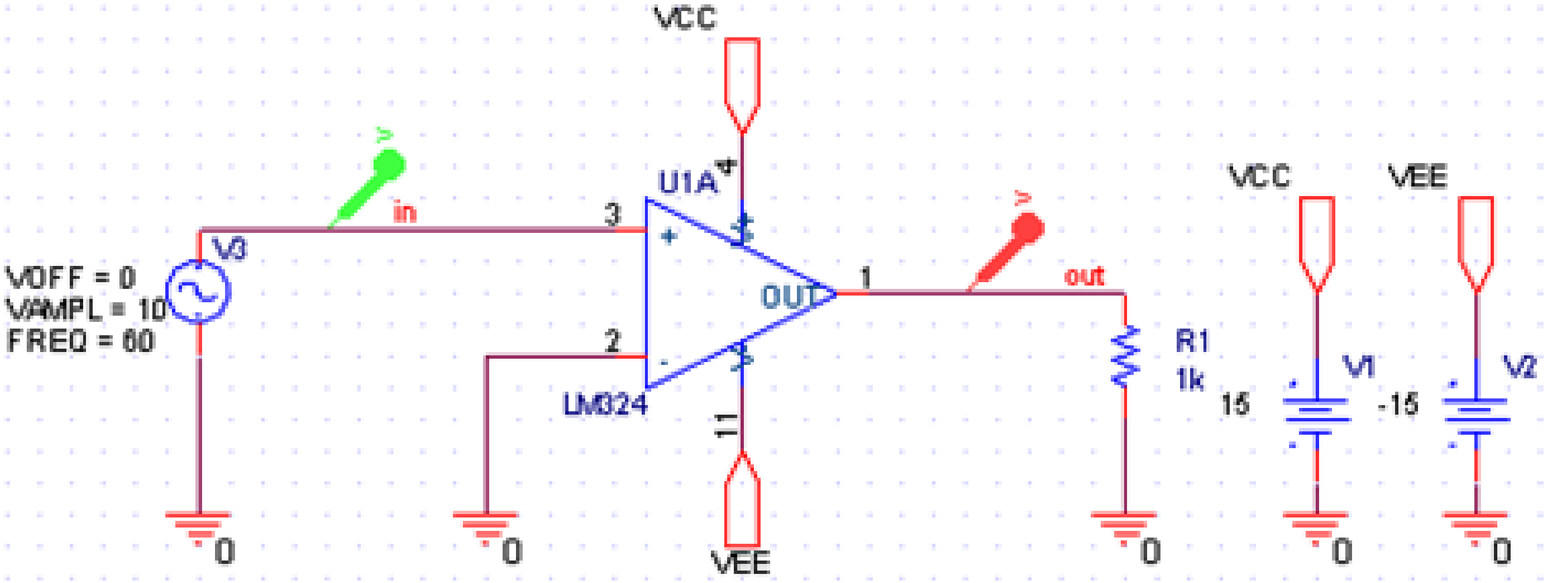


R3
3k
R2
1k
U1A
VEE
LM324
11
2
-
OUT
1
out
in
3
+
4
V4
VOFF = 0
VAMPL = 0.5
FREQ = 1k
R1
3.9k
VCC
VEE
V1
V2
15
-15
VCC
0
0
0
0
0

