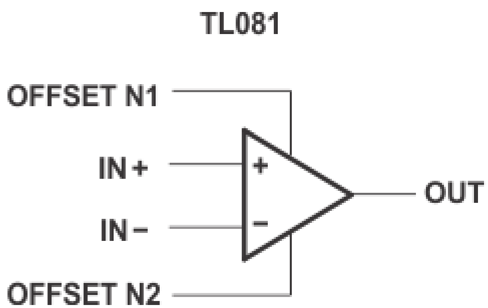
Operational Amplifier

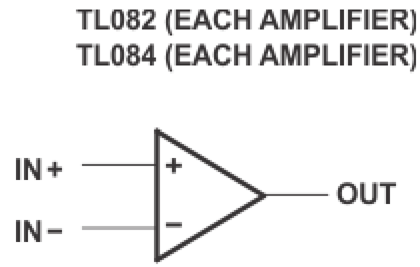
Operational Amplifier

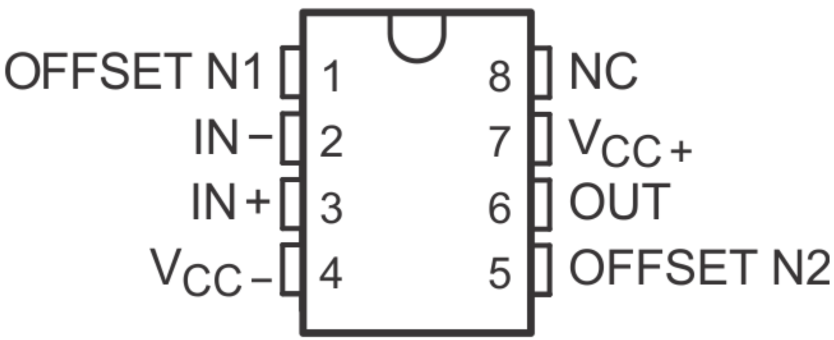
Invented Karl D. Swartzel Jr.

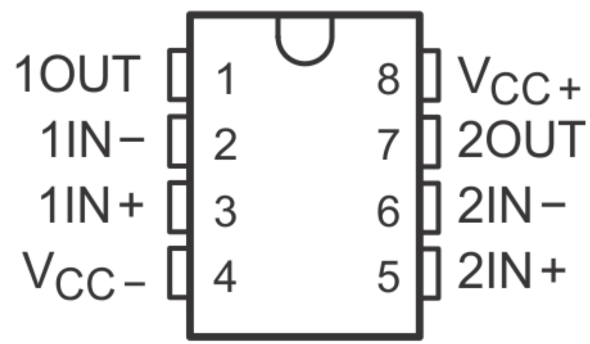
First production 1941

Schematic Symbol







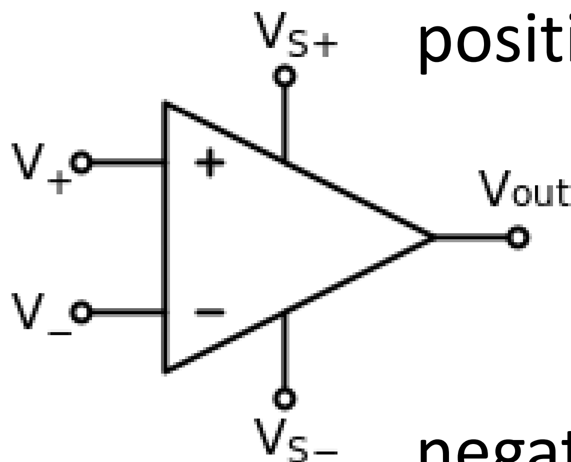


Symbol for Operational Amplifier

Pin configuration

positive power supply

non-inverting input

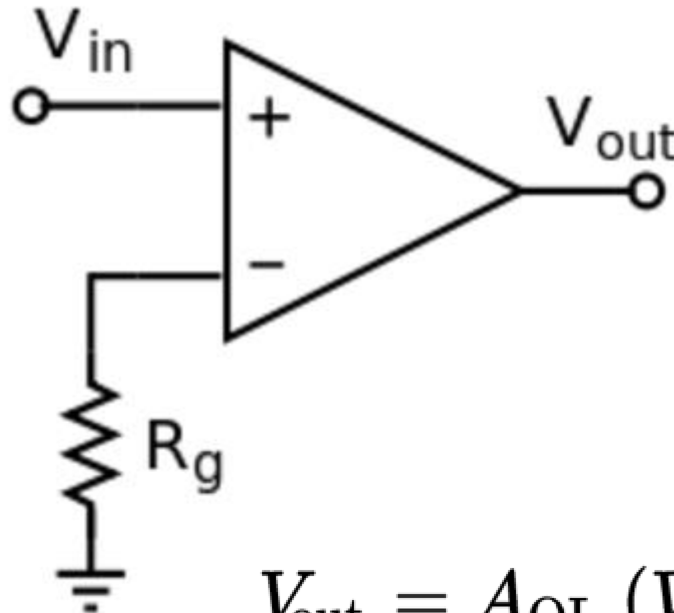


output

inverting input

negative power supply

Open loop amplifier

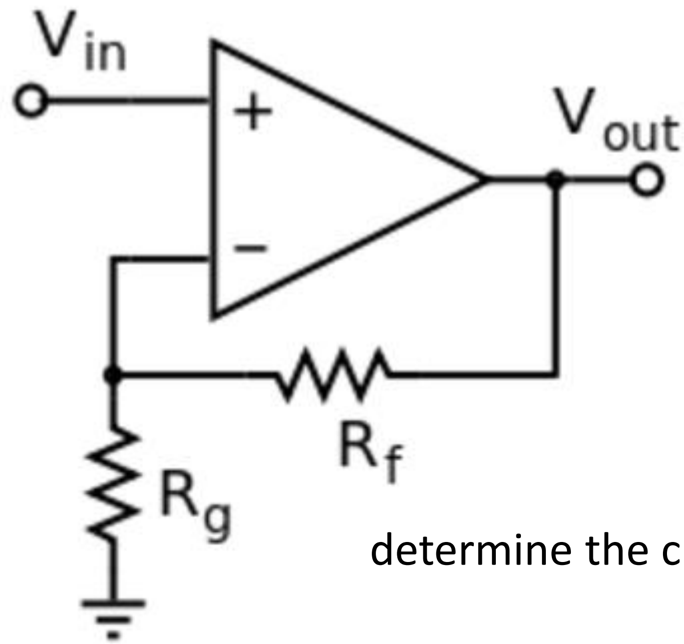


$$V_{\mathrm{out}} = A_{\mathrm{OL}}\left(V_+ - V_-\right)$$

The magnitude of A_{OL} is typically very large—100,000 or more

Closed loop amplifier

An op-amp with negative feedback (a non-inverting amplifier)



determine the closed-loop gain A_{CL}:

$$A_{\mathrm{CL}} = \frac{V_{\mathrm{out}}}{V_{\mathrm{in}}} = 1 + \frac{R_f}{R_g}$$

Operation Amplifier in Closed-loop

R_f = Feedback resistance because it is connected in the feedback path of the circuit (connecting input and output points).

