Electronics Reference

September 4, 2022

Contents

[1] Joint Electron Device Engineering Council - American
[2] European
[3] Japanese Industrial Standard

Chapter 1

Components Introduction

§1.1 Resistors

1.1.1 Types

Type	Power	Price	Noise	Tolerance	Inductive
Carbon[1]	¼-5W	High	High	Poor	No
Carbon Film	¼-5W	Low	Low	Good	Slightly
Metal Film	¼-3W	Low	Low	Good	Slightly
Metal Oxide	¼-1W	Low	Very Low	Good	No
Wirewound	<1kW	High	Very Low	Good	Yes

[1]Not generally used, but still used as as replacements in vintage equipment for authenticity

1.1.2 Colour Coding

1.1.2.1 4 band

Colour	1st digit	2nd digit	Multiplier	Tolerance
Silver	–	–	$\times 0.01\Omega$	5%
Gold	–	–	$\times 0.1\Omega$	10%
Black	–	0	$\times 1\Omega$	20%
Brown	1	1	$\times 10\Omega$	–
Red	2	2	$\times 100\Omega$	–
Orange	3	3	$\times 1\text{k}\Omega$	–
Yellow	4	4	$\times 10\text{k}\Omega$	–
Green	5	5	$\times 100\text{k}\Omega$	–
Blue	6	6	$\times 1\text{M}\Omega$	–
Violet	7	7	$\times 10\text{M}\Omega$	–
Gray	8	8	$\times 100\text{M}\Omega$	–
White	9	9	$\times 1{,}000\text{M}\Omega$	–

1.1.2.2 5/6 band

Colour	1st	2nd	3rd	Multiplier	Tolerance	Temp. coeff.[2]
Silver	–	–	–	$\times 0.01\Omega$	5%	–
Gold	–	–	–	$\times 0.1\Omega$	10%	–
Black	–	0	0	$\times 1\Omega$	20%	–
Brown	1	1	1	$\times 10\Omega$	1%	100
Red	2	2	2	$\times 100\Omega$	2%	50
Orange	3	3	3	$\times 1\text{k}\Omega$	3%	15
Yellow	4	4	4	$\times 10\text{k}\Omega$	4%	25
Green	5	5	5	$\times 100\text{k}\Omega$	0.5%	–
Blue	6	6	6	$\times 1\text{M}\Omega$	0.25%	10
Violet	7	7	7	$\times 10\text{M}\Omega$	0.1%	5
Gray	8	8	8	$\times 100\text{M}\Omega$	0.05%	–
White	9	9	9	$\times 1{,}000\text{M}\Omega$	–	–

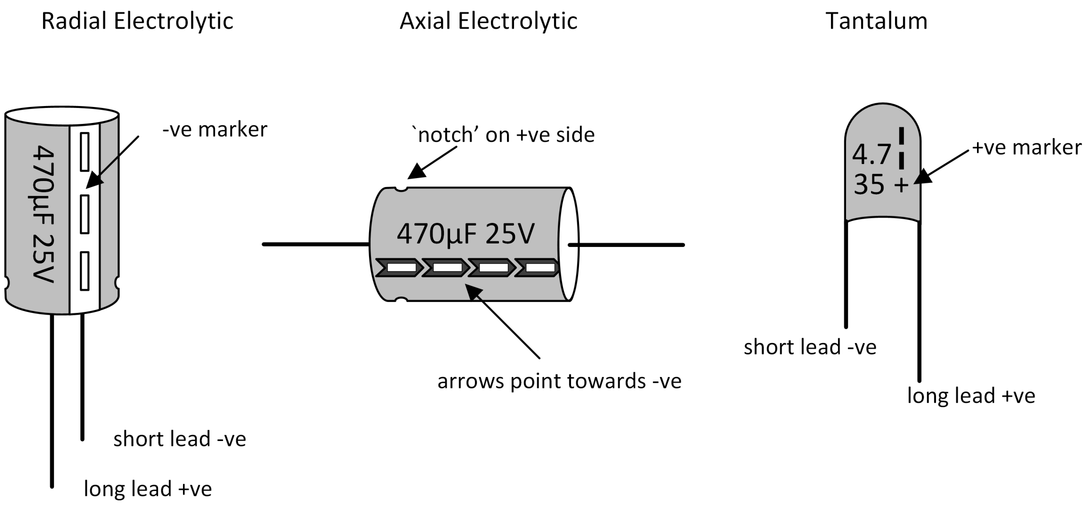
§1.2 Capacitors

1.2.1 Types

[2] ppm/K - 6 band only

	Tantalum	Electrolytic	Ceramic	Polyester	Polythene	Polystyrene	Polypropylene
ESR	Low	Good	Medium	Low	Low	Very Low	Very Low
Ind.	Medium	Med.-High	Low	High	High	Low	Medium
Cap.	0.1-1,500μ	0.1-43,000μ	0.1 p-100μ	1n-160μ	10n-4.7μ	22p-2μ	68pF-22μ
Voltage	2V-125V	6.3V-450V	6.3V-50kV	50V-1kV	16V-400V	50V-630V	50V-3kV
Polarised	Yes	Yes	No	No	No	No	No
Failure	Short	Open	Short	Open	Open	Open	Open
Size	Small	Medium	Small	Med.-Large	Large	Large	Large
Cost	High	Low	High	Low	Medium	Low	Medium

1.2.2 Polarity Marking



1.2.3 Numeric Coding

1.2.3.1 Capacitance Value

Marking	Capacitance (pF)	Capacitance (nF)	Capacitance (μF)
10	10 pF	0.01 nF	–
22	22 pF	0.022 nF	–
47	47 pF	0.047 nF	–
101	100 pF	0.1 nF	–
221	220 pF	0.22 nF	–
471	470 pF	0.47 nF	–
102	1,000 pF	1 nF	–
222	–	2.2 nF	–
472	–	4.7 nF	–
103	–	10 nF	0.01uF
223	–	22 nF	0.022uF
473	–	47 nF	0.047uF
104	–	100 nF	0.1uF
224	–	220 nF	0.22uF
474	–	470 nF	0.47uF
105	–	–	1uF
225	–	–	2.2uF
475	–	–	4.7uF

1.2.3.2 Tolerance

Letter	Tolerance	Letter	Tolerance
A	±0.05 pF	B	±0.1 pF
C	±0.25 pF	D	±0.5 pF
E	±0.5%	F	±1%
G	±2%	H	±3%
J	±5%	K	±10%
L	±15%	M	±20%
N	±30%	P	-0%, + 100%
S	-20%, + 50%	W	-0%, + 200%
X	-20%, + 40%	–	–

§1.3 Inductors

1.3.1 Numeric Coding

1.3.1.1 Inductance Value

Marking	Inductance (nH)	Inductance (μH)	Inductance (mH)
1R0	1 nH	–	–
2R2	2.2 nH	–	–
4R7	4.7 nH	–	–
100	10 nH	0.01 μH	–
220	22 nH	0.022 μH	–
470	47 nH	0.047 μH	–
101	100 nH	0.1 μH	–
221	220 nH	0.22 μH	–
471	470 nH	0.47 μH	–
102	1,000 nH	1 μH	–
222	2,200 nH	2.2 μH	–
472	4,700 nH	4.7 μH	–
103	–	10 μH	–
223	–	22 μH	–
473	–	47 μH	–
104	–	10 μH	0.01 mH
224	–	22 μH	0.022 mH
474	–	47 μH	0.047 mH
105	–	100 μH	0.1 mH
225	–	220 μH	0.22 mH
475	–	470 μH	0.47 mH
106	–	1,000 μH	1 mH
226	–	2,200 μH	2.2 mH
476	–	4,700 μH	4.7 mH
107	–	–	10 mH
227	–	–	22 mH
477	–	–	47 mH
108	–	–	100 mH
228	–	–	220 mH
478	–	–	470 mH

1.3.1.2 Tolerance

Letter	**Tolerance**
F	$\pm 1\%$
G	$\pm 2\%$
J	$\pm 5\%$
K	$\pm 10\%$
M	$\pm 20\%$

1.3.2 Colour Coding

Colour	**1st digit**	**2nd digit**	**Multiplier**	**Tolerance**
Silver	–	–	$\times 0.01\ \mu$H	5%
Gold	–	–	$\times 0.1\ \mu$H	10%
Black	–	0	$\times 1\ \mu$H	20%
Brown	1	1	$\times 10\ \mu$H	–
Red	2	2	$\times 100\ \mu$H	–
Orange	3	3	$\times 1$ mH	–
Yellow	4	4	$\times 10$ mH	–
Green	5	5	$\times 100$ mH	–
Blue	6	6	$\times 1$ H	–
Violet	7	7	$\times 10$ H	–
Gray	8	8	$\times 100$ H	–
White	9	9	$\times 1{,}000$ H	–