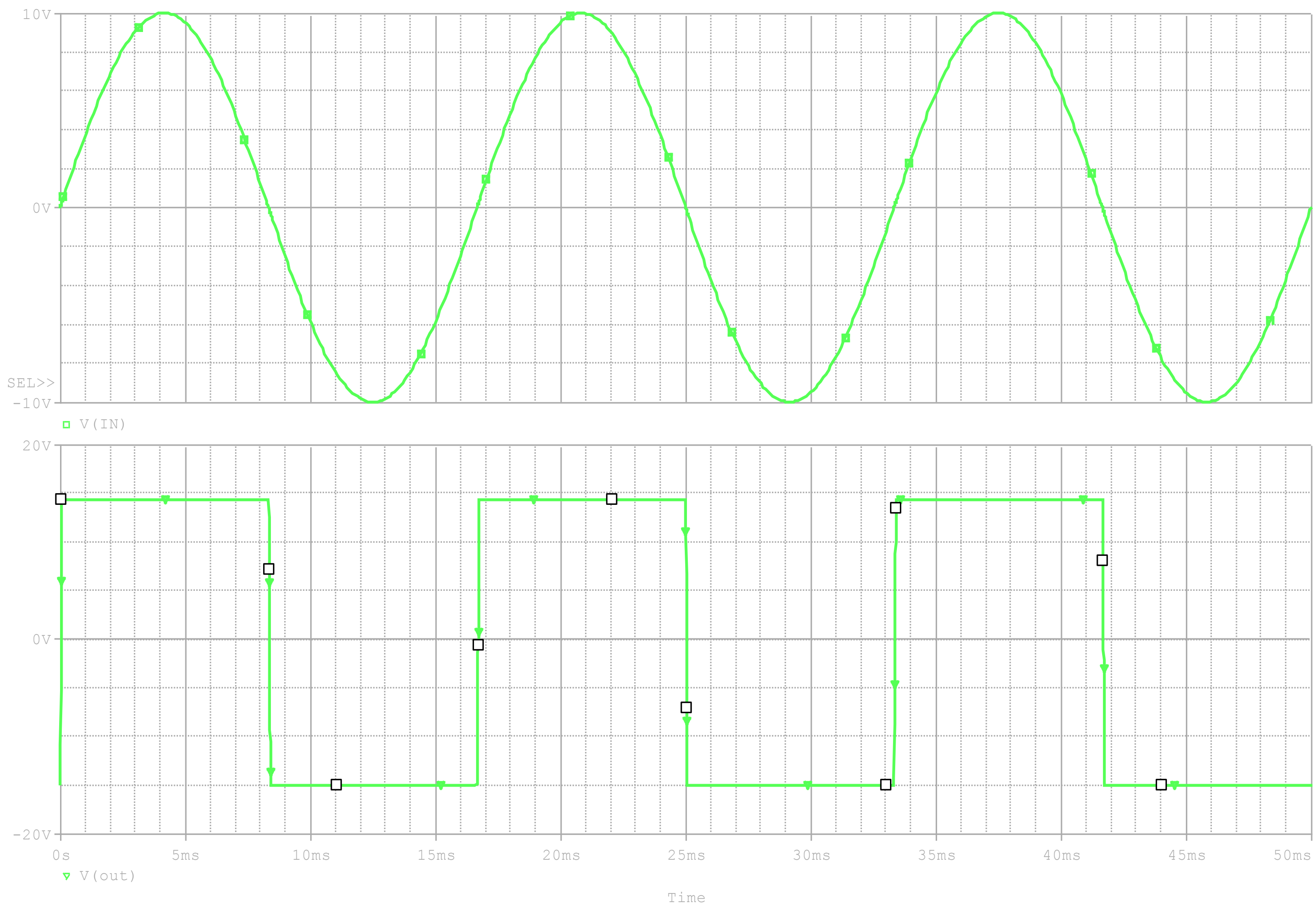
R3=3k, Av= 1+Rf/Rin = 1+ 3 = 4



10-4 비교기 (comparator) ; Zero Level Detection

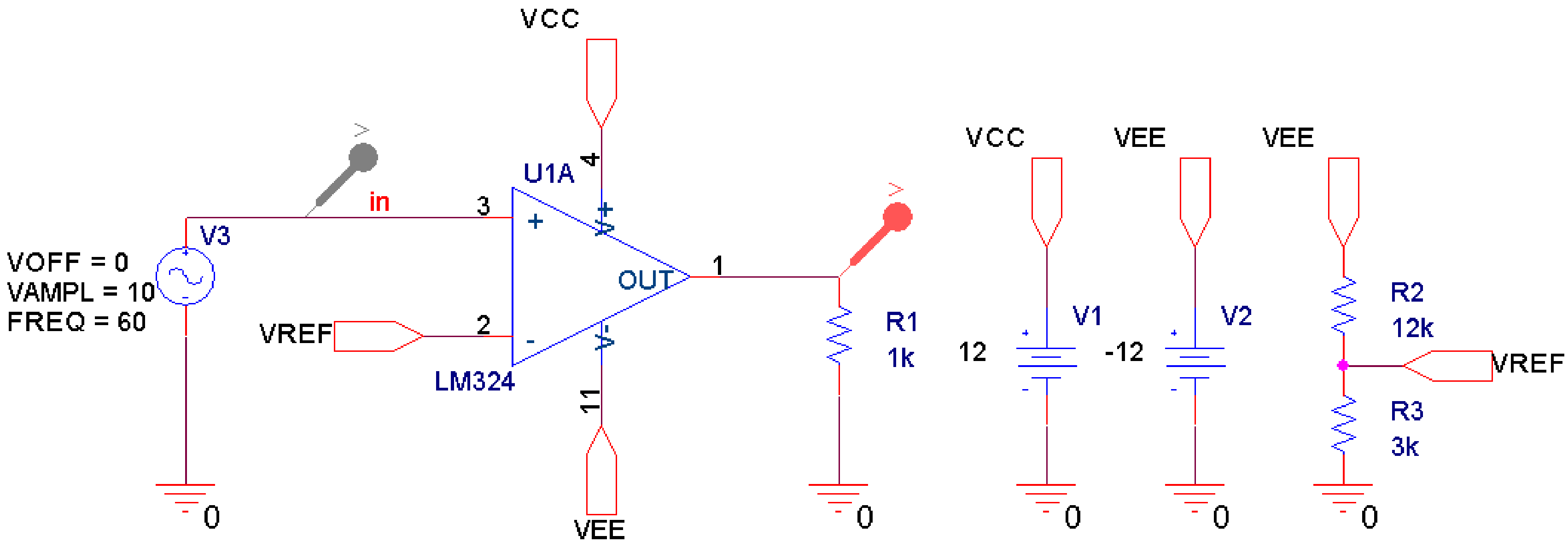


구형파 발생기



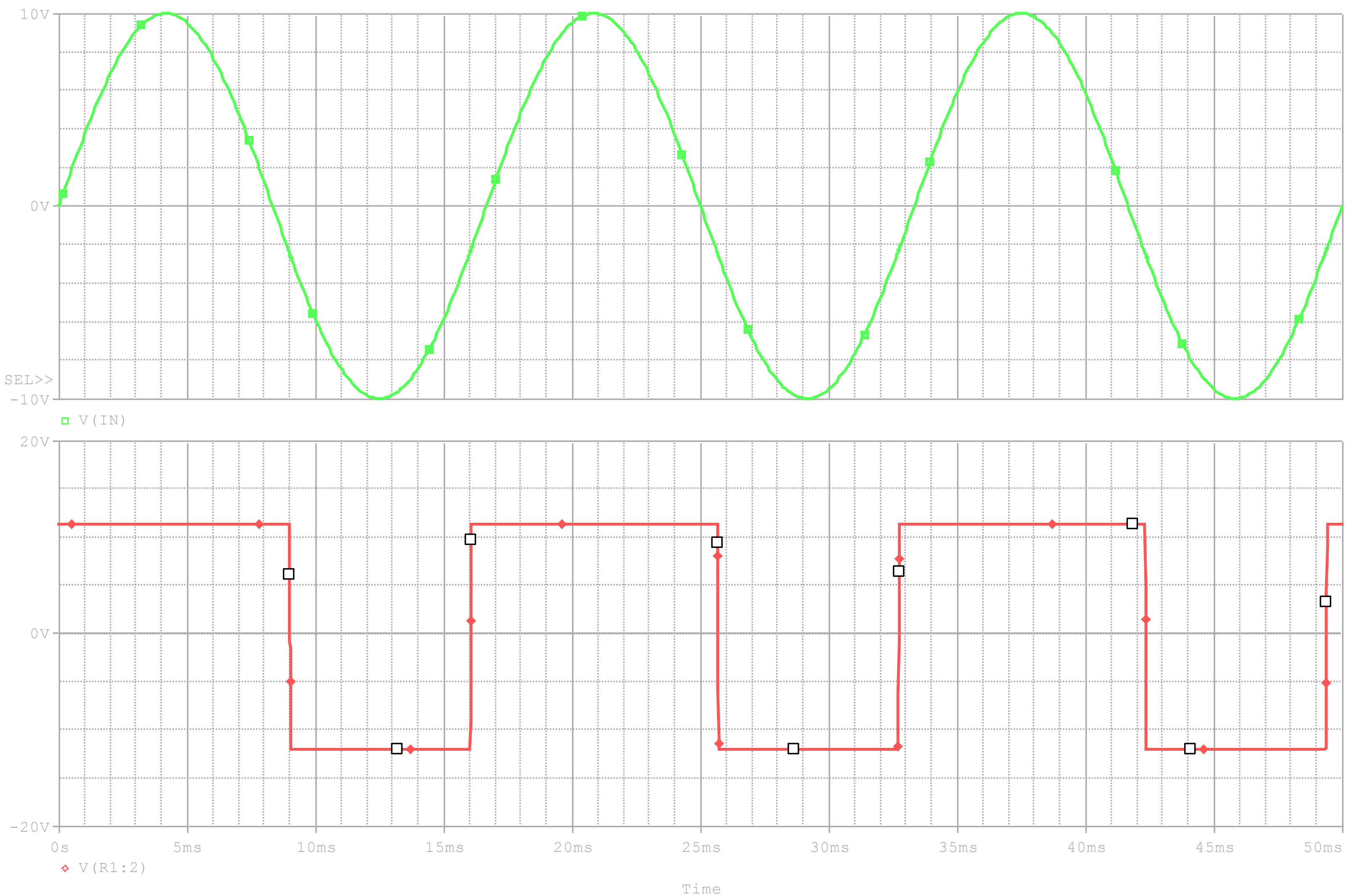
10V
0V
SEL>>
-10V
V(IN)
20V
0V
-20V
0s
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms
V(out)
Time

Vref =-3V인 경우



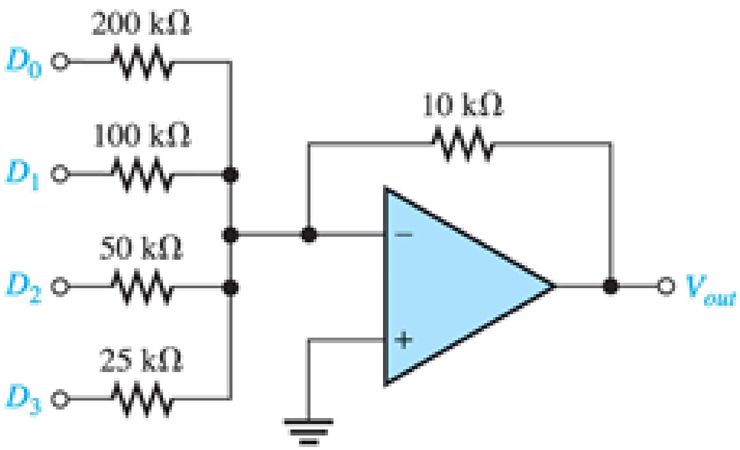
VCC
U1A
4
in
3
+
V+
V3
VOFF = 0
VAMPL = 10
FREQ = 60
OUT
1
VREF
2
-
V-
LM324
11
VEE
R1
1k
0
VCC
VEE
VEE
V1
12
V2
-12
R2
12k
VREF
R3
3k
0

Vref = -3V인 경우

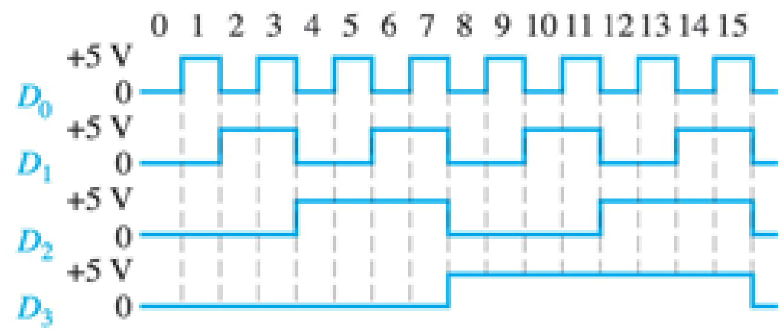


10V
0V
SEL>>
-10V
V(IN)
20V
0V
-20V
0s
5ms
10ms
15ms
20ms
25ms
30ms
35ms
40ms
45ms
50ms
V(R1:2)
Time

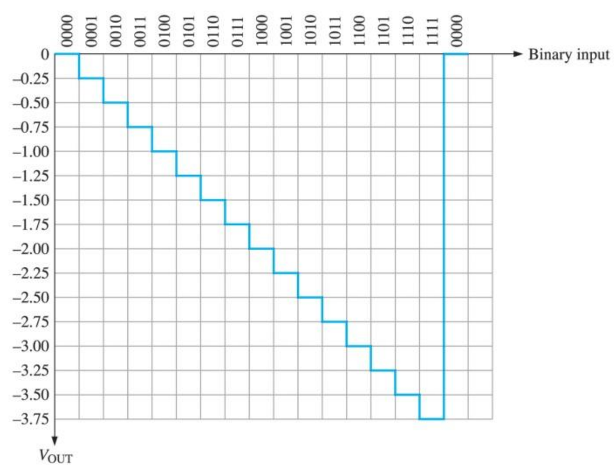
10-5. DAC[Digital Analog Converter]



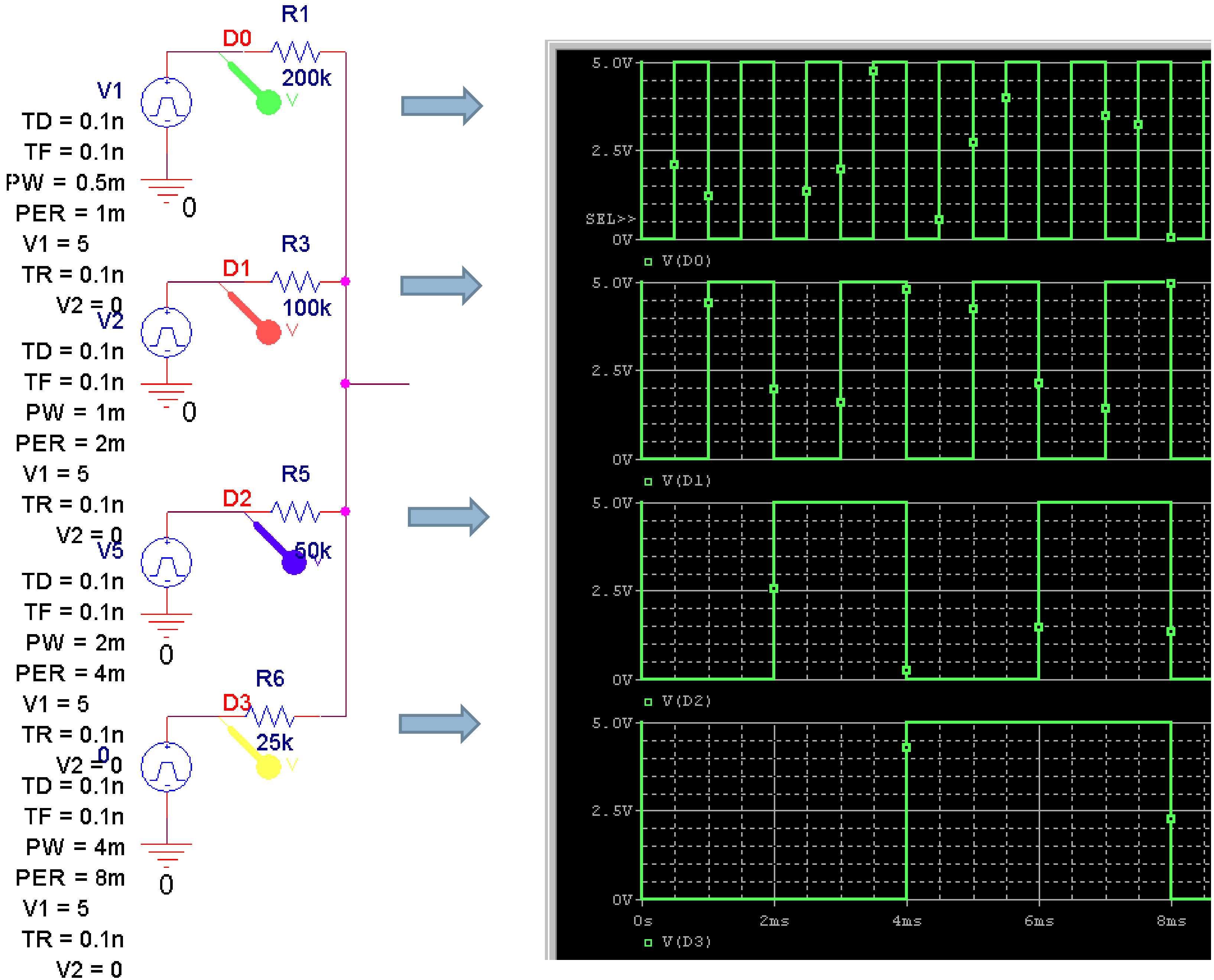
(a)



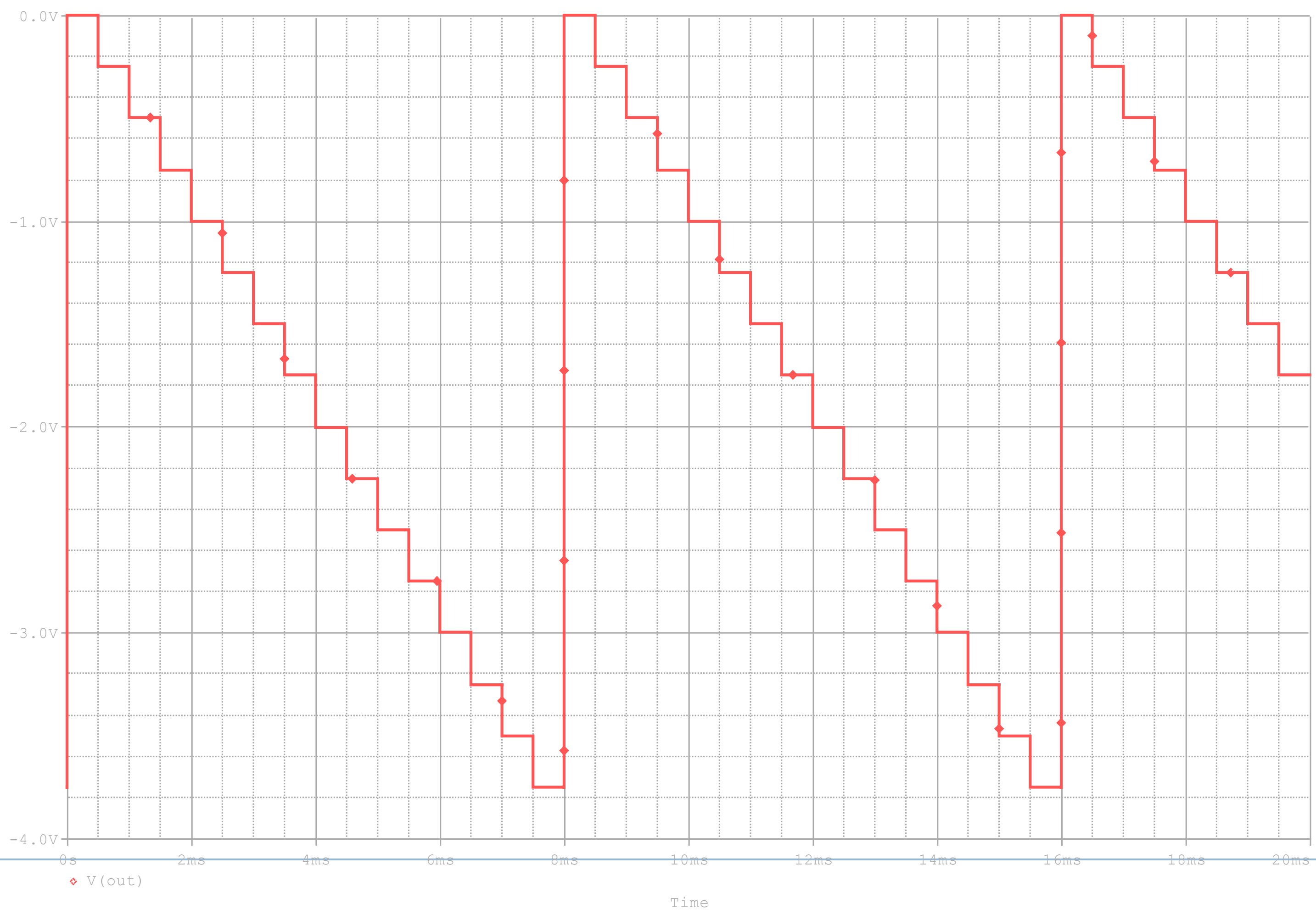
(b)