R_1 = Resistance connected in the input side of the circuit.

$$A_{VCL} = A_v = \frac{V_0}{V_i} = \left(\frac{R_f}{R_1}\right)$$

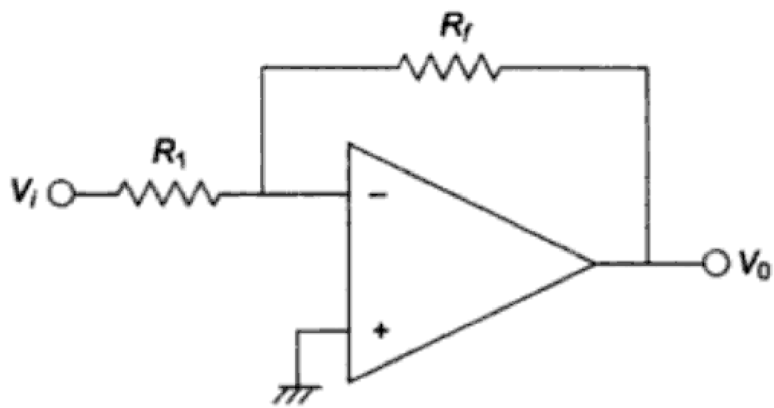
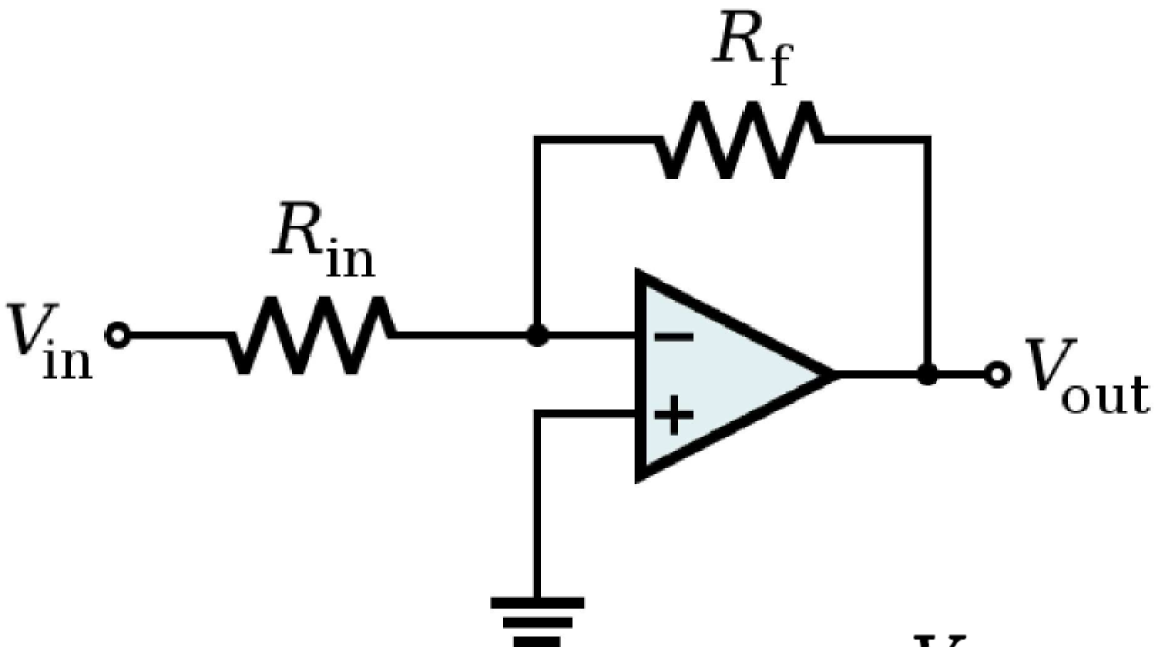