§1.4 Wire Gauges

AWG	Dia mm	SWG	Dia mm	Max Amps	Ω/ 100m
11	2.3	13	2.34	12.0	0.53
12	2.05	14	2.03	9.3	0.67
13	1.83	15	1.83	7.4	0.85
14	1.63	16	1.63	5.9	1.1
15	1.45	17	1.42	4.7	1.4
16	1.29	18	1.219	3.7	1.7
18	1.024	19	1.016	2.3	2.7
19	0.912	20	0.914	1.8	3.4
20	0.812	21	0.813	1.5	4.3
21	0.723	22	0.711	1.2	5.4
22	0.644	23	0.610	0.920	6.9
23	0.573	24	0.559	0.729	8.6
24	0.511	25	0.508	0.577	10.9
25	0.455	26	0.457	0.457	13.7
26	0.405	27	0.417	0.361	17.4
27	0.361	28	0.376	0.288	21.8
28	0.321	30	0.315	0.226	27.6
29	0.286	32	0.274	0.182	34.4
30	0.255	33	0.254	0.142	43.9
31	0.226	34	0.234	0.113	55.4
32	0.203	36	0.193	0.091	68.5
33	0.180	37	0.173	0.072	87.0
34	0.160	38	0.152	0.056	110.5
35	0.142	39	0.132	0.044	139.8

§1.5 Semiconductors

1.5.1 Semiconductor Numbering

1.5.1.1 JEDEC[3] numbering system

[**Digit**[4]]**N**[**SerialNo**[5]][**Gain**] e.g. 2N3904C

[3] Joint Electron Device Engineering Council - American
[4] Number of P-N junctions
[5] 100 to 9999

Digit	Type	Gain	Gain Group
1	Diode	A	Low gain
2	Bipolar/FET Transistor	B	Medium Gain
3	Double Gate Mosfet/SCR	C	High Gain
4	Opto Coupler	no suffix	any

1.5.1.2 Pro-Electron Numbering System[6]

[**Letter1**][**Letter2**][**SerialNo**[7]][**Suffix**] e.g. BFY51

Letter1	Material	Letter2	Device Type
A	Germanium	A	Diode, low power or signal
B	Silicon	B	Diode, variable capacitance
C	Gallium Arsenide	C	Transistor, audio frequency, low power
D	Compound Material	D	Transistor, audio frequency, power
		E	Diode, tunnel
		F	Transistor, high frequency, low power
		G	Miscellaneous Devices
		H	Diode, sensitive to magnetism
		K	Hall effect device
		L	Transistor, high frequency, power
		N	Photocoupler
		P	Light Detector
		Q	Light emitter
		R	Switching, low power: thyristor, diac, unijunction
		S	Transistor, low power, switching
		T	Switching, power: thyristor, diac, unijunction
		U	Transistor, switching, power
		W	Surface acoustic wave device
		X	Diode, multiplier, e.g. varactor
		Y	Diode, rectifying
		Z	Diode, voltage reference

1.5.1.3 JIS[8] numbering system

[**Digit**[9]][**2Letters**][**SerialNo**[10]][**Suffix**[11]] e.g. 2SC1030

[6] European
[7] 10 to 9999
[8] Japanese Industrial Standard
[9] Number of P-N junctions
[10] 10 to 9999
[11] Optional- the type is approved for use by various Japanese organizations.

Digit	Type	2Letters	Application
1	Diode	SA	PNP HF Transistors
2	Bipolar/FET Transistor	SB	PNP AF Transistors
3	Double Gate Mosfet/SCR	SC	NPN HF Transistors
		SD	NPN AF Transistor
		SE	Diodes
		SF	Thyristors
		SG	Gunn devices
		SH	Unijunction Transistors
		SJ	p-channel FET/Mosfet
		SK	n-channel FET/Mosfet
		SM	Triacs
		SQ	LEDs
		SR	Rectifiers
		SS	Signal diodes
		ST	Diodes
		SV	Varicaps
		SZ	Zener Diodes

1.5.1.4 Manufacturer Numbering

Major manufacturers often produce their own code and numbering scheme for commercial reasons. The following abbreviations represent device prefixes for some of the larger semiconductor manufacturers:

Prefix	Manufacturer	Type
MJ	Motorola	Power, metal case
MJE	Motorola	Power, plastic case
MPS	Motorola	Low power, plastic case
MRF	Motorola	HF, VHF and microwave transistor
RCA	RCA	-
RCS	RCS	-
TIP	Texas Instruments	Power transistor, plastic case
TIPL	Texas Instruments	Planar power transistor
TIS	Texas Instruments	Small signal transistor (plastic case)
ZT	Ferranti	-
ZTX	Ferranti	-

1.5.2 Semiconductor Packages

TO3

TO5

TO18

TO39

TO52

TO72

TO92

TO126

TO220

Package	Size	Cap Dia.	Cap Ht.	Lead length	Lead pitch
TO-3	39.3×26.6×1.7	22.2	5.7	11.7	10.9
TO-5	8.9 $\varnothing$(base)	8.1	6.3	38.1	5.08
TO-18	5.5 $\varnothing$(base)	4.7	4.8	12.7	2.97
TO-39	9.1 $\varnothing$(base)	8.5	4.3	13.4	2.54
TO-52	5.6 $\varnothing$(base)	4.7	3.4	12.7	2.54
TO-72	5.55 $\varnothing$(base)	4.73	4.83	12.7	2.54
TO-92	4.58×4.58 (H×W)	3.86 (T)	-	14.47	1.27
TO-126	11×8×3.25	-	-	16.1	2.28
TO-220	9.2×9.9 (H×W)	4.5 (T)	-	13.1	2.54

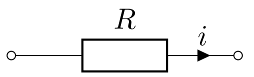
All sizes in mm.

Chapter 2

Circuit Elements

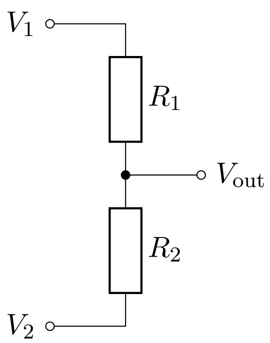
§2.1 Resistor Configurations

Configuration 2.1.0.1 (Series Resistor)



i

Configuration 2.1.0.2 (Potential Divider)

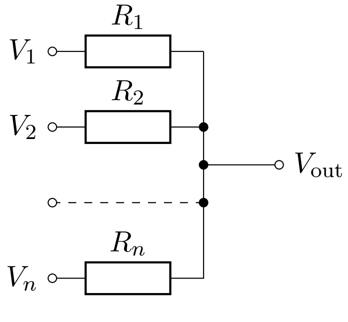


$$V_{\text{out}} = \frac{R_2}{R_1 + R_2}(V_1 - V_2) + V_2.$$

If $V_2 = 0$, then;

$$V_{\text{out}} = \frac{R_2}{R_1 + R_2}V_1.$$

Configuration 2.1.0.3 (Voltage Averager)

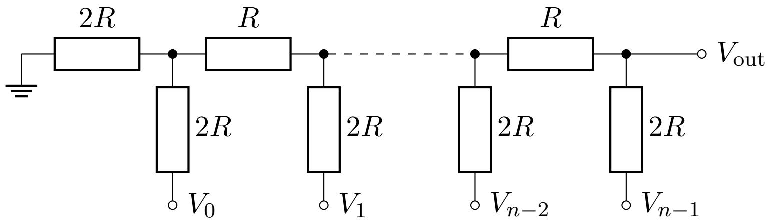


$$V_{\text{out}} = \frac{\sum_{i=1}^{n} \frac{V_i}{R_i}}{\sum_{i=1}^{n} \frac{1}{R_i}}.$$

If $R_1 = R_2 = \cdots = R_n$, then;

$$V_{\text{out}} = \frac{1}{n}\sum_{i=1}^{n} V_i.$$

Configuration 2.1.0.4 (R-2R Network)



$$V_{\text{out}} = \sum_{i=0}^{n-1} \frac{V_i}{2^{n-i}}$$

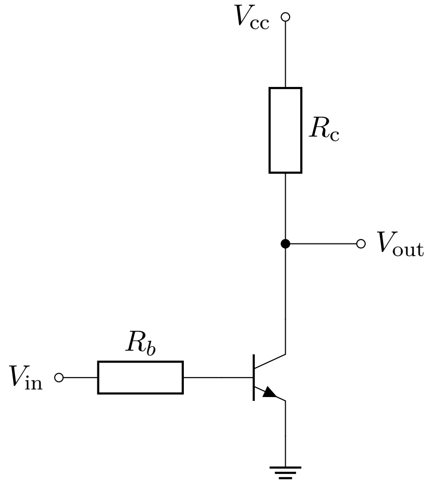
§2.2 Diode Configurations

§2.3 Transistor Configurations

2.3.1 BJT

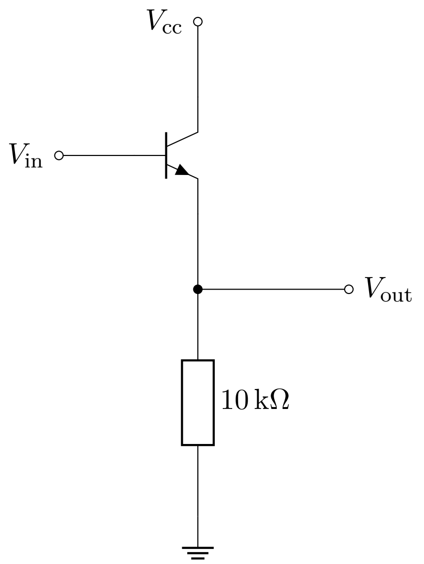
2.3.1.1 NPN

Configuration 2.3.1.1 (Common Emitter)



$$\begin{aligned} V_{\mathrm{out}} &= V_{\mathrm{cc}} - \beta R_{\mathrm{c}} \frac{V_{\mathrm{in}} - 0.7}{R_{\mathrm{b}}}; \\ Z_{\mathrm{in}} &= R_{\mathrm{b}}; \\ Z_{\mathrm{out}} &= R_{\mathrm{c}}. \end{aligned}$$