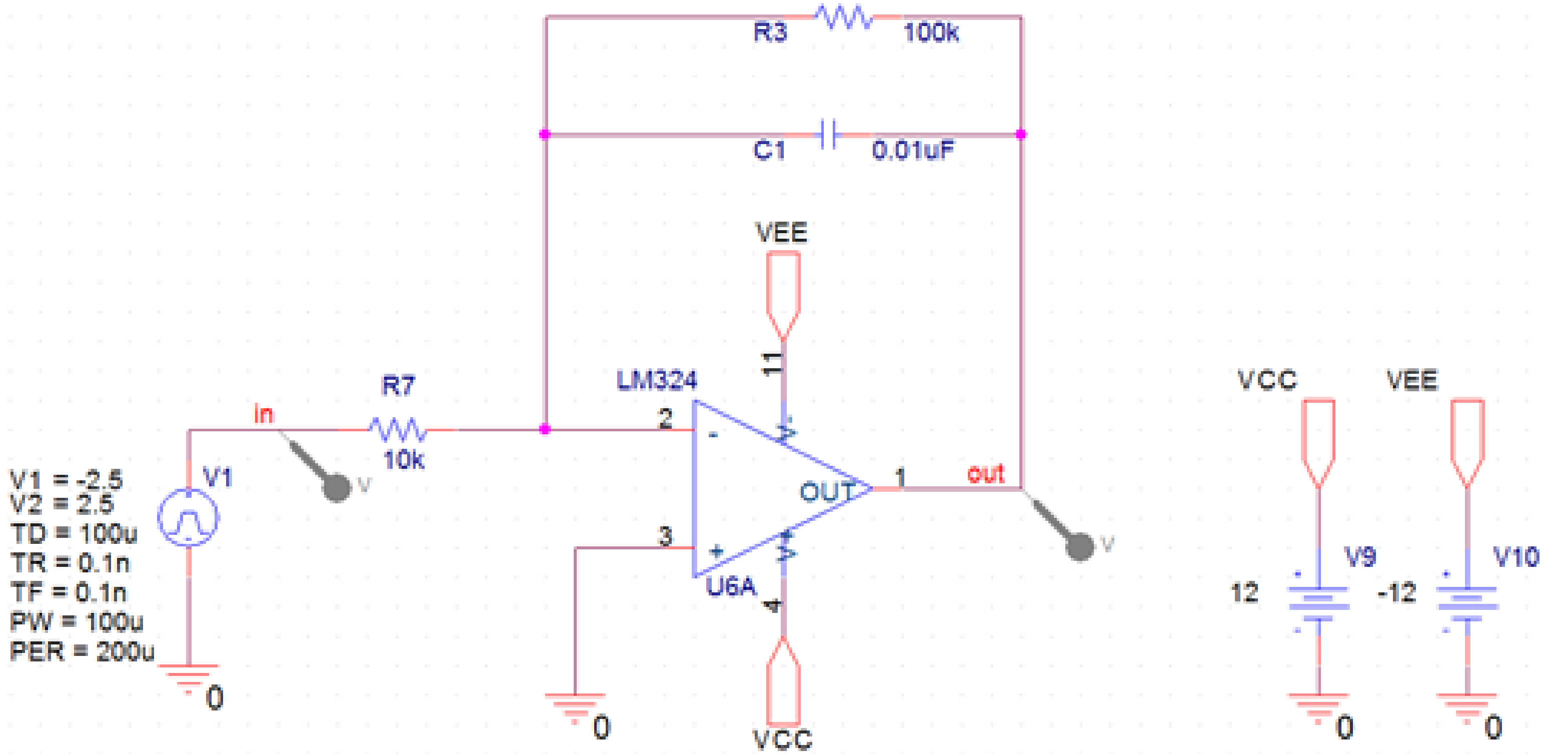
출처: Floyd 전자회로 7판


R1
D0
200k
V1
TD = 0.1n
TF = 0.1n
PW = 0.5m
PER = 1m
V1 = 5
TR = 0.1n
V2 = 0
0
R3
D1
100k
V2
TD = 0.1n
TF = 0.1n
PW = 1m
PER = 2m
V1 = 5
TR = 0.1n
V2 = 0
0
R5
D2
50k
V5
TD = 0.1n
TF = 0.1n
PW = 2m
PER = 4m
V1 = 5
TR = 0.1n
V2 = 0
0
R6
D3
25k
0
TD = 0.1n
TF = 0.1n
PW = 4m
PER = 8m
V1 = 5
TR = 0.1n
V2 = 0
0
5.0V
2.5V
SEL>>
0V
V(D0)
V(D1)
V(D2)
V(D3)
0s
2ms
4ms
6ms
8ms

DAC 결과 파형

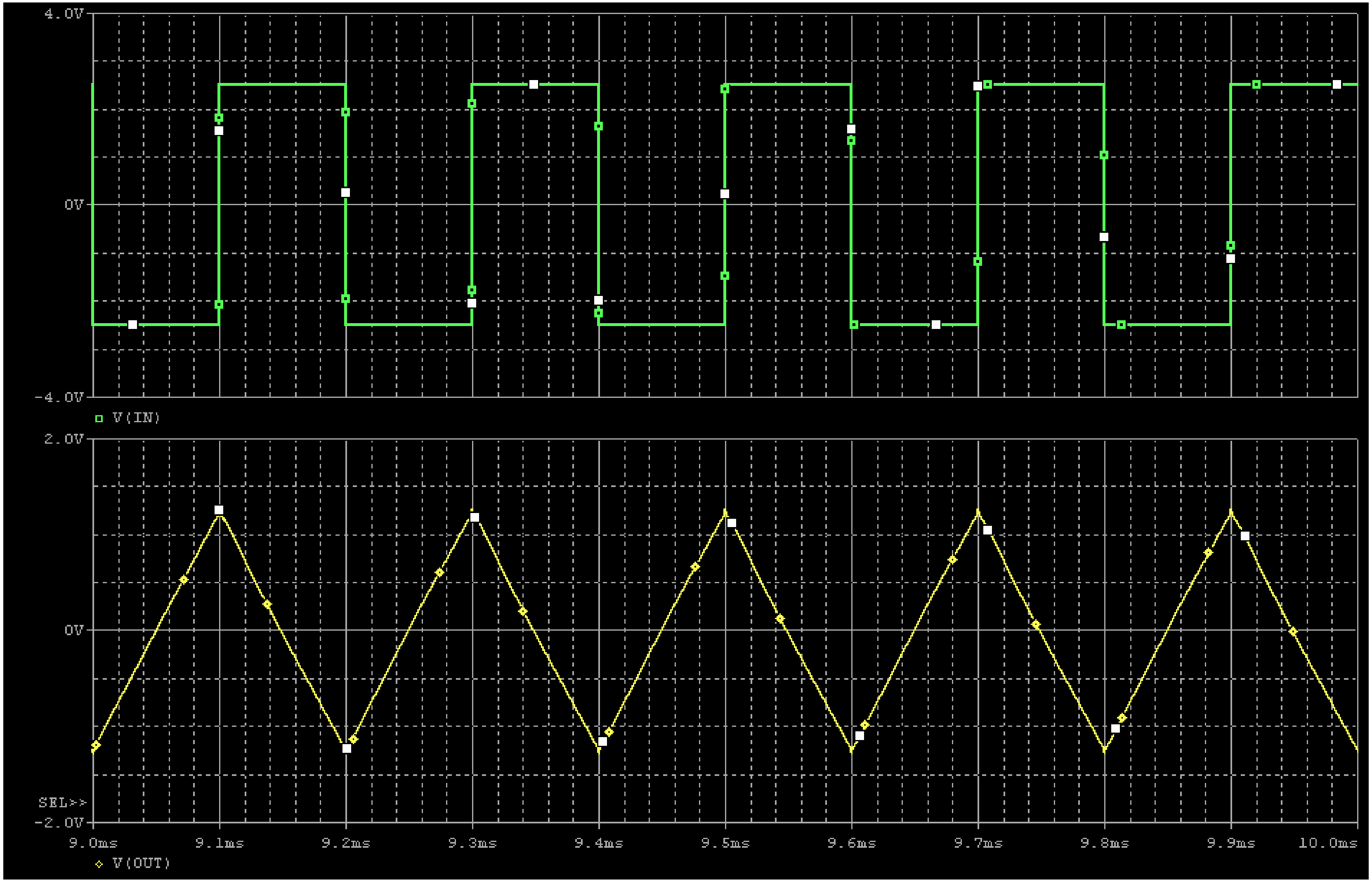

0.0V
-1.0V
-2.0V
-3.0V
-4.0V
0s
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
18ms
20ms
V(out)
Time

10-6 적분기 응용



R3
100k
C1
0.01uF
VEE
11
LM324
2
-
V-
OUT
1
out
3
+
V+
U6A
4
VCC
R7
10k
in
V1
V1 = -2.5
V2 = 2.5
TD = 100u
TR = 0.1n
TF = 0.1n
PW = 100u
PER = 200u
0
0
VCC
VEE
V9
V10
12
-12
0
0

삼각파 발생기



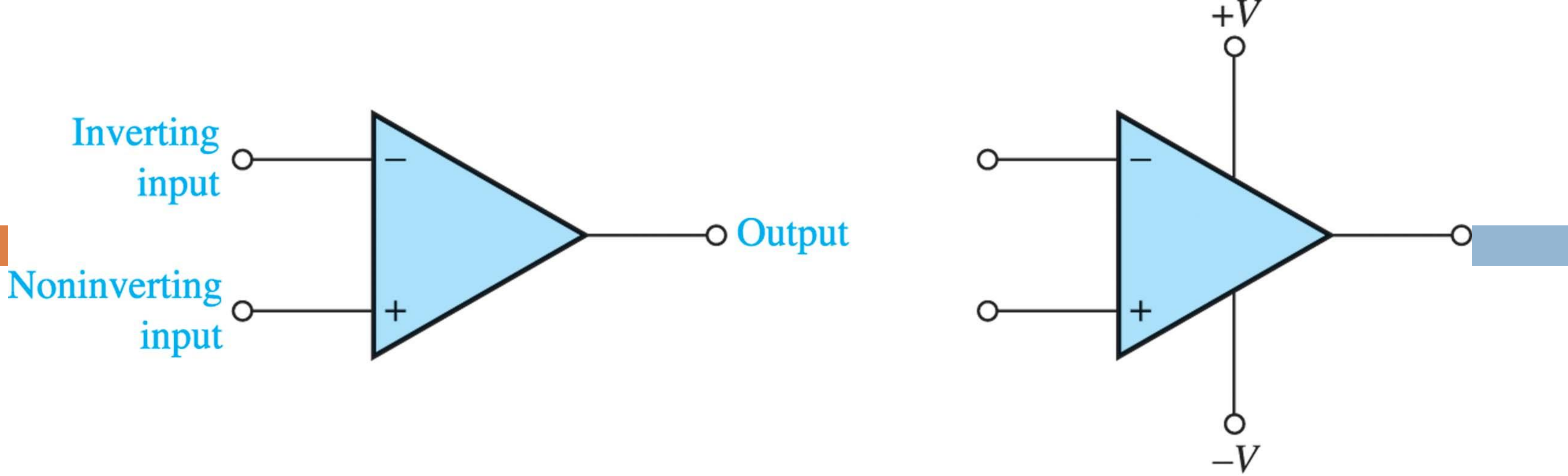
4.0V
0V
-4.0V
V(IN)
2.0V
0V
SEL>>
-2.0V
9.0ms
9.1ms
9.2ms
9.3ms
9.4ms
9.5ms
9.6ms
9.7ms
9.8ms
9.9ms
10.0ms
V(OUT)