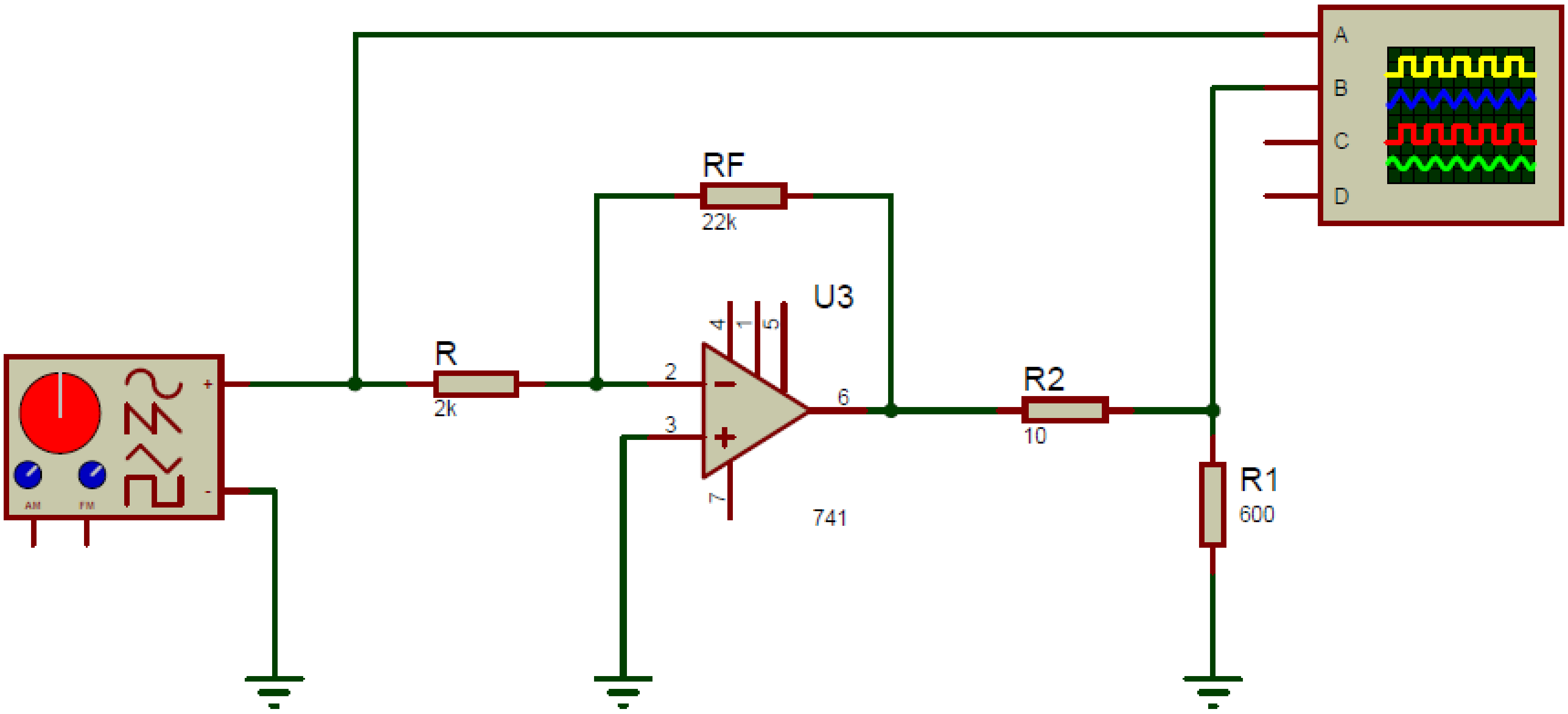
Fig. 1.13 Operational Amplifier in Closed-loop