Configuration 2.3.1.2 (Common Collector)

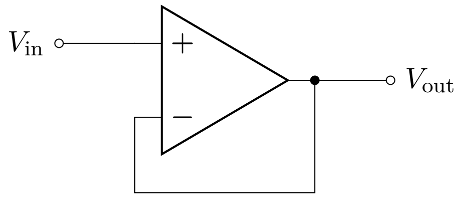


e

§2.4 Op Amp Configurations

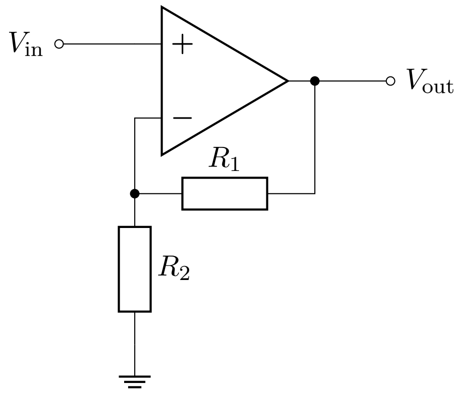
2.4.1 Standard Amplifiers

Configuration 2.4.1.1 (Unity Gain Buffer)



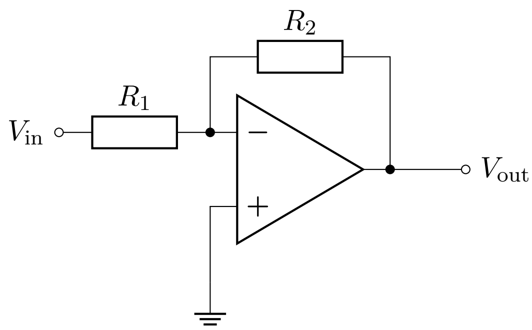
$$V_{\text{out}} = V_{\text{in}}.$$

Configuration 2.4.1.2 (Noninverting Amplifier)



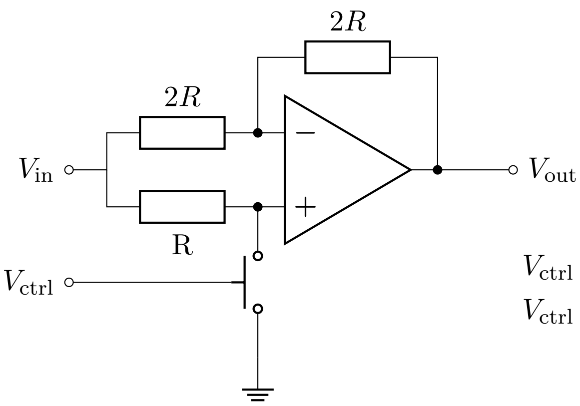
$$V_{\text{out}} = \left(1 + \frac{R_2}{R_1}\right) V_{\text{in}}.$$

Configuration 2.4.1.3 (Inverting Amplifier)



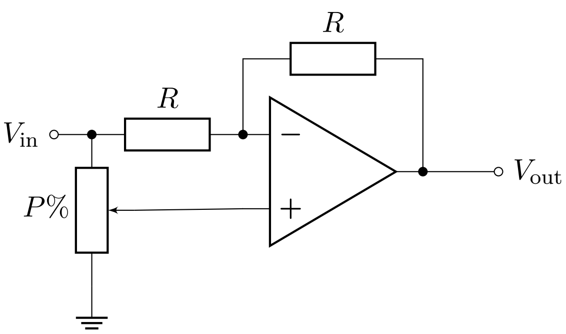
$$V_{\text{out}} = -\frac{R_1}{R_2} V_{\text{in}};$$
$$Z_{\text{in}} = R_1.$$

Configuration 2.4.1.4 (Switchable Inverter)



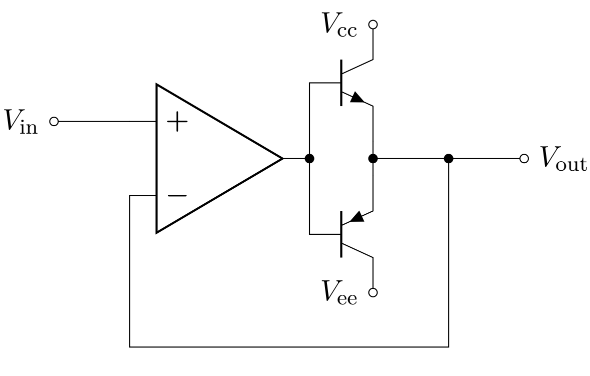
$$V_{\text{ctrl}} = 0V \implies V_{\text{out}} = V_{\text{in}};$$
$$V_{\text{ctrl}} = 5V \implies V_{\text{out}} = -V_{\text{in}}.$$

Configuration 2.4.1.5 (Variable Gain Amplifier)



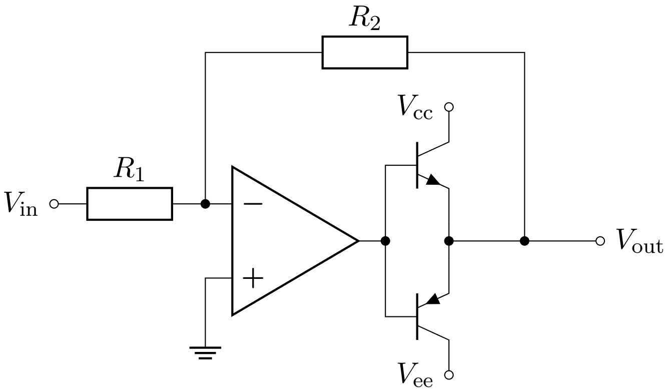
$$V_{\text{out}} = 2(P - 50\%)V_{\text{in}}$$

Configuration 2.4.1.6 (Unity Gain Buffer with High Current Output)



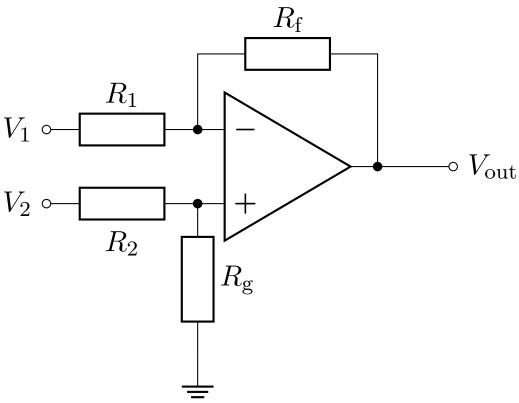
$$V_{\text{out}} = V_{\text{in}}.$$

Configuration 2.4.1.7 (Inverting Amplifier with High Current Output)



$$V_{\text{out}} = -\frac{R_1}{R_2} V_{\text{in}}.$$

Configuration 2.4.1.8 (Differential Amplifier)



$$V_{\text{out}} = \frac{(R_f + R_1)R_g}{(R_g + R_2)R_1} V_2 - \frac{R_f}{R_1} V_1.$$