참고자료

Floyd 전자회로 7판 :

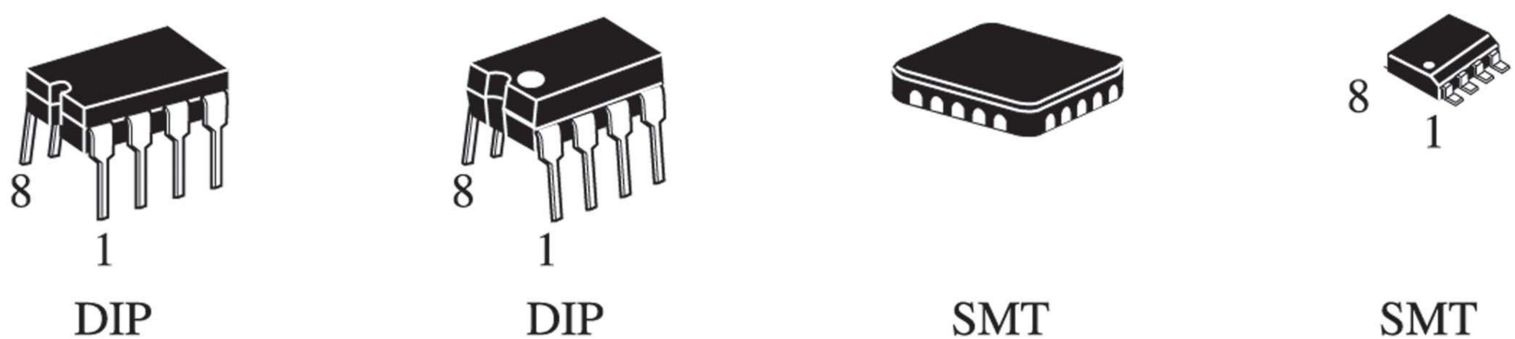
12장 연산증폭기

13장 기본 연산 증폭기 회로



(a) 기호

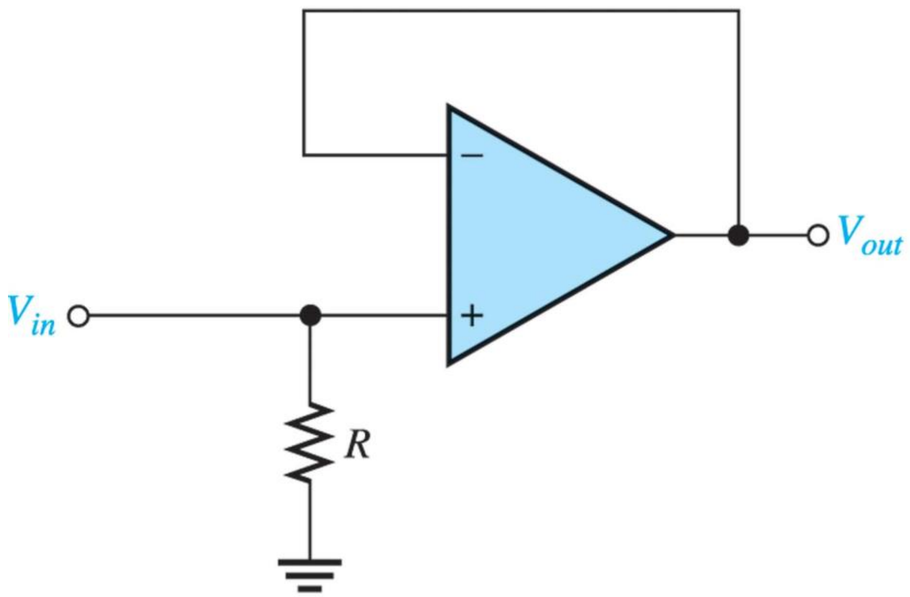
(b) 직류 공급전압 연결 기호



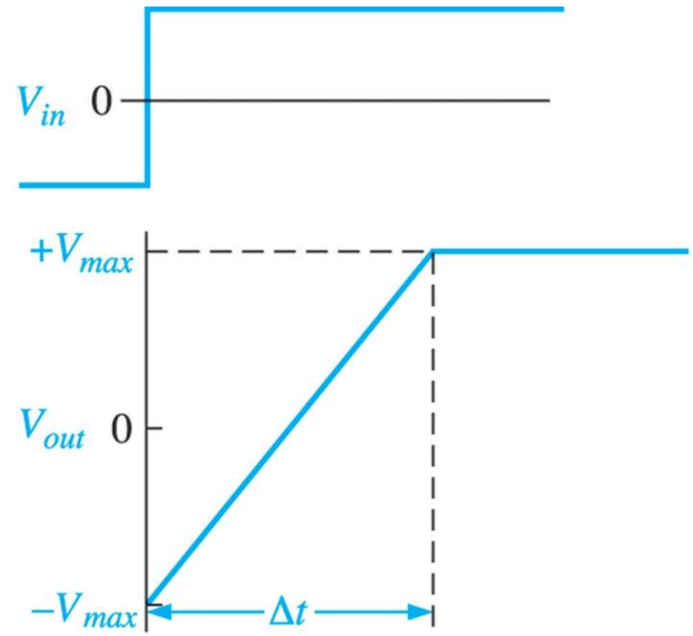
(c) 전형적인 패키지. DIP(Dual-In-line Package) 패키지나 SMT(Surface-Mount Technology) 패키지 위에서 봤을 때 1번 핀은 항상 점(dot)이나 V자 홈(notch)의 왼쪽임.

출처: Floyd 전자회로 7판

슬루율(SLEW RATE)