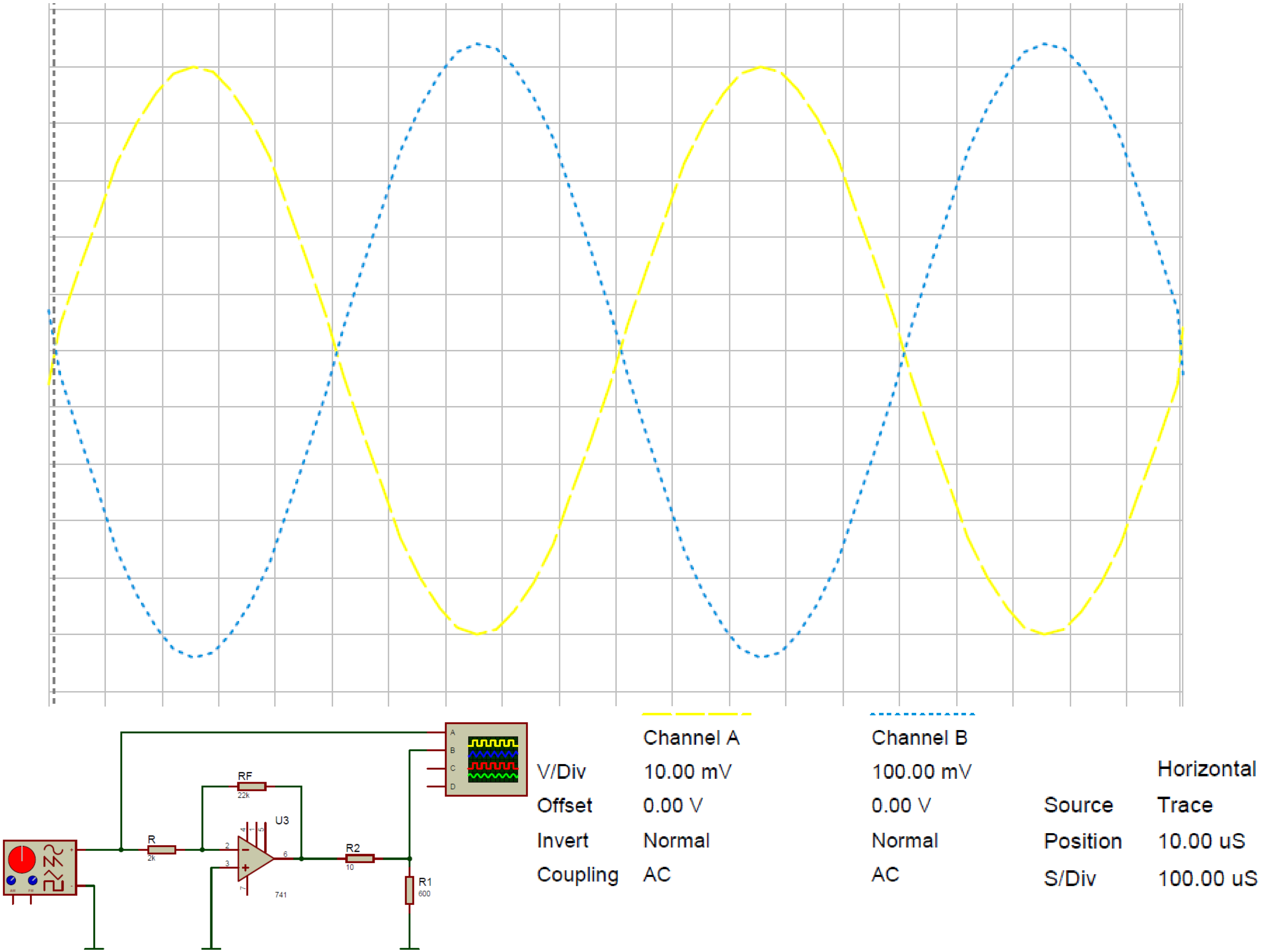
Inverting Amplifier circuit



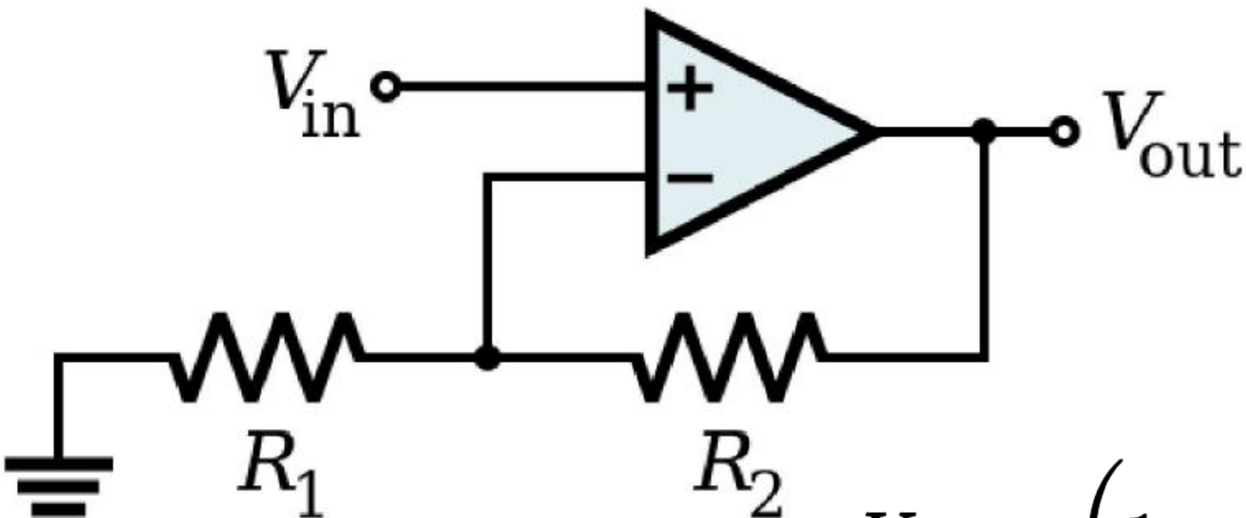
$$V_{\mathrm{out}} = -\frac{R_{\mathrm{f}}}{R_{\mathrm{in}}} V_{\mathrm{in}}\,.$$

Inverting Amplifier simulate



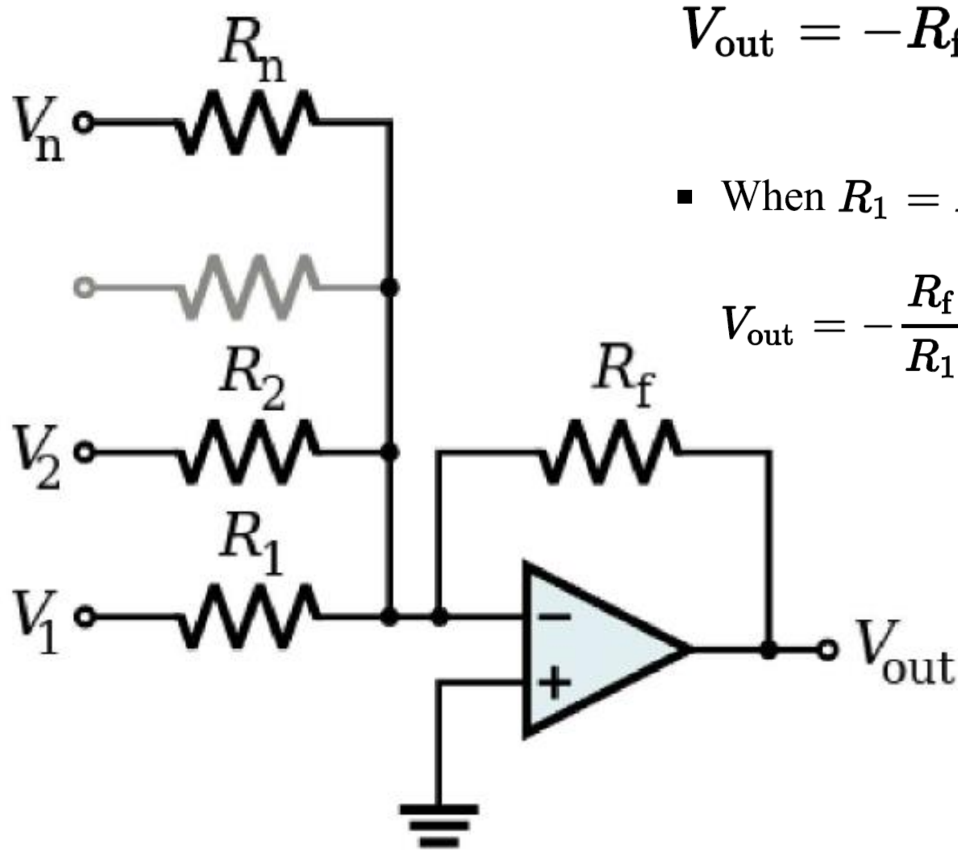

RF
22k
R
2k
U3
741
R2
10
R1
600
A
B
C
D
Channel A
Channel B
V/Div
10.00 mV
100.00 mV
Offset
0.00 V
0.00 V
Invert
Normal
Normal
Coupling
AC
AC
Horizontal
Source
Trace
Position
10.00 uS
S/Div
100.00 uS

Non-inverting Amplifier circuit



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

Adder circuit or summing amplifier

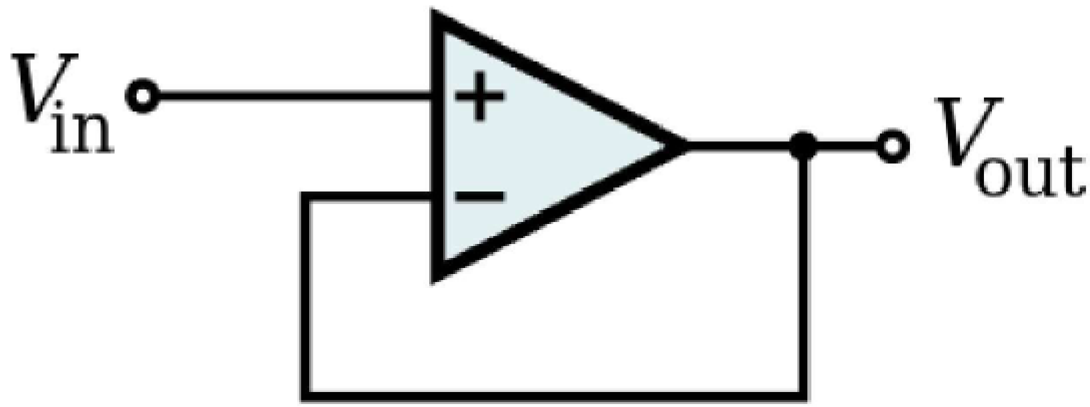


$$V_{\text{out}} = -R_{\text{f}} \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n} \right)$$