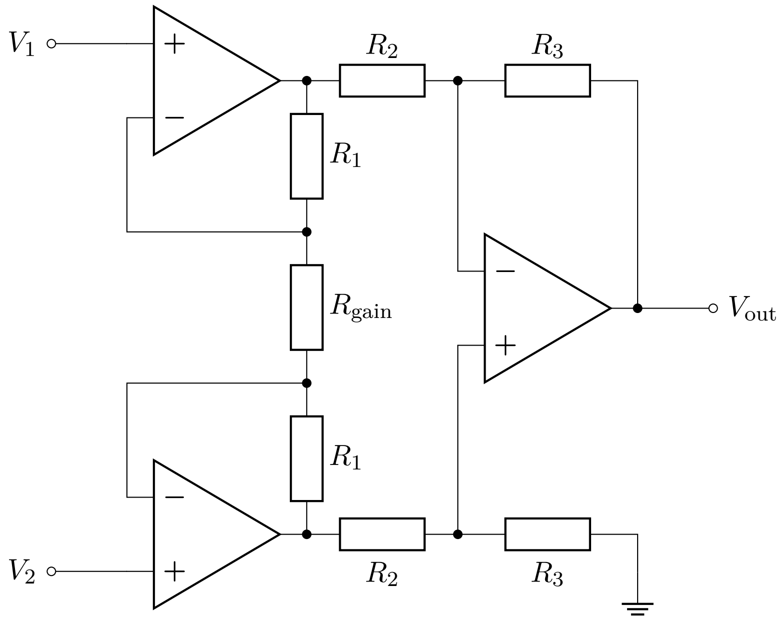
If $\dfrac{R_1}{R_f} = \dfrac{R_2}{R_g}$, then;

$$V_{\text{out}} = \frac{R_f}{R_1}(V_2 - V_1).$$

If $\dfrac{R_1}{R_f} = 1 = \dfrac{R_2}{R_g}$, then;

$$V_{\text{out}} = V_2 - V_1.$$

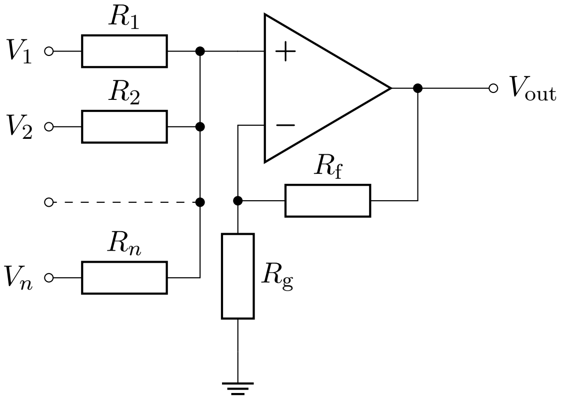
Configuration 2.4.1.9 (Instrumentation Amplifier)



$$V_{\text{out}} = \frac{R_3}{R_2}\left(1 + \frac{2R_1}{R_{\text{gain}}}\right)(V_2 - V_1).$$

2.4.2 Mathematical Operations

Configuration 2.4.2.1 (Noninverting Summing Amplifier)



$$V_{out} = \left(1 + \frac{R_f}{R_g}\right) \frac{\sum_{i=1}^{n} \frac{V_i}{R_i}}{\sum_{i=1}^{n} \frac{1}{R_i}}.$$

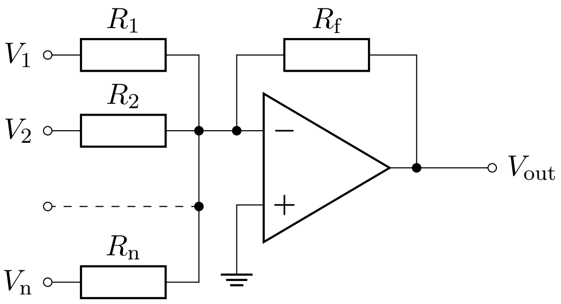
If $R_1 = R_2 = \cdots = R_n$, then;

$$V_{out} = \frac{1}{n} \left(1 + \frac{R_f}{R_g}\right) \sum_{i=1}^{n} V_i.$$

If also $\dfrac{R_f}{R_g} = n - 1$, then;

$$V_{out} = \sum_{i=1}^{n} V_i.$$

Configuration 2.4.2.2 (Inverting Summing Amplifier)



$$V_{out} = -R_f \left(\sum_{i=1}^{n} \frac{V_i}{R_i}\right).$$

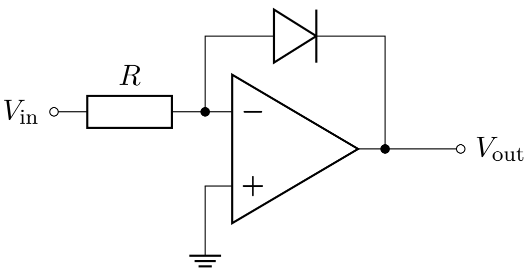
If $R_1 = R_2 = \cdots = R_n$, then;

$$V_{out} = -\frac{R_f}{R_1} \sum_{i=1}^{n} V_n.$$

If $R_1 = R_2 = \cdots = R_n = R_f$, then;

$$V_{out} = -\sum_{i=1}^{n} V_i.$$

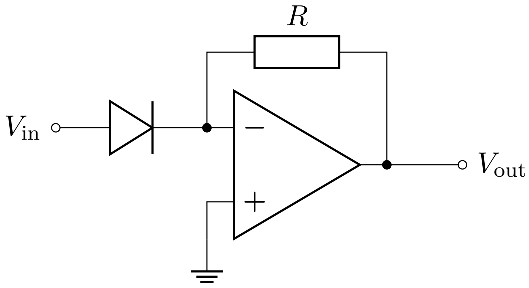
Configuration 2.4.2.3 (Logarithmic Amplifier)



$$V_{out} = -V_T \ln\left(\frac{V_{in}}{I_S R}\right);$$

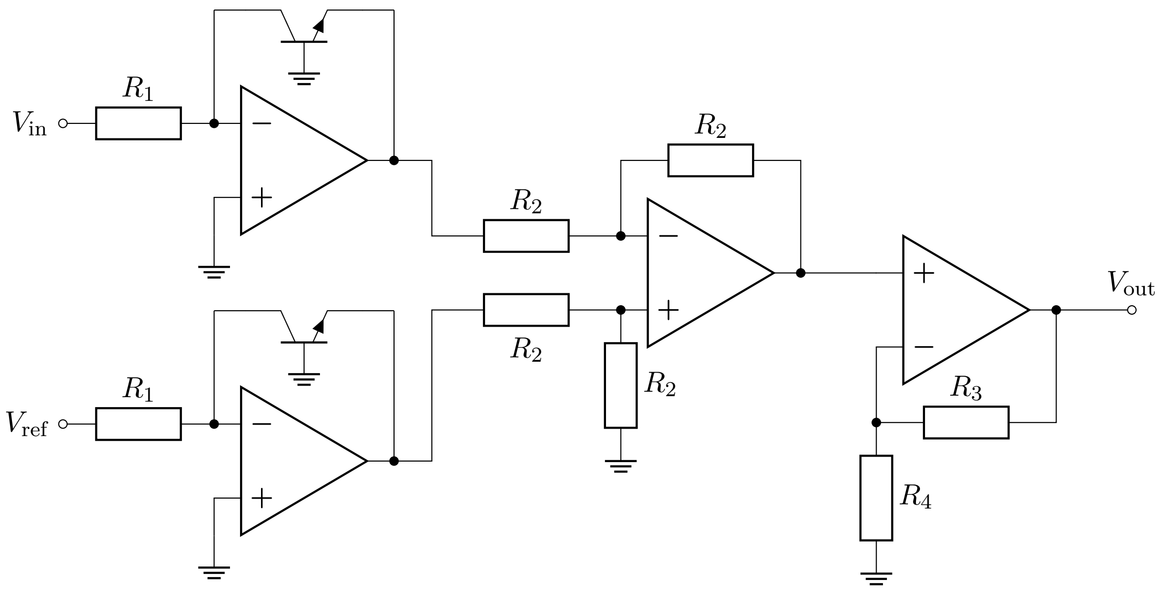
$$V_T = \frac{kT}{q}.$$

Configuration 2.4.2.4 (Exponential Amplifier)



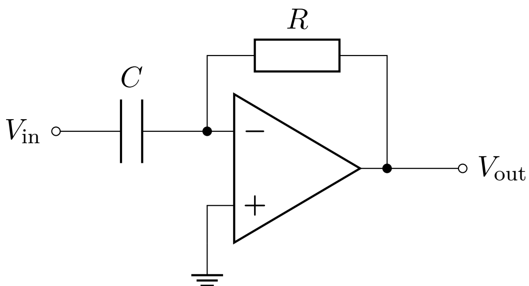
$$V_{\text{out}} = -RI_{\text{S}}e^{\frac{V_{\text{in}}}{V_{\text{T}}}};$$
$$V_{\text{T}} = \frac{kT}{q}.$$

Configuration 2.4.2.5 (Temperature-Compensating Logarithmic Amplifier)



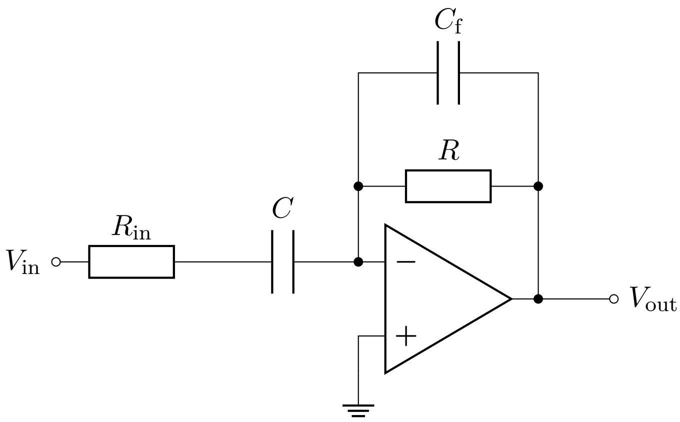
$$V_{\text{out}} = \left(1 + \frac{R_3}{R_4}\right) V_T \ln\left(\frac{V_{\text{in}}}{V_{\text{ref}}}\right).$$