(a) 시험회로

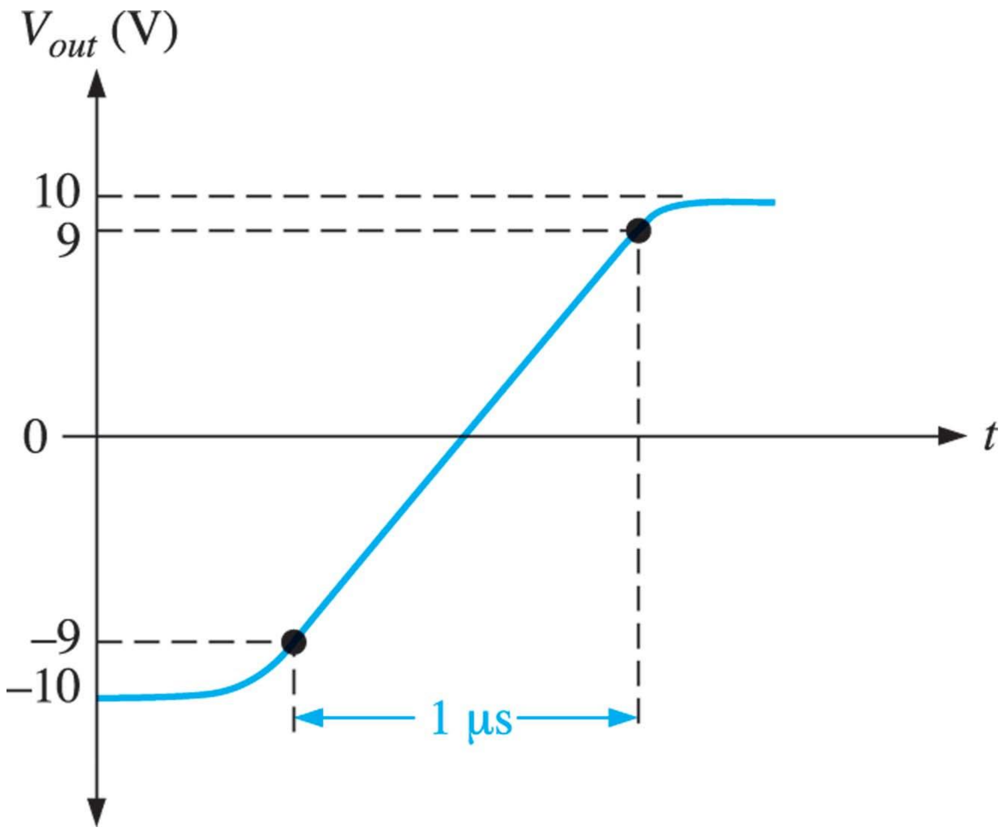


(b) 계단파 입력전압과 이에 따른 출력전압

출처: Floyd 전자회로 7판

Slew rate = (+9V – (-9V))/1usec

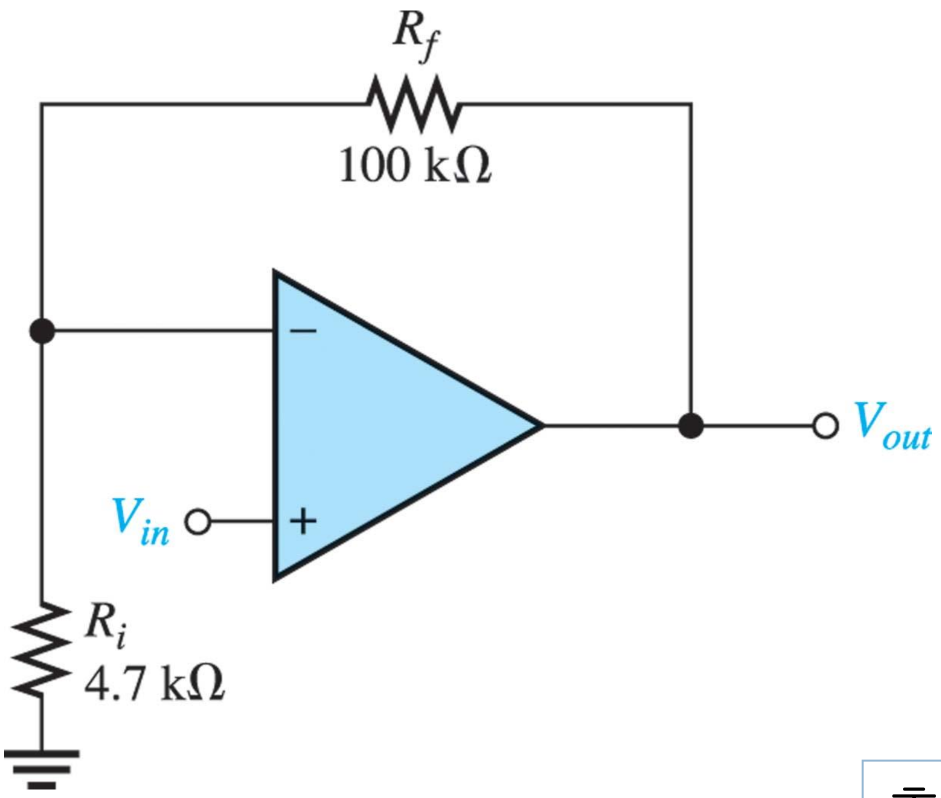
= 18V/us



출처: Floyd 전자회로 7판

비반전 증폭기

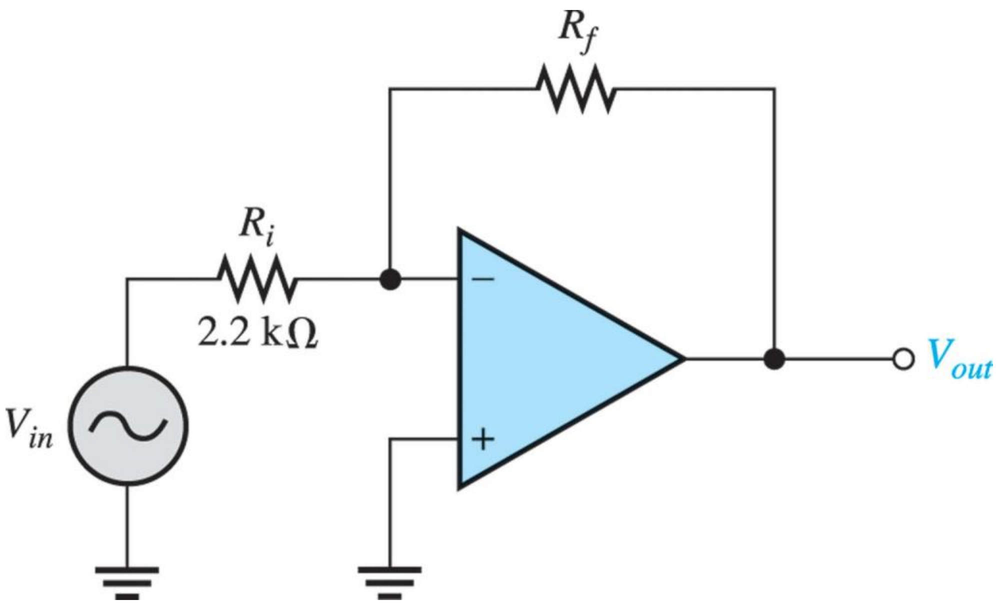
- Av= 1+Rf/Ri =1+ (100/4.7) = 22.3



출처: Floyd 전자회로 7판

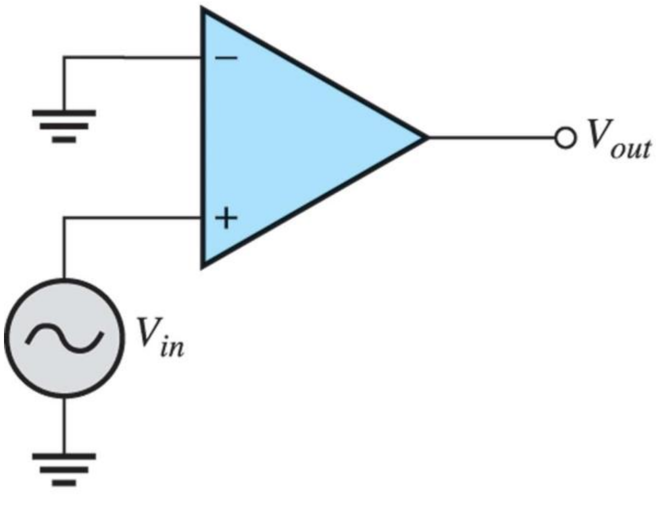
반전 증폭기

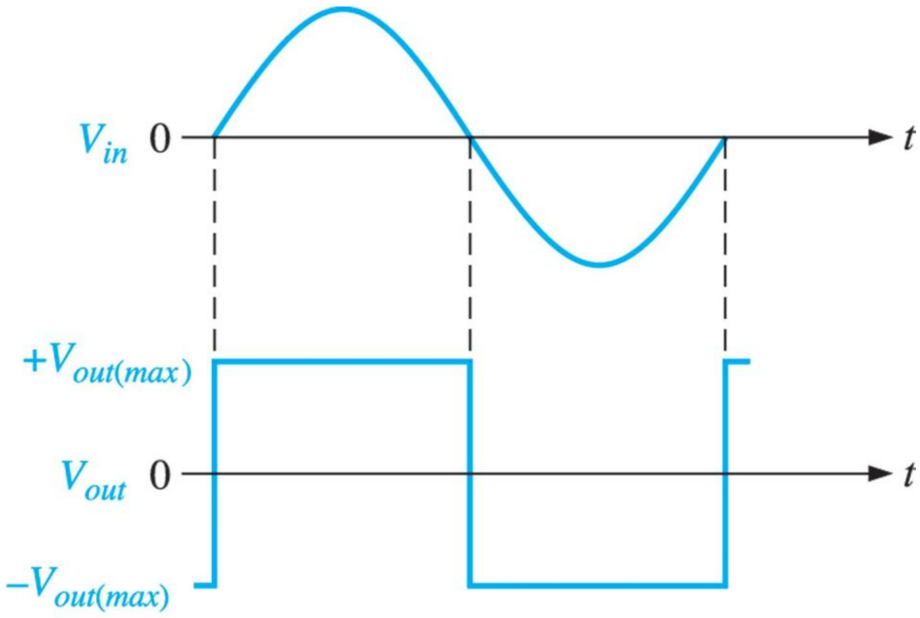
- Av= - Rf/Ri
- Av= -100이려면 Rf는?