- When $R_1 = R_2 = \cdots = R_n$, and R_{f} independent

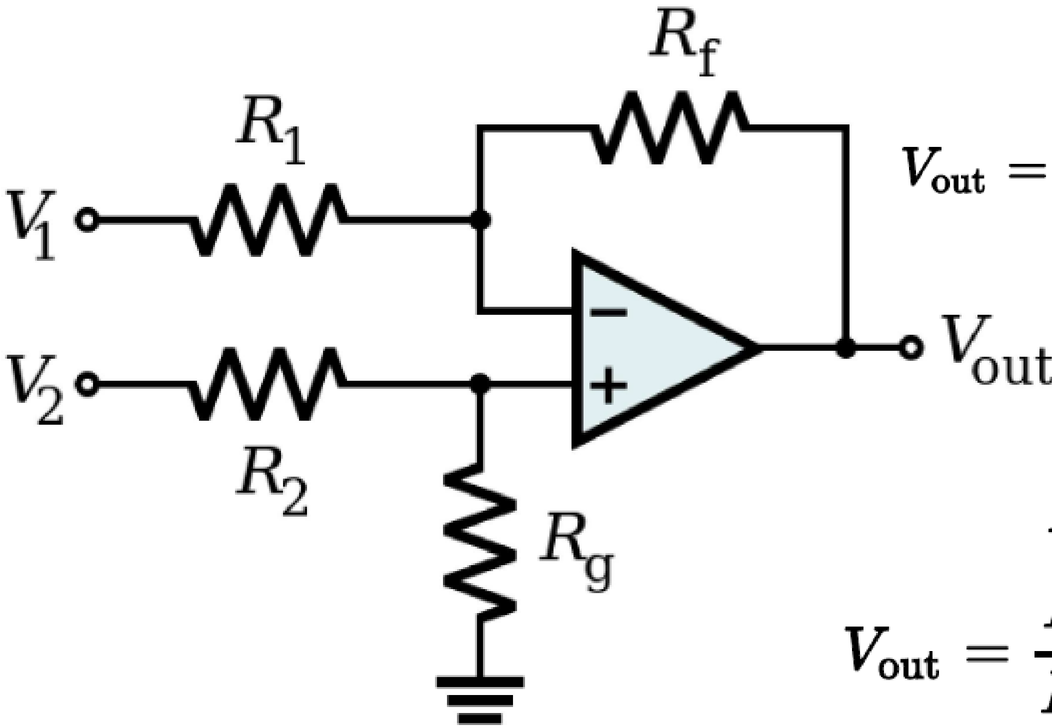
$$V_{\text{out}} = -\frac{R_{\text{f}}}{R_1}(V_1 + V_2 + \cdots + V_n)$$