Configuration 2.4.2.6 (Ideal Differentiating Amplifier)



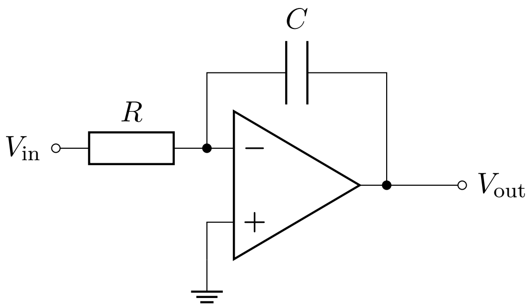
$$V_{\text{out}} = -RC\frac{dV_{\text{in}}}{dt}$$

Configuration 2.4.2.7 (Practical Differentiating Amplifier)



$$V_\mathrm{out} = -RC\frac{dV_\mathrm{in}}{dt}$$

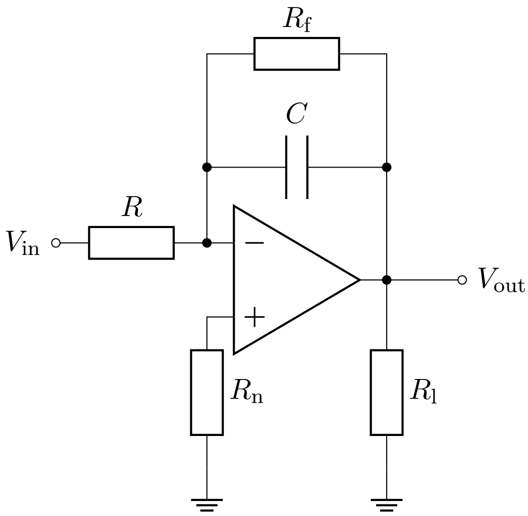
Configuration 2.4.2.8 (Ideal Integrating Amplifier)



$$V_{\text{out}}(t_1) = V_{\text{out}}(t_0) - \frac{1}{RC}\int_{t_0}^{t_1} V_{\text{in}}(t)\,dt;$$

$$\frac{dV_{\text{out}}}{dt} = -\frac{1}{RC}V_{\text{in}}.$$

Configuration 2.4.2.9 (Practical Integrating Amplifier)

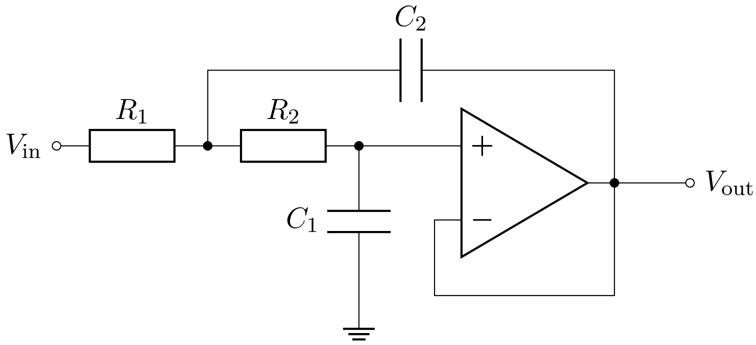


$$V_{\text{out}}(t_1) = V_{\text{out}}(t_0) - \frac{1}{RC}\int_{t_0}^{t_1} V_{\text{in}}(t)\,dt;$$

$$\frac{dV_{\text{out}}}{dt} = -\frac{1}{RC}V_{\text{in}}.$$

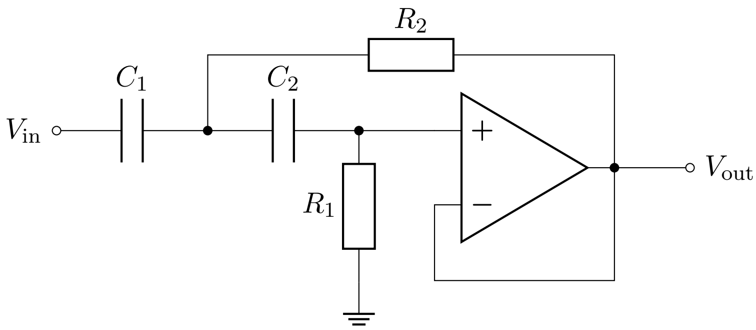
2.4.3 Filters

Configuration 2.4.3.1 (Second Order Sallen-Key Low-Pass Filter)



$$f_o = \frac{1}{2\pi R_1 C_1 R_2 C_2}$$

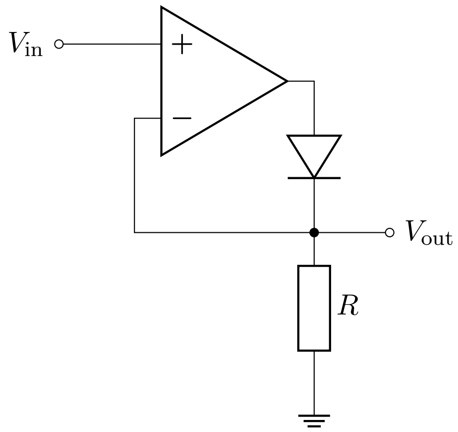
Configuration 2.4.3.2 (Second Order Sallen-Key High-Pass Filter)



$$f_o = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

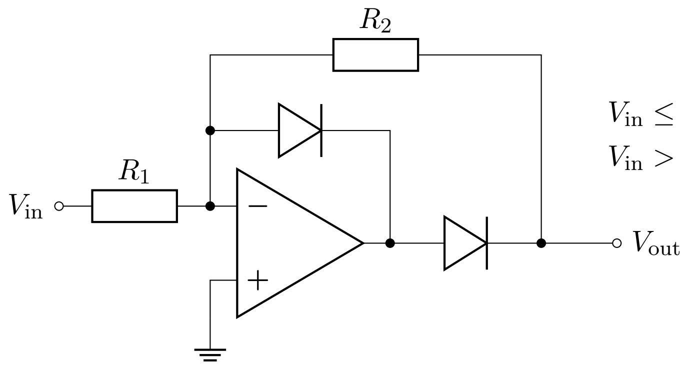
2.4.4 Rectifiers

Configuration 2.4.4.1 (Ideal Half-wave Rectifier)



$$V_{\text{in}} \geq 0 \implies V_{\text{out}} = V_{\text{in}};$$
$$V_{\text{in}} < 0 \implies V_{\text{out}} = 0V.$$

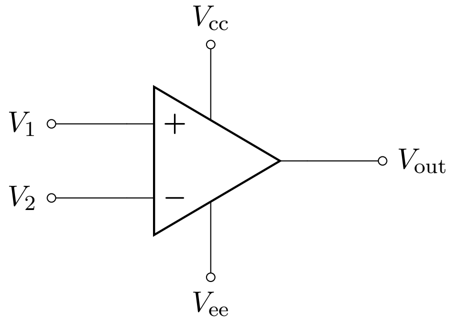
Configuration 2.4.4.2 (Practical Half-wave Rectifier)



$$V_{\text{in}} \leq 0 \implies V_{\text{out}} = -V_{\text{in}};$$
$$V_{\text{in}} > 0 \implies V_{\text{out}} = 0V.$$

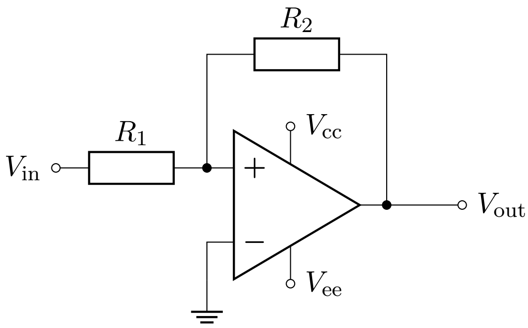
2.4.5 Comparators

Configuration 2.4.5.1 (Basic Comparator)



$$V_1 > V_2 \implies V_{out} = V_{cc};$$
$$V_1 < V_2 \implies V_{out} = V_{ee}.$$

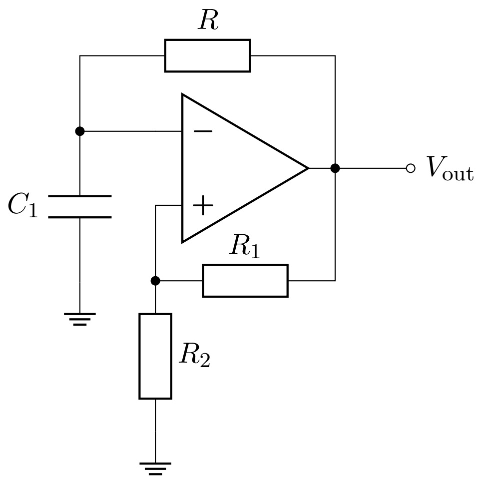
Configuration 2.4.5.2 (Schmitt Trigger)



$$V_{\text{thresh}\uparrow} = -\frac{R_1}{R_2}V_{ee}; \qquad V_{\text{thresh}\downarrow} = -\frac{R_1}{R_2}V_{cc};$$
$$V_{\text{out}\uparrow} = V_{cc}; \qquad V_{\text{out}\downarrow} = V_{ee}.$$