출처: Floyd 전자회로 7판

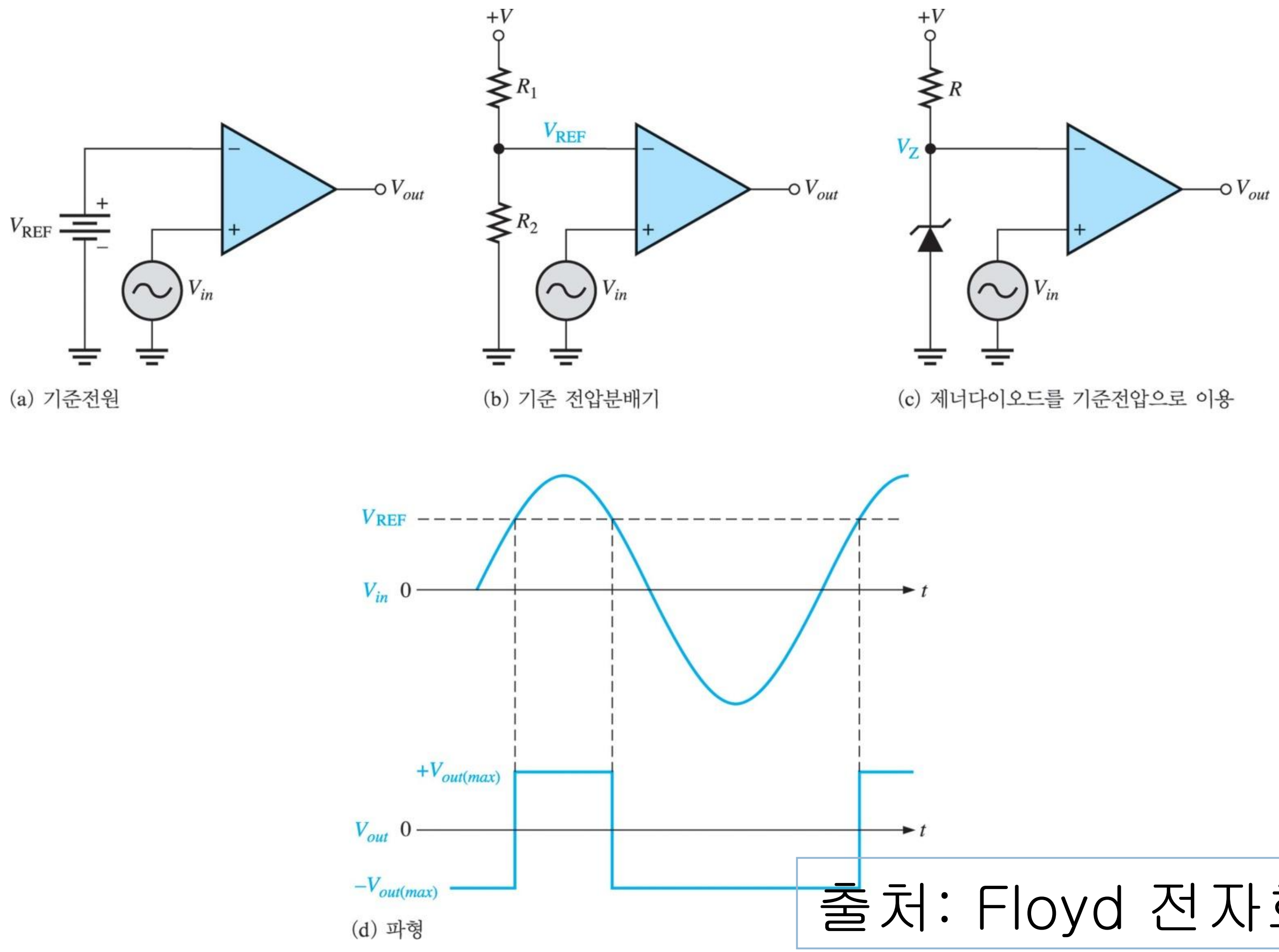
비교기(Comaparator)
- 영 전위 검출





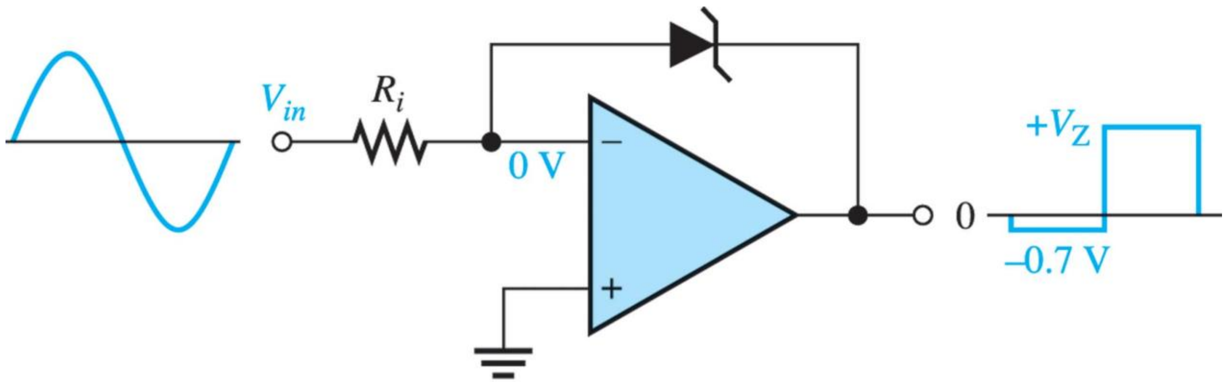
출처: Floyd 전자회로 7판

비교기(Comaparator)
- 영이 아닌 전위 검출

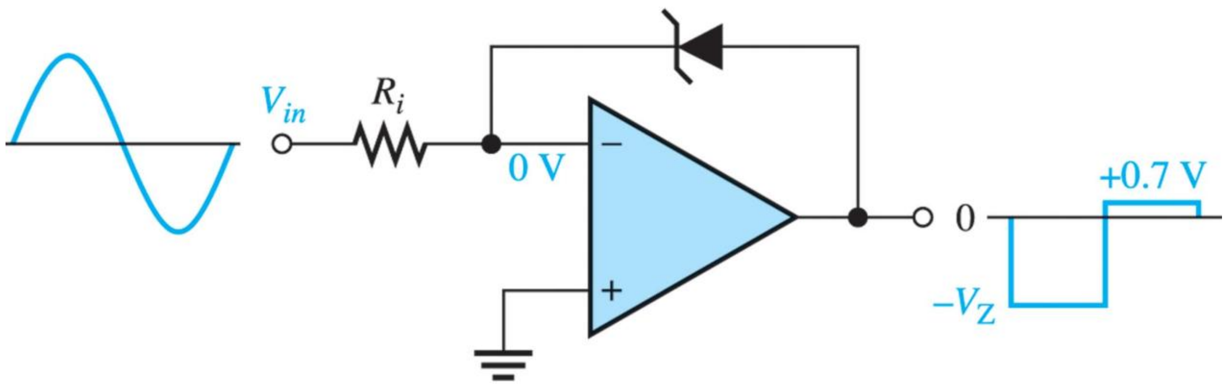


출처: Floyd 전자회로 7판

비교기(Comaparator)
_ 제너를 이용한 출력 제한



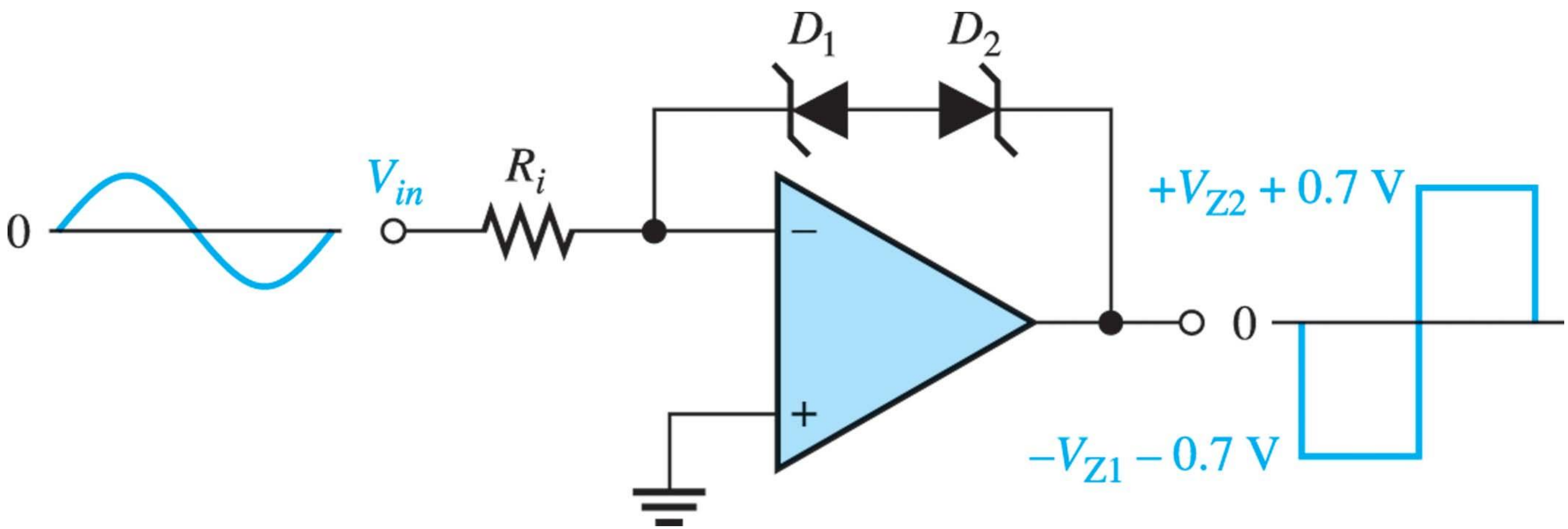
(a) 정(+) 전압에서의 제한



(b) 부(−) 전압에서의 제한

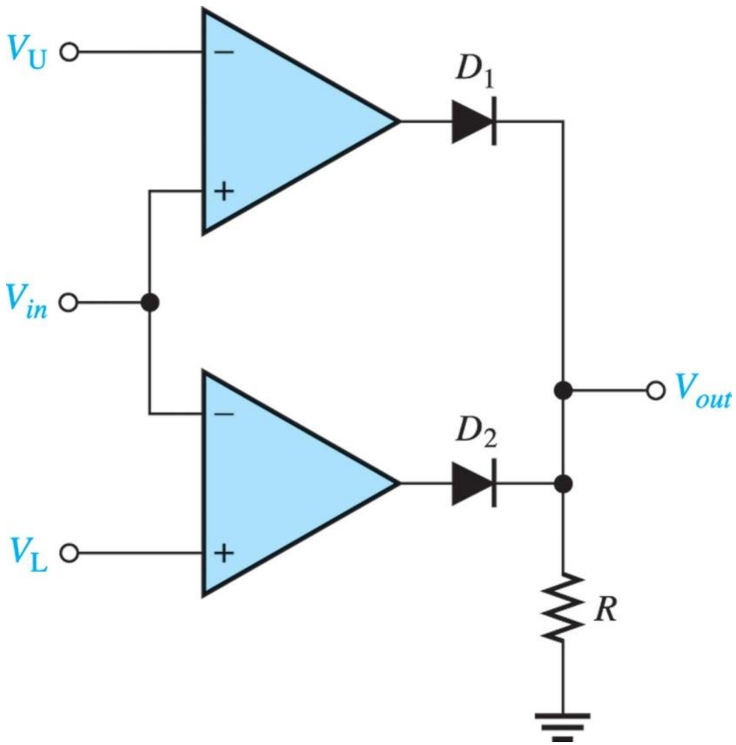
출처: Floyd 전자회로 7판

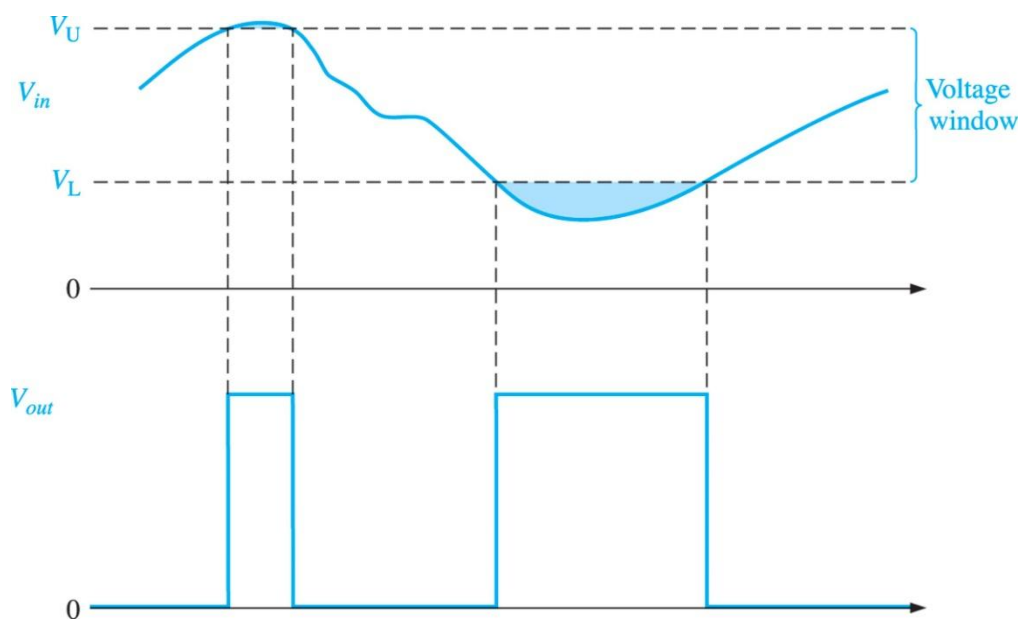
비교기(Comaparator)
- 제너를 이용한 이중제한



출처: Floyd 전자회로 7판

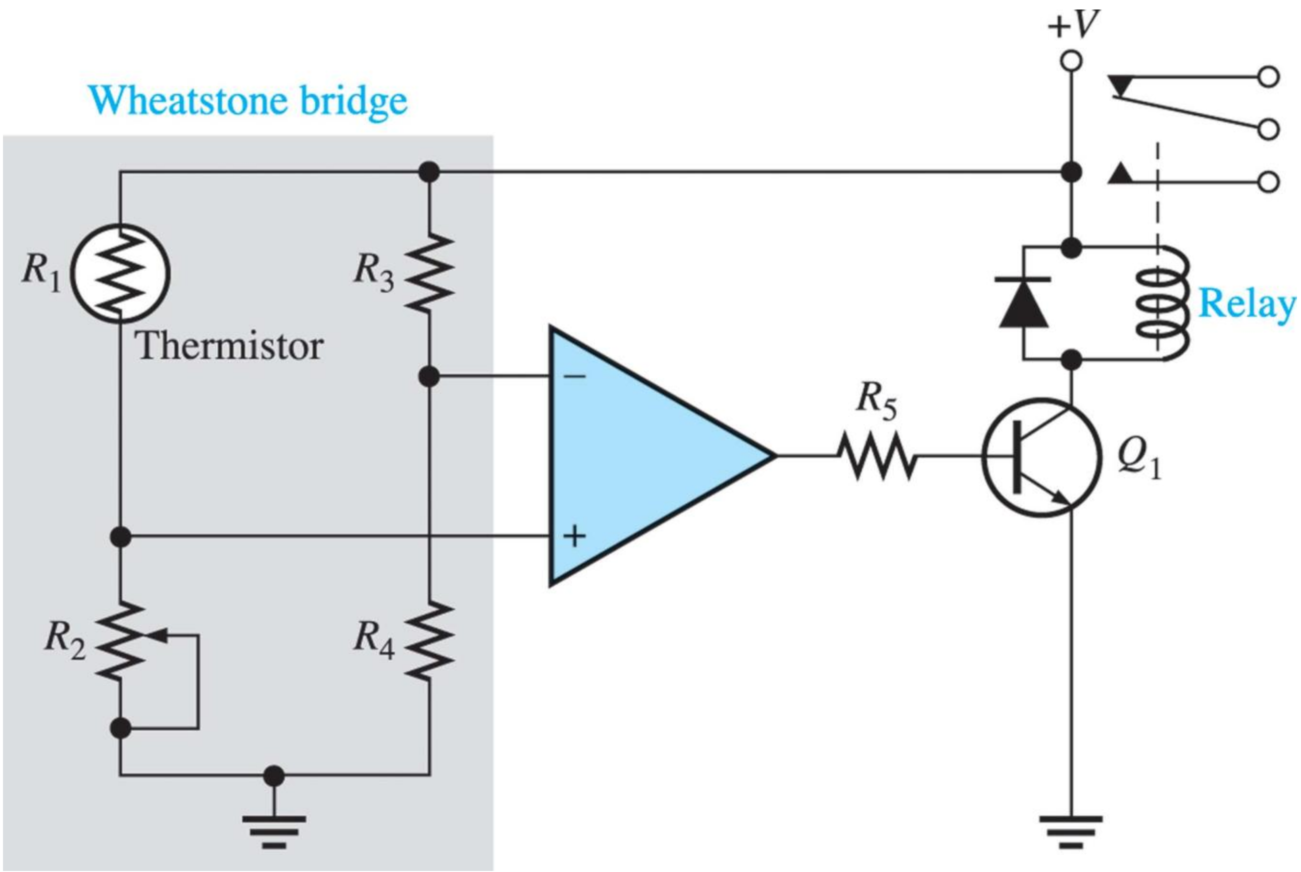
윈도우 비교기





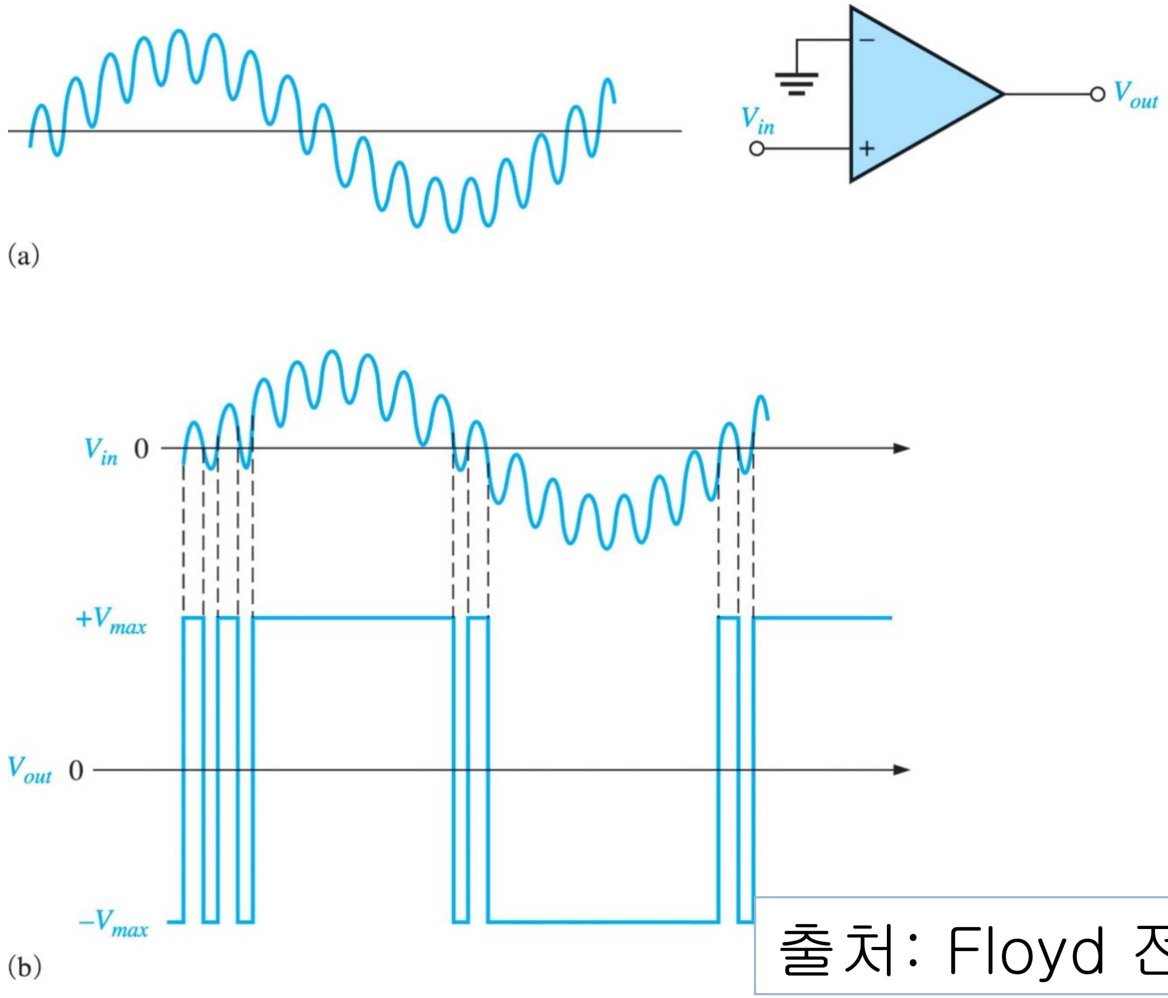
출처: Floyd 전자회로 7판

비교기 응용 - 과열 검출회로



출처: Floyd 전자회로 7판

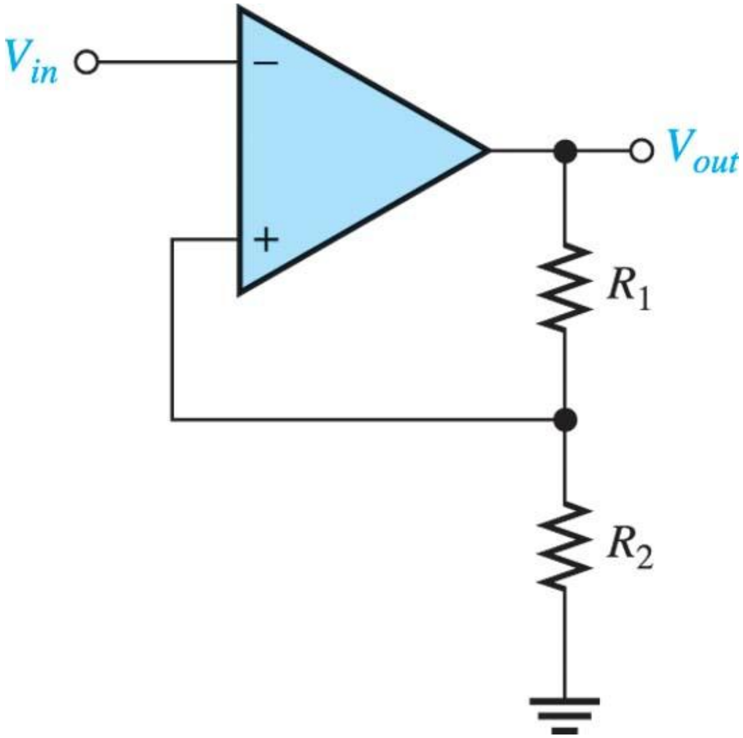
비교기에서 잡음의 영향



출처: Floyd 전자회로 7판

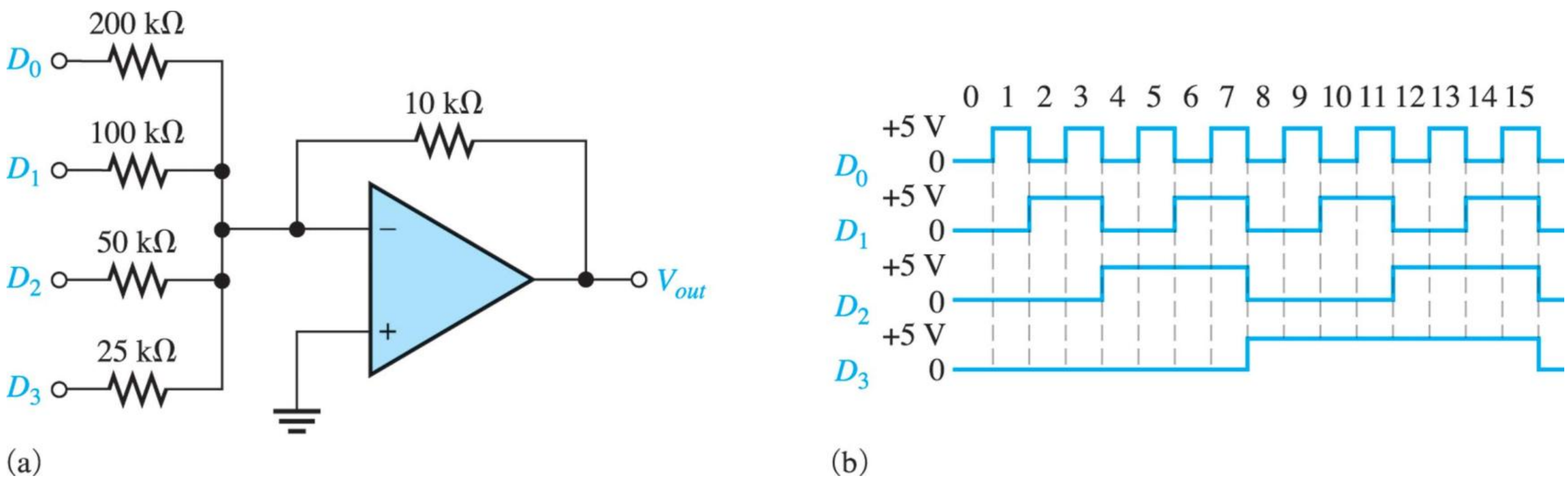
히스테리시스로 _ 잡음의 영향 줄이기

- 교재 참조



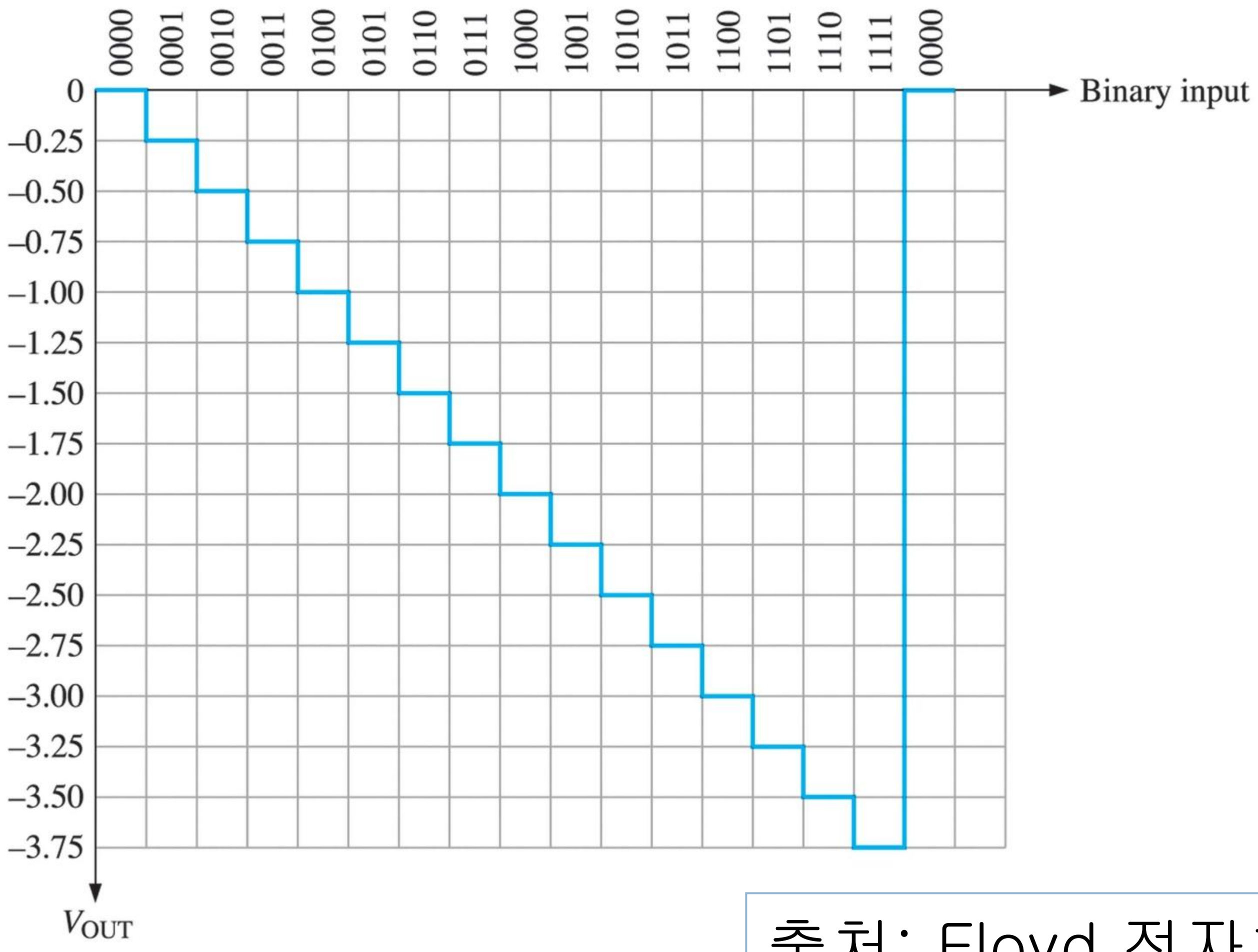
출처: Floyd 전자회로 7판

스케일링 가산기 - DAC



출처: Floyd 전자회로 7판

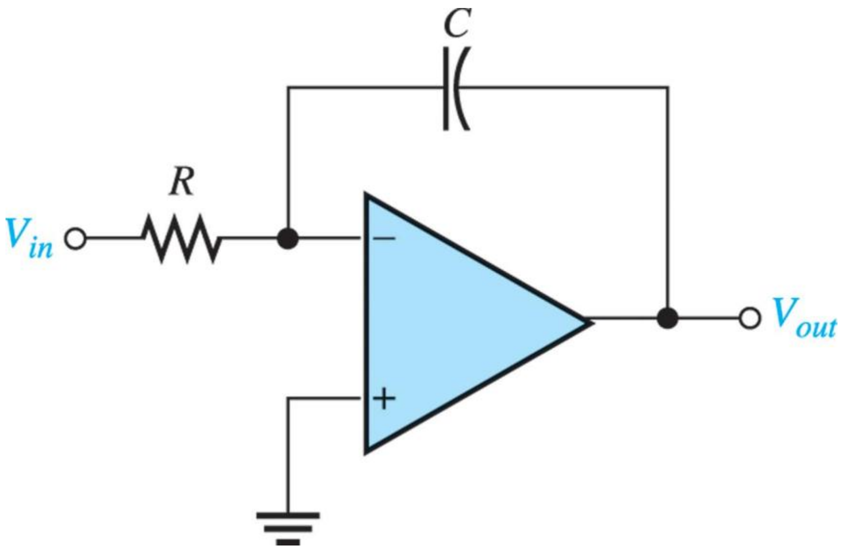
DAC 결과



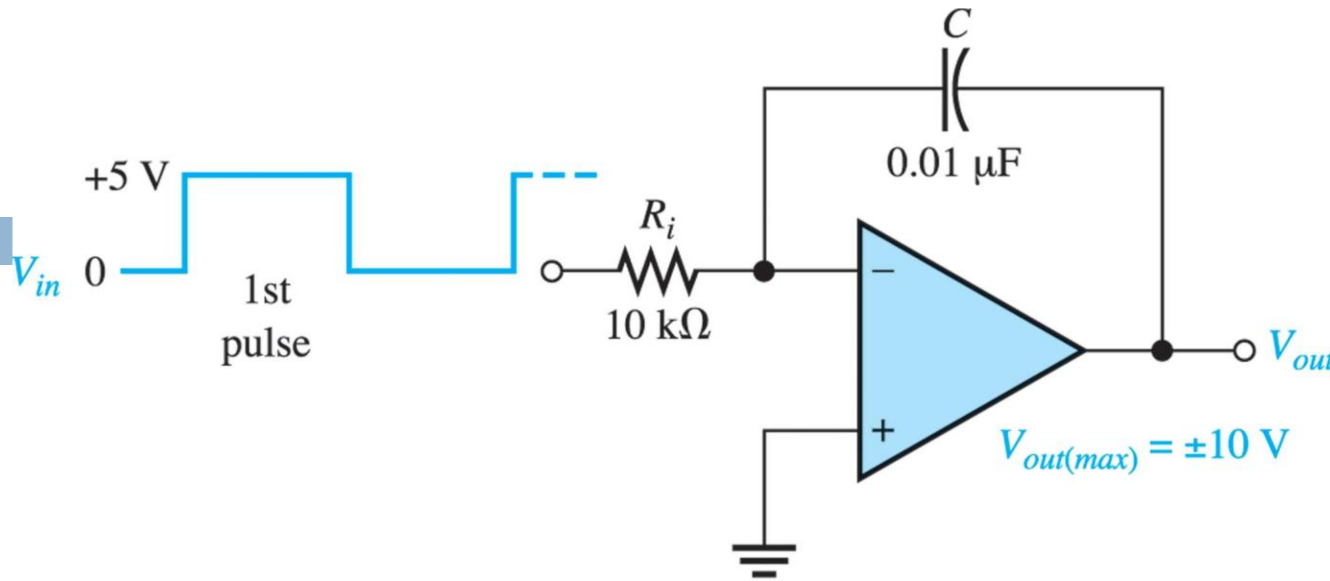
출처: Floyd 전자회로 7판

적분기(Integrator)

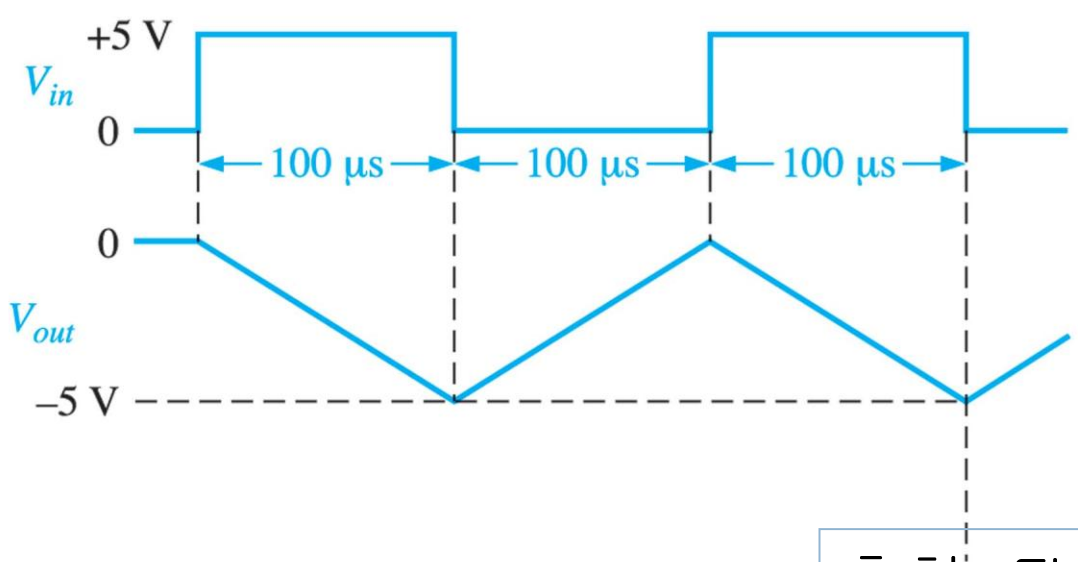
- $\Delta Vout/\Delta t = -Vin/RC$
- 함수 전체의 면적을 구한다



출처: Floyd 전자회로 7판



(a)



(b)

출처: Floyd 전자회로 7판

Resistance Tolerance (± %)

0.1% 0.25% 0.5%	1%	2% 5%	10%	0.1% 0.25% 0.5%	1%	2% 5%	10%	0.1% 0.25% 0.5%	1%	2% 5%	10%	0.1% 0.25% 0.5%	1%	2% 5%	10%	0.1% 0.25% 0.5%	1%	2% 5%	10%	0.1% 0.25% 0.5%	1%	2% 5%	10%