Voltage follower or buffer amplifier



V out = V in

Sub-tractor circuit or Differential Amplifier

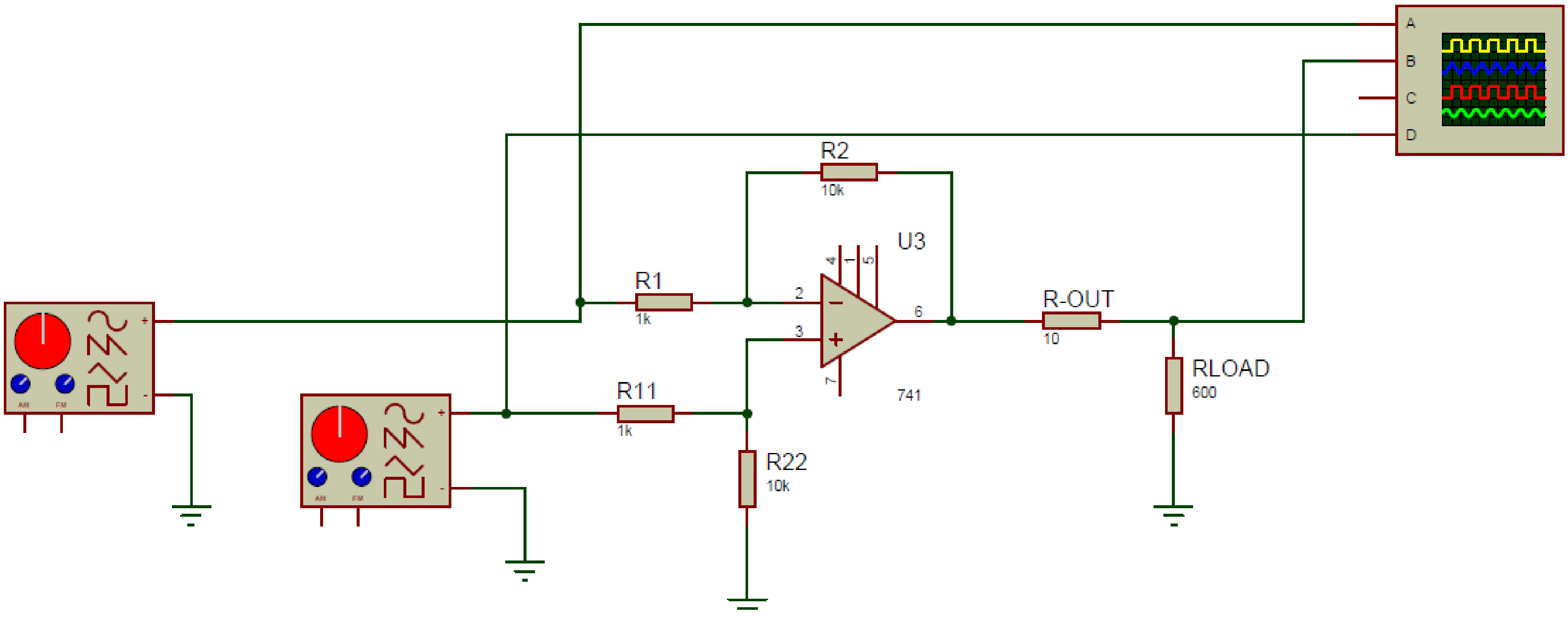


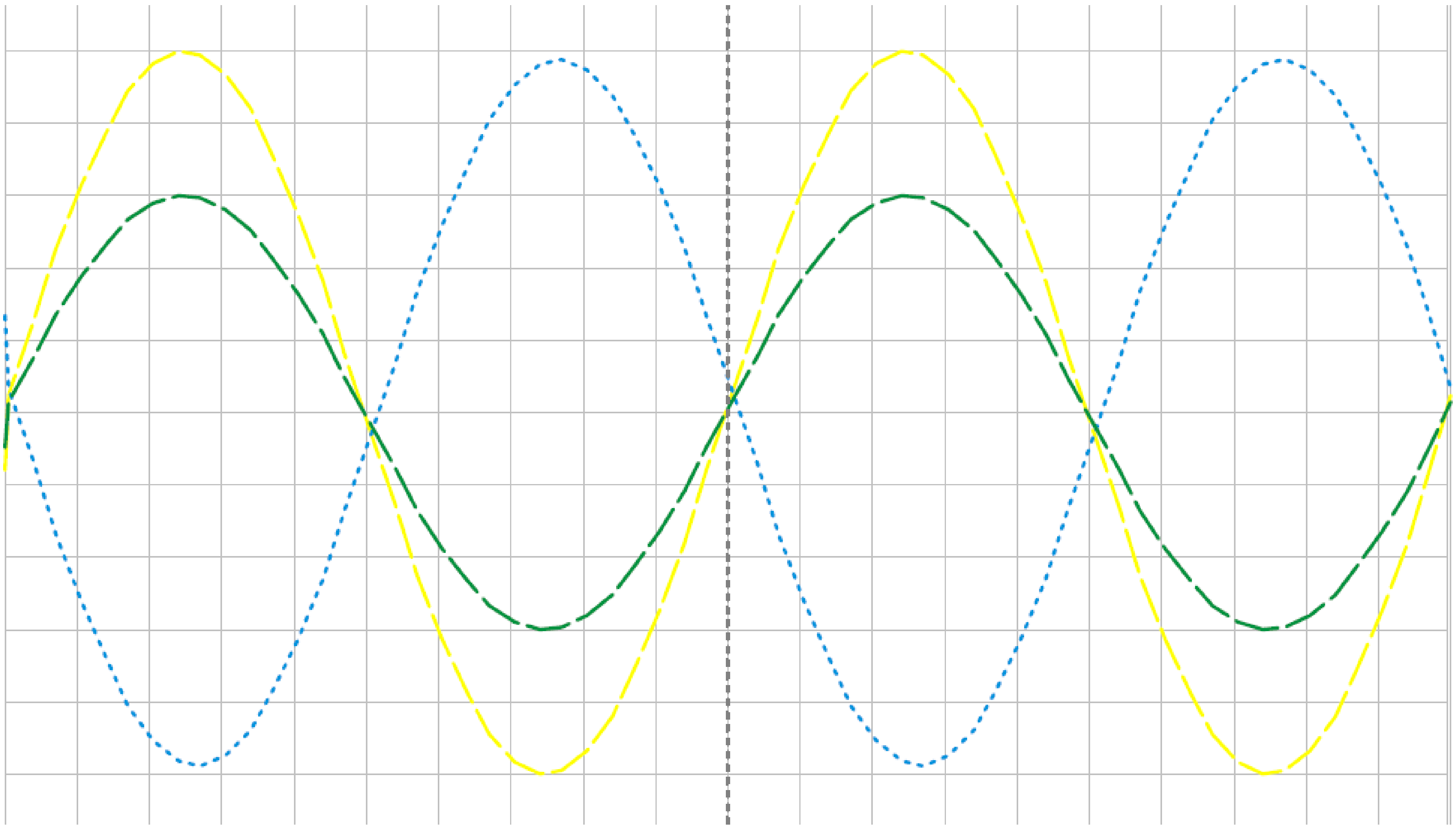
$$V_{out} = \frac{(R_f + R_1)\,R_g}{(R_g + R_2)\,R_1} V_2 - \frac{R_f}{R_1} V_1$$