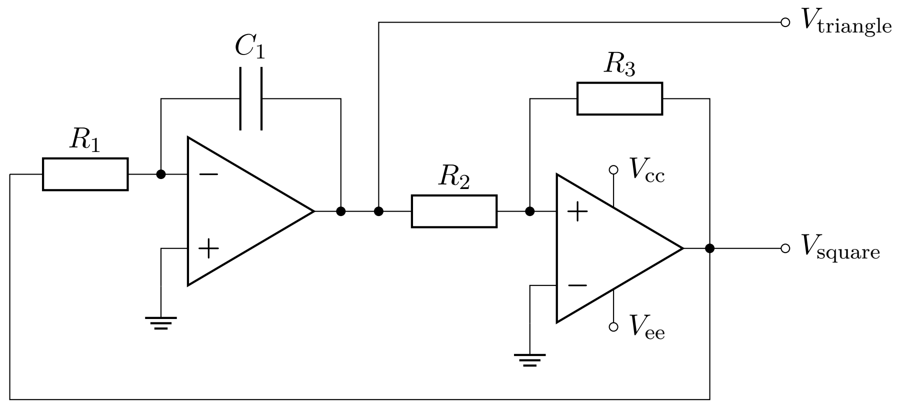
2.4.6 Oscillators

Configuration 2.4.6.1 (Astable Multivibrator)



$$f = \frac{1}{2RC\ln\left(\dfrac{1+\dfrac{R_2}{R_1+R_2}}{1-\dfrac{R_2}{R_1+R_2}}\right)}$$

Configuration 2.4.6.2 (Triangle-Wave Oscillator)



$$V_{\text{ee}} < 0 < V_{\text{cc}};$$

$$V_{\text{square}} \in \left\{V_{\text{cc}}, V_{\text{ee}}\right\};$$

$$-\frac{R_2}{R_3}V_{\text{cc}} \le V_{\text{triangle}} \le -\frac{R_2}{R_3}V_{\text{ee}};$$

$$T_\uparrow = -\frac{R_2}{R_3}\cdot\frac{R_1C_1}{V_{\text{ee}}}; \qquad T_\downarrow = \frac{R_2}{R_3}\cdot\frac{R_1C_1}{V_{\text{cc}}};$$

$$f = -\frac{1}{R_1C_1}\cdot\frac{R_3}{R_2}\cdot\frac{V_{\text{cc}}V_{\text{ee}}}{(V_{\text{cc}}-V_{\text{ee}})^2};$$

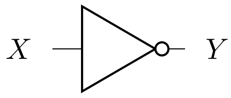
$$V_{\text{cc}} = -V_{\text{ee}} \implies f = \frac{1}{4R_1C_1}\frac{R_3}{R_2}.$$

§2.5 RCL Circuits

§2.6 Digital

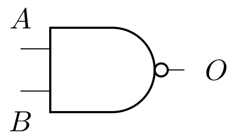
2.6.1 Logic Gates

Definition 2.6.1.1 (Inverter)



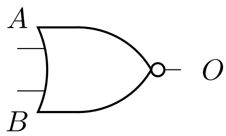
[redacted]	Y
F	T
T	F

Definition 2.6.1.2 (NAND Gate)



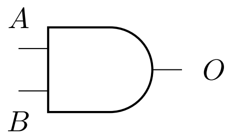
A	B	O
F	F	T
F	T	T
T	F	T
T	T	F

Definition 2.6.1.3 (NOR Gate)



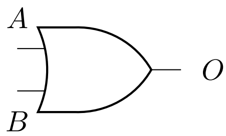
A	B	O
F	F	T
F	T	F
T	F	F
T	T	F

Definition 2.6.1.4 (AND Gate)



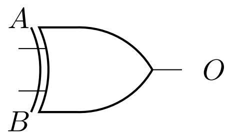
A	B	O
F	F	F
F	T	F
T	F	F
T	T	T

Definition 2.6.1.5 (OR Gate)



A	B	O
F	F	F
F	T	T
T	F	T
T	T	T

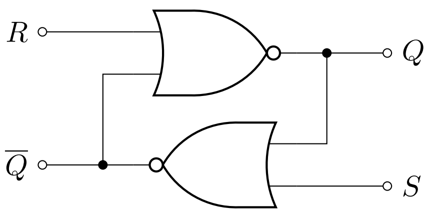
Definition 2.6.1.6 (XOR Gate)



A	B	O
F	F	F
F	T	T
T	F	T
T	T	F

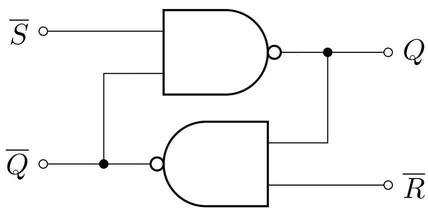
2.6.2 Latches & Flip Flops

Configuration 2.6.2.1
(SR NOR Latch)



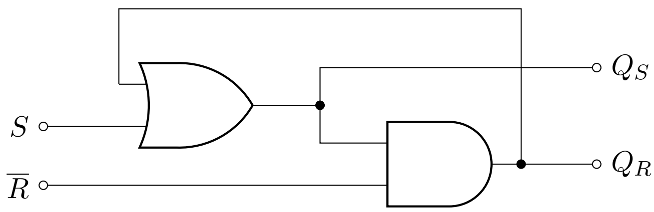
S	R	Q	$\overline{Q}$
F	F	Q	$\overline{Q}$
F	T	F	T
T	F	T	F
T	T	X	X

Configuration 2.6.2.2
($\overline{\text{SR}}$ NAND Latch)



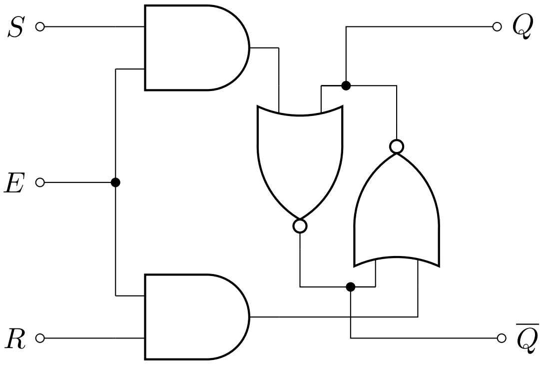
$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$
F	F	X	X
F	T	T	F
T	F	F	T
T	T	Q	$\overline{Q}$

Configuration 2.6.2.3 (SR AND-OR Latch)



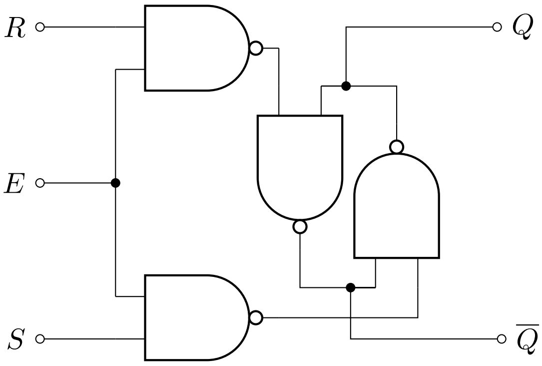
S	$\overline{R}$	Q_S	Q_R
F	F	F	F
F	T	Q_S	Q_R
T	F	T	F
T	T	T	T

Configuration 2.6.2.4 (Gated SR NOR Latch)



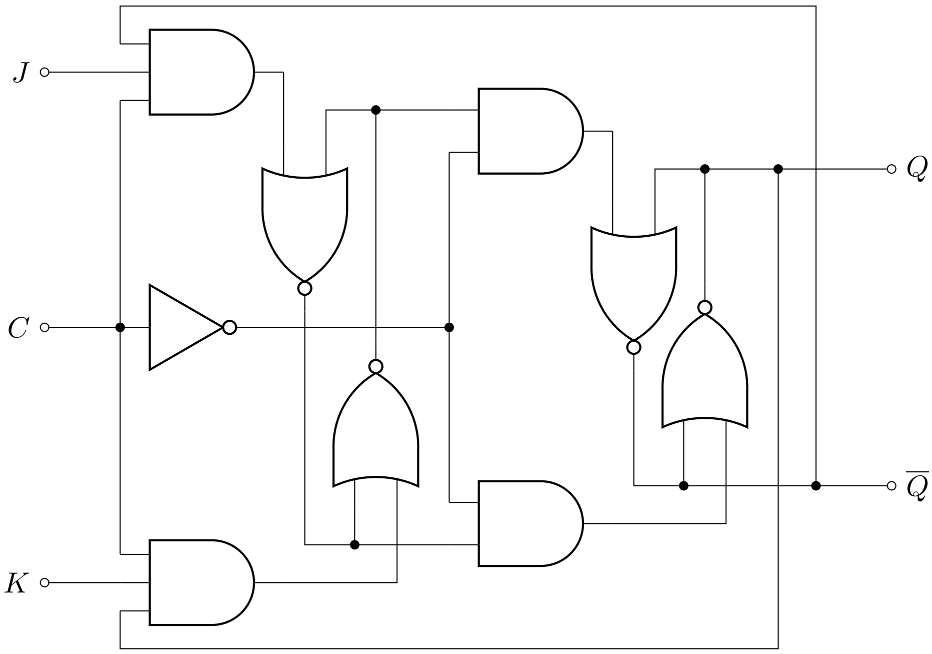
E	S	R	Q	$\overline{Q}$
F	X	X	Q	$\overline{Q}$
T	F	F	Q	$\overline{Q}$
T	F	T	F	T
T	T	F	T	F
T	T	T	X	X