10.0	10.0	10	10	14.7	14.7	—	—	21.5	21.5	—	—	31.6	31.6	—	—	46.4	46.4	—	—	68.1	68.1	68	68
10.1	—	—	—	14.9	—	—	—	21.8	—	—	—	32.0	—	—	—	47.0	—	47	47	69.0	—	—	—
10.2	10.2	—	—	15.0	15.0	15	15	22.1	22.1	22	22	32.4	32.4	—	—	47.5	47.5	—	—	69.8	69.8	—	—
10.4	—	—	—	15.2	—	—	—	22.3	—	—	—	32.8	—	—	—	48.1	—	—	—	70.6	—	—	—
10.5	10.5	—	—	15.4	15.4	—	—	22.6	22.6	—	—	33.2	33.2	33	33	48.7	48.7	—	—	71.5	71.5	—	—
10.6	—	—	—	15.6	—	—	—	22.9	—	—	—	33.6	—	—	—	49.3	—	—	—	72.3	—	—	—
10.7	10.7	—	—	15.8	15.8	—	—	23.2	23.2	—	—	34.0	34.0	—	—	49.9	49.9	—	—	73.2	73.2	—	—
10.9	—	—	—	16.0	—	16	—	23.4	—	—	—	34.4	—	—	—	50.5	—	—	—	74.1	—	—	—
11.0	11.0	11	—	16.2	16.2	—	—	23.7	23.7	—	—	34.8	34.8	—	—	51.1	51.1	51	—	75.0	75.0	75	—
11.1	—	—	—	16.4	—	—	—	24.0	—	24	—	35.2	—	—	—	51.7	—	—	—	75.9	—	—	—
11.3	11.3	—	—	16.5	16.5	—	—	24.3	24.3	—	—	35.7	35.7	—	—	52.3	52.3	—	—	76.8	76.8	—	—
11.4	—	—	—	16.7	—	—	—	24.6	—	—	—	36.1	—	36	—	53.0	—	—	—	77.7	—	—	—
11.5	11.5	—	—	16.9	16.9	—	—	24.9	24.9	—	—	36.5	36.5	—	—	53.6	53.6	—	—	78.7	78.7	—	—
11.7	—	—	—	17.2	—	—	—	25.2	—	—	—	37.0	—	—	—	54.2	—	—	—	79.6	—	—	—
11.8	11.8	—	—	17.4	17.4	—	—	25.5	25.5	—	—	37.4	37.4	—	—	54.9	54.9	—	—	80.6	80.6	—	—
12.0	—	12	12	17.6	—	—	—	25.8	—	—	—	37.9	—	—	—	56.2	—	—	—	81.6	—	—	—