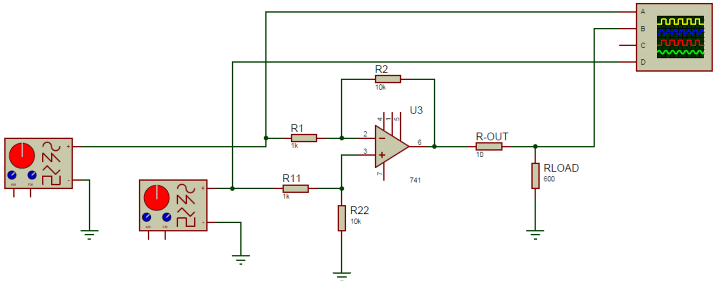
$$R_1 / R_f = R_2 / R_g$$

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

Sub-tractor circuit or Differential Amplifier simulate

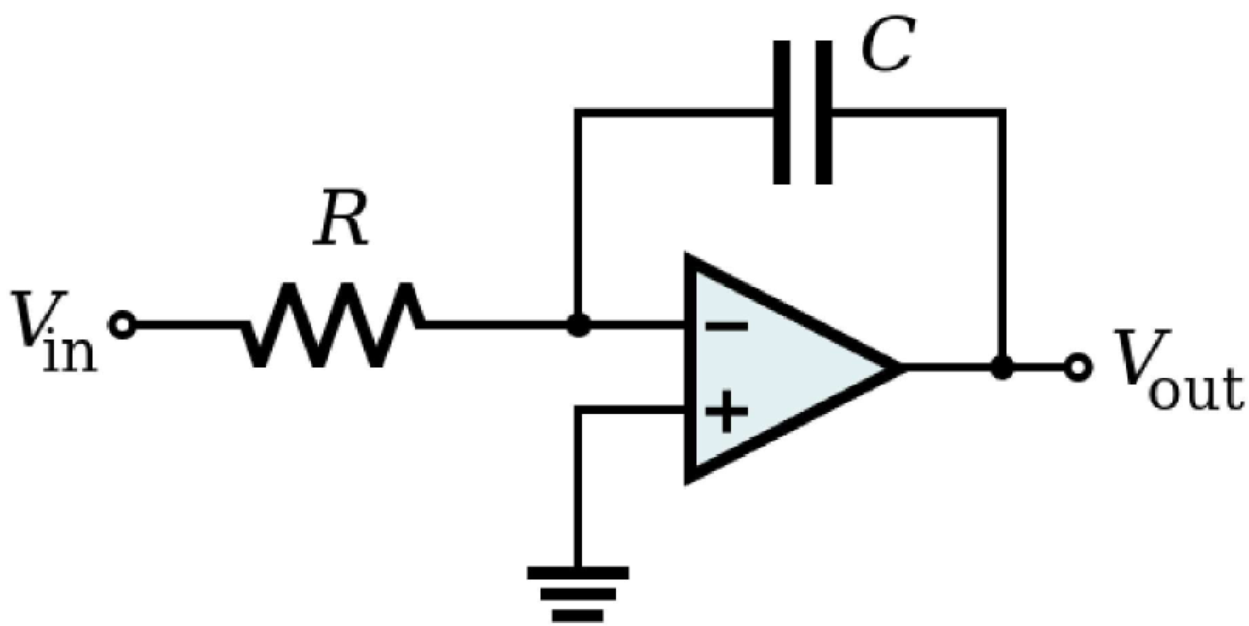






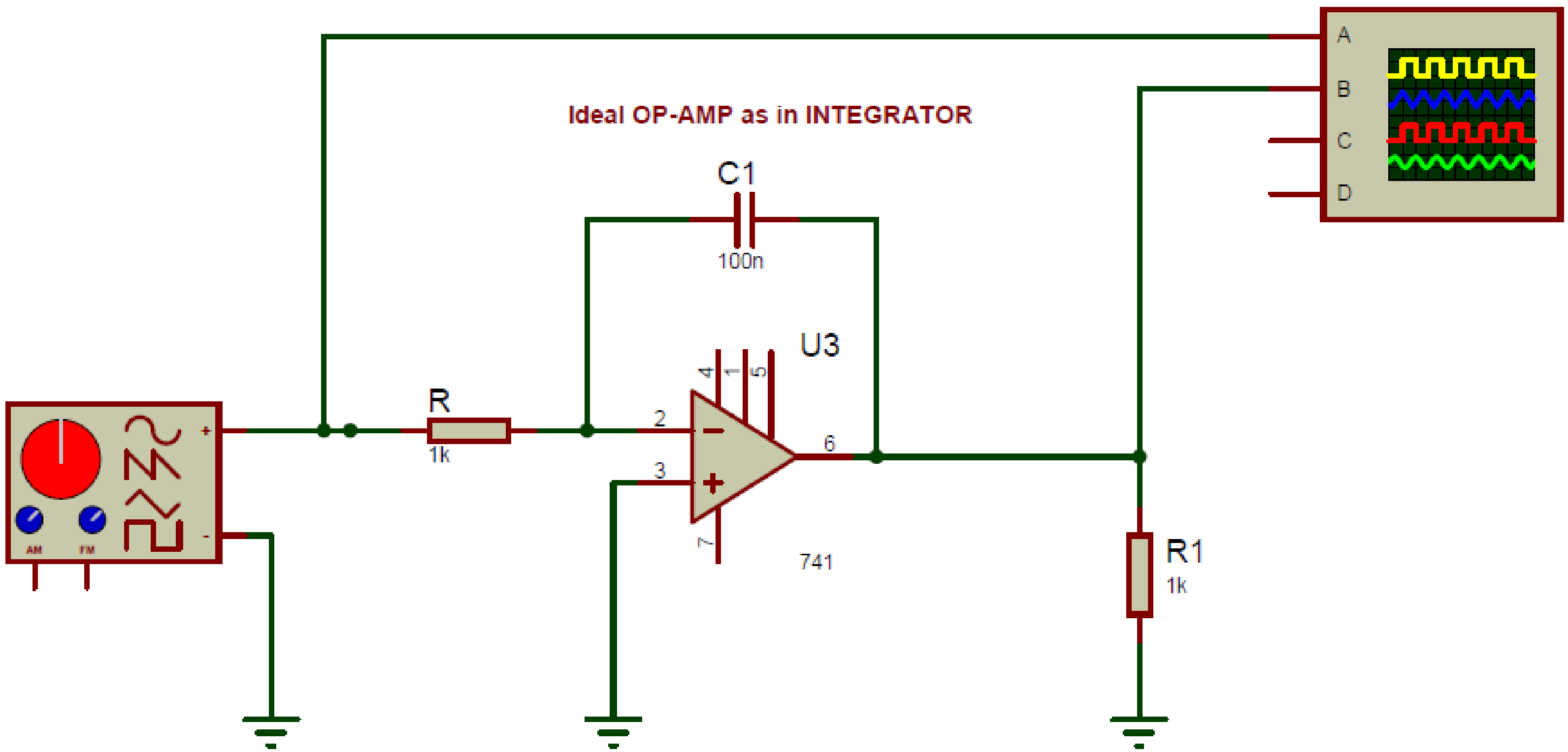
	Channel A	Channel B	Channel C	Channel D
V/Div	50.00 mV	200.00 mV	200.00 mV	50.00 mV
Offset	0.00 V	0.00 V	-800.00 mV	-20.00 mV
Invert	Normal	Normal	Normal	Normal
Coupling	AC	AC	Off	AC

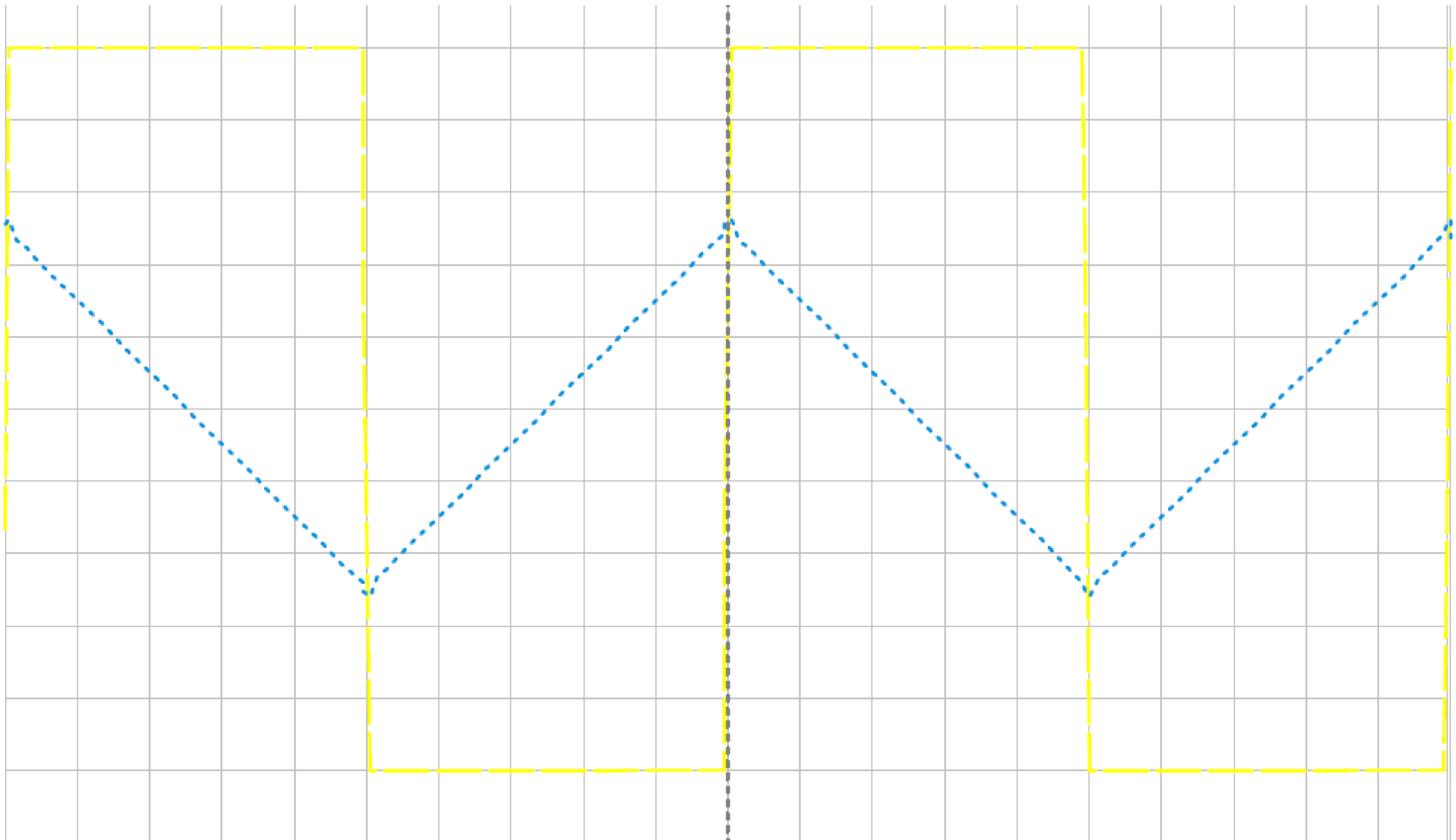
Inverting integrator circuit

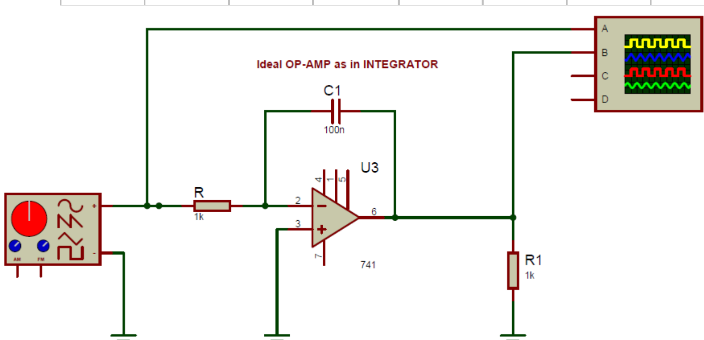


$$V_{\text{out}}(t_1) = V_{\text{out}}(t_0) - \frac{1}{RC}\int_{t_0}^{t_1} V_{\text{in}}(t)\, \mathrm{d}t$$

Inverting integrator simulate

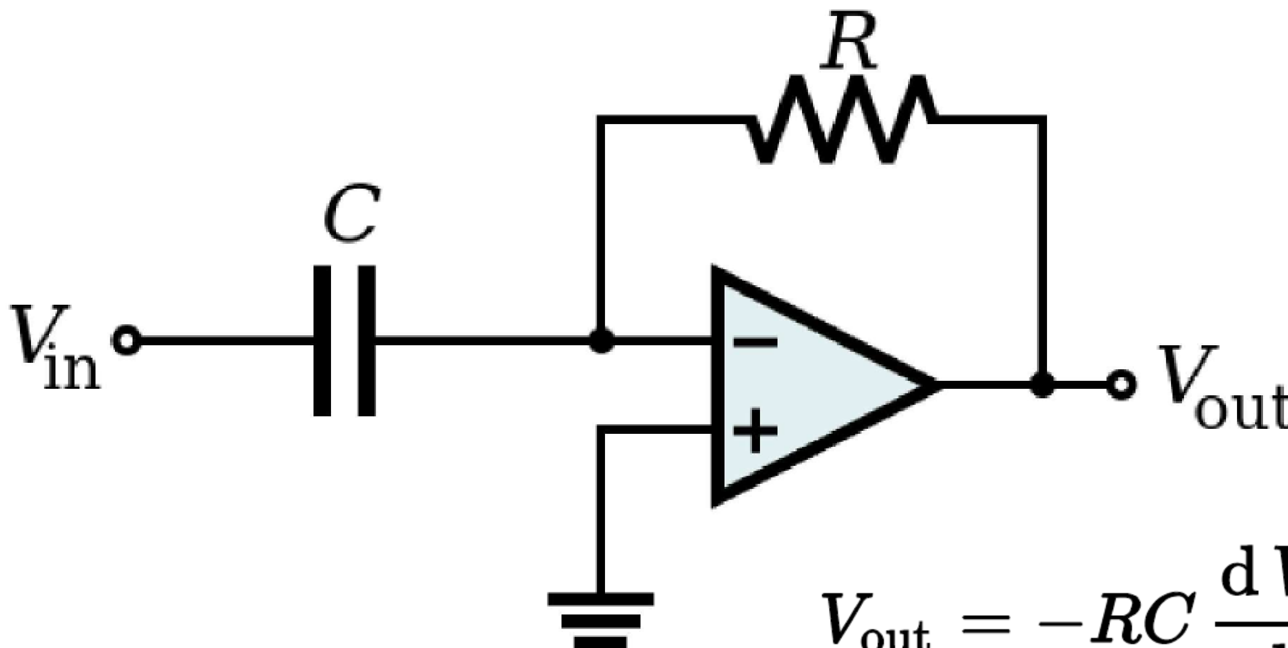