Configuration 2.6.2.5 (Gated SR NAND Latch)



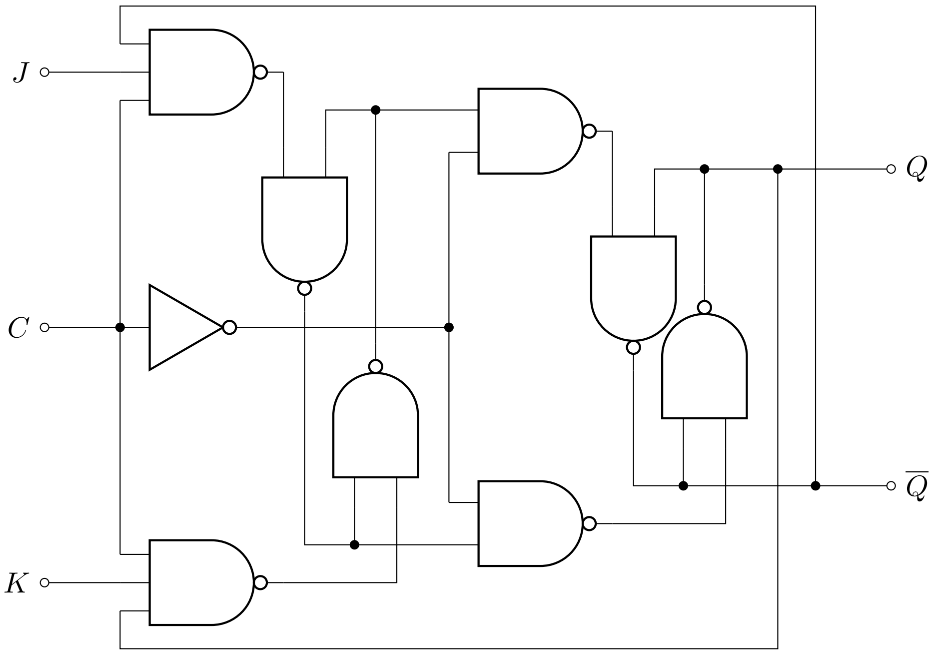
E	S	R	Q	$\overline{Q}$
F	X	X	Q	$\overline{Q}$
T	F	F	Q	$\overline{Q}$
T	F	T	F	T
T	T	F	T	F
T	T	T	X	X

Configuration 2.6.2.6 (JK Master-Slave Flip-Flop)



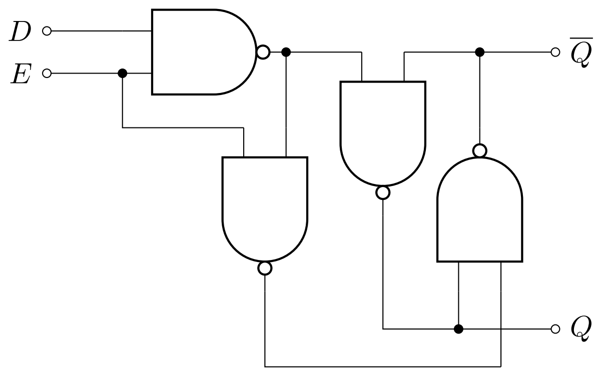
C	J	K	Q	$\overline{Q}$
X	F	F	Q	$\overline{Q}$
$\uparrow$	F	T	F	T
$\uparrow$	T	F	T	F
$\uparrow$	T	T	Q	$\overline{Q}$
$\downarrow$	F	T	Q	$\overline{Q}$
$\downarrow$	T	F	Q	$\overline{Q}$
$\downarrow$	T	T	$\overline{Q}$	Q

Configuration 2.6.2.7 (JK Master-Slave Flip-Flop (NAND version))



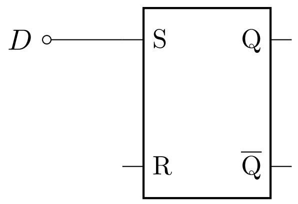
C	J	K	Q	$\overline{Q}$
X	F	F	Q	$\overline{Q}$
$\uparrow$	F	T	F	T
$\uparrow$	T	F	T	F
$\uparrow$	T	T	Q	$\overline{Q}$
$\downarrow$	F	T	Q	$\overline{Q}$
$\downarrow$	T	F	Q	$\overline{Q}$
$\downarrow$	T	T	$\overline{Q}$	Q

Configuration 2.6.2.8 (D-Type Latch)



E	D	Q	$\overline{Q}$
F	F	Q	$\overline{Q}$
F	T	Q	$\overline{Q}$
T	F	F	T
T	T	T	F

Configuration 2.6.2.9 (D-Type Latch)



e

Chapter 3

Component Reference

§3.1 Transistors

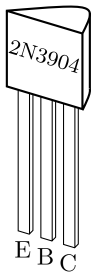
3.1.1 BJTs

3.1.1.1 NPN

Component 3.1.1.1.1 (2N3904)

General purpose

Parameter	Condition	Symbol	Min	Max	Unit
Collector-Emitter Voltage	–	V_{ceo}	–	40	V
Collector-Base Voltage	–	V_{cbo}	–	60	V
Emitter-Base Voltage	–	V_{ebo}	–	6	V
Collector Current	–	I_c	–	200	mA
Power Dissipation	$T_A = 25°$	P_D	–	625	mW
	$T_C = 25°$		–	1.5	W
DC Current Gain	$I_c = 0.1mA$	h_{FE}	40	–	–
	$I_c = 1mA$		70	–	–
	$I_c = 10mA$		100	300	–
	$I_c = 50mA$		60	–	–
	$I_c = 100mA$		30	–	–
Small-Signal Current Gain	$I_c = 1mA$ $V_{ce} = 10V$ $f = 1kHz$	h_{fe}	100	400	–



3.1.1.2 PNP

3.1.2 MOSFETs

3.1.2.1 N-Channel

3.1.2.2 P-Channel

3.1.3 JFETs

3.1.3.1 N-Channel

3.1.3.2 P-Channel

§3.2 Integrated Circuits

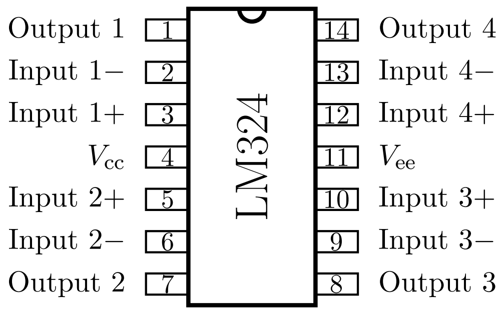
3.2.1 Linear

3.2.1.1 Operational Amplifiers

Component 3.2.1.1.1 (LM324)

Low-Power Quad Operational Amplifier

Parameter	Symbol	Min	Typ	Max	Units
Supply Voltage		3	–	32	V
Supply Current		–	1.5	3	mA
Output Source Current		20	40	–	mA
Output Sink Current		10	20	–	μA
Short Circuit to ground		–	40	60	mA
Slew Rate		–	0.5	–	V/μs

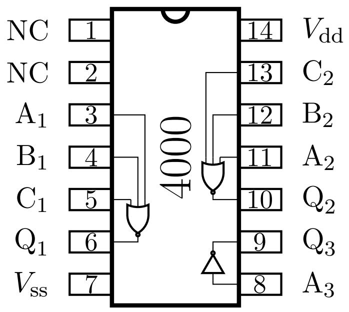


3.2.2 Logic

3.2.2.1 CMOS 4000 Series

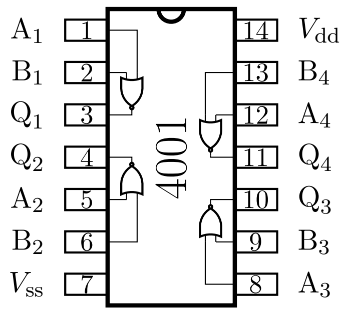
Component 3.2.2.1.1 (4000)