12.1	12.1	—	—	17.8	17.8	—	—	26.1	26.1	—	—	38.3	38.3	—	—	56.6	56.6	56	56	82.5	82.5	82	82
12.3	—	—	—	18.0	—	18	18	26.4	—	—	—	38.8	—	—	—	56.9	—	—	—	83.5	—	—	—
12.4	12.4	—	—	18.2	18.2	—	—	26.7	26.7	—	—	39.2	39.2	39	39	57.6	57.6	—	—	84.5	84.5	—	—
12.6	—	—	—	18.4	—	—	—	27.1	—	27	27	39.7	—	—	—	58.3	—	—	—	85.6	—	—	—
12.7	12.7	—	—	18.7	18.7	—	—	27.4	27.4	—	—	40.2	40.2	—	—	59.0	59.0	—	—	86.6	86.6	—	—
12.9	—	—	—	18.9	—	—	—	27.7	—	—	—	40.7	—	—	—	59.7	—	—	—	87.6	—	—	—
13.0	13.0	13	—	19.1	19.1	—	—	28.0	28.0	—	—	41.2	41.2	—	—	60.4	60.4	—	—	88.7	88.7	—	—
13.2	—	—	—	19.3	—	—	—	28.4	—	—	—	41.7	—	—	—	61.2	—	—	—	89.8	—	—	—
13.3	13.3	—	—	19.6	19.6	—	—	28.7	28.7	—	—	42.2	42.2	—	—	61.9	61.9	62	—	90.9	90.9	91	—
13.5	—	—	—	19.8	—	—	—	29.1	—	—	—	42.7	—	—	—	62.6	—	—	—	92.0	—	—	—
13.7	13.7	—	—	20.0	20.0	20	—	29.4	29.4	—	—	43.2	43.2	43	—	63.4	63.4	—	—	93.1	93.1	—	—
13.8	—	—	—	20.3	—	—	—	29.8	—	—	—	43.7	—	—	—	64.2	—	—	—	94.2	—	—	—
14.0	14.0	—	—	20.5	20.5	—	—	30.1	30.1	30	—	44.2	44.2	—	—	64.9	64.9	—	—	95.3	95.3	—	—
14.2	—	—	—	20.8	—	—	—	30.5	—	—	—	44.8	—	—	—	65.7	—	—	—	96.5	—	—	—
14.3	14.3	—	—	21.0	21.0	—	—	30.9	30.9	—	—	45.3	45.3	—	—	66.5	66.5	—	—	97.6	97.6	—	—
14.5	—	—	—	21.3	—	—	—	31.2	—	—	—	45.9	—	—	—	67.3	—	—	—	98.8	—	—	—

NOTE: These values are generally available in multiples of 0.1, 1, 10, 100, 1 k, and 1 M.

출처: Floyd 전자회로 7판