Dual 3-Input NOR + Inverter



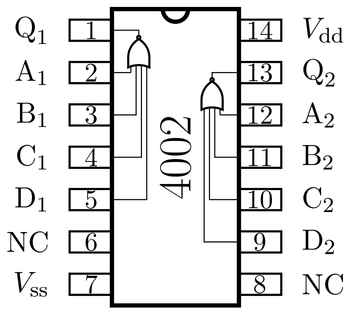
Component 3.2.2.1.2 (4001)

Quad 2-Input NOR



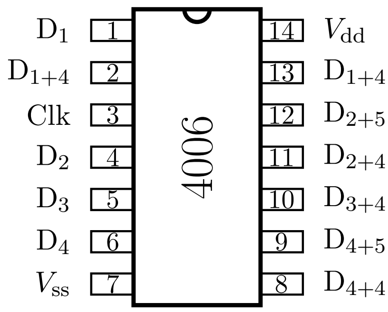
Component 3.2.2.1.3 (4002)

Dual 4-Input NOR



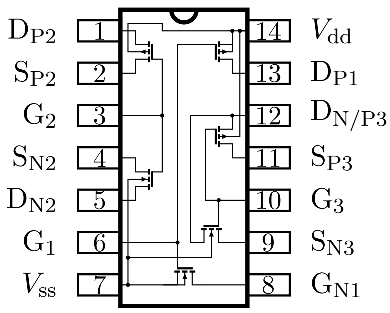
Component 3.2.2.1.4 (4006)

18-Stage Static Shift Register



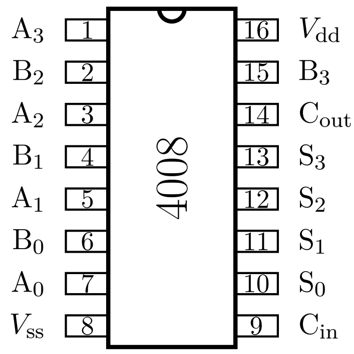
Component 3.2.2.1.5 (4007)

Dual CMOS Pair + Inverter



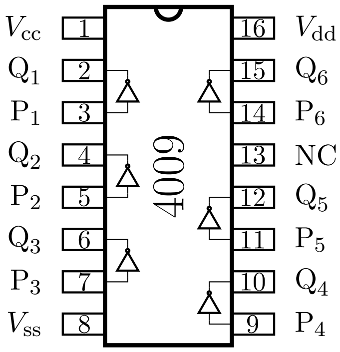
Component 3.2.2.1.6 (4008)

4-bit Binary Full Adder



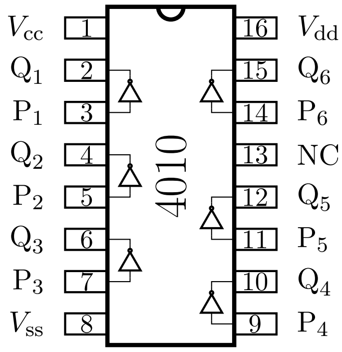
Component 3.2.2.1.7 (4009)

Hex Inverter



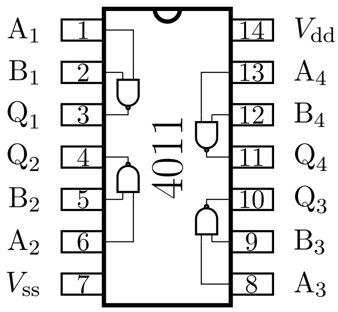
Component 3.2.2.1.8 (4010)

Hex Inverting Buffer



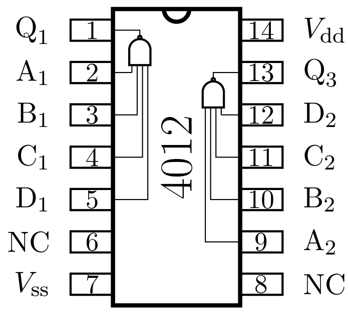
Component 3.2.2.1.9 (4011)

Quad 2-Input NAND



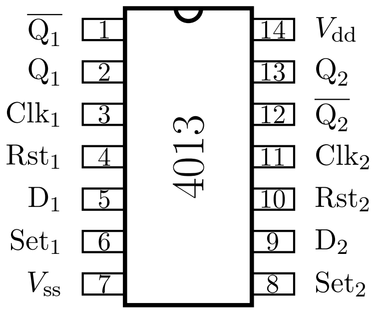
Component 3.2.2.1.10 (4012)

Dual 4-Input NAND



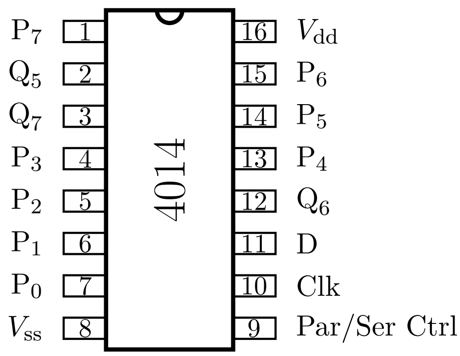
Component 3.2.2.1.11 (4013)

Dual D-Type Flip-flop



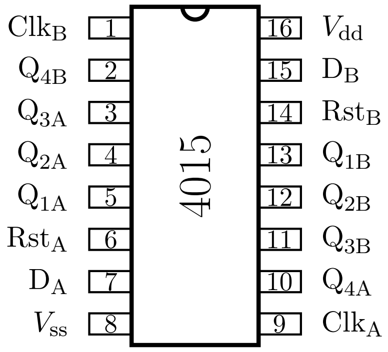
Component 3.2.2.1.12 (4014)

8-Bit Shift Register



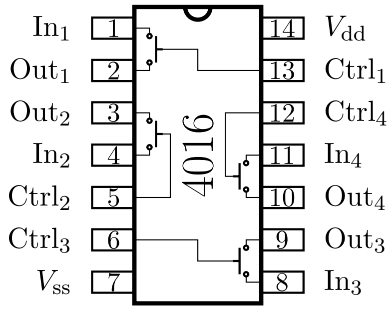
Component 3.2.2.1.13 (4015)

Dual 4-Bit Shift Register



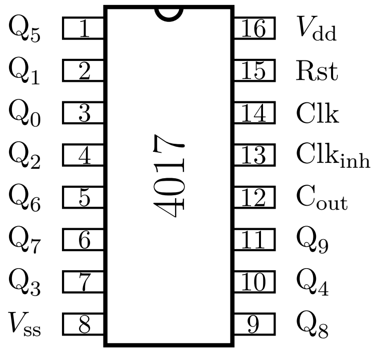
Component 3.2.2.1.14 (4016)

Quad Bilateral Switch



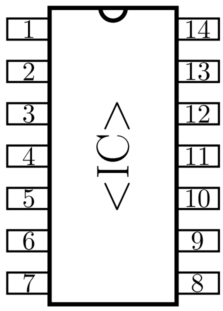
Component 3.2.2.1.15 (4017)

10-stage Ring Counter



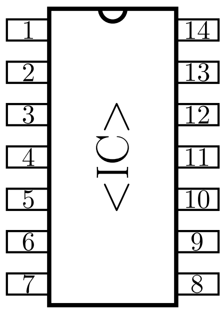
Component 3.2.2.1.16 (<IC>)

<Description>



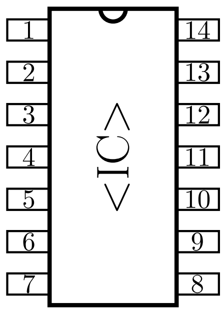
Component 3.2.2.1.17 (<IC>)

<Description>



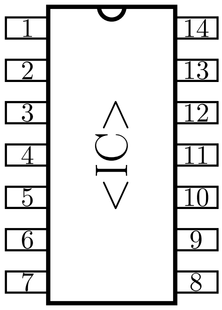
Component 3.2.2.1.18 (<IC>)

<Description>



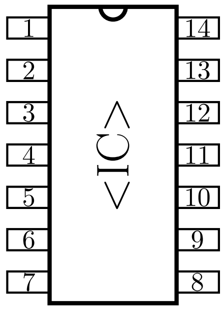
Component 3.2.2.1.19 (<IC>)

<Description>



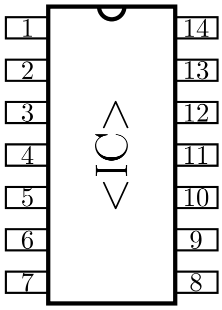
Component 3.2.2.1.20 (<IC>)

<Description>



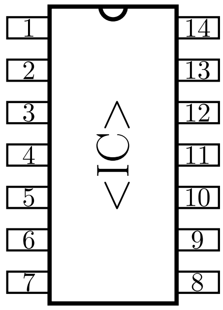
Component 3.2.2.1.21 (<IC>)

<Description>



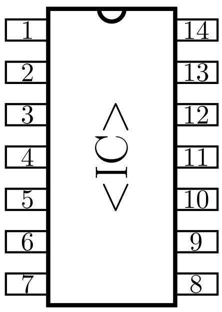
Component 3.2.2.1.22 (<IC>)

<Description>



Component 3.2.2.1.23 (<IC>)

<Description>



Component 3.2.2.1.24 (<IC>)

<Description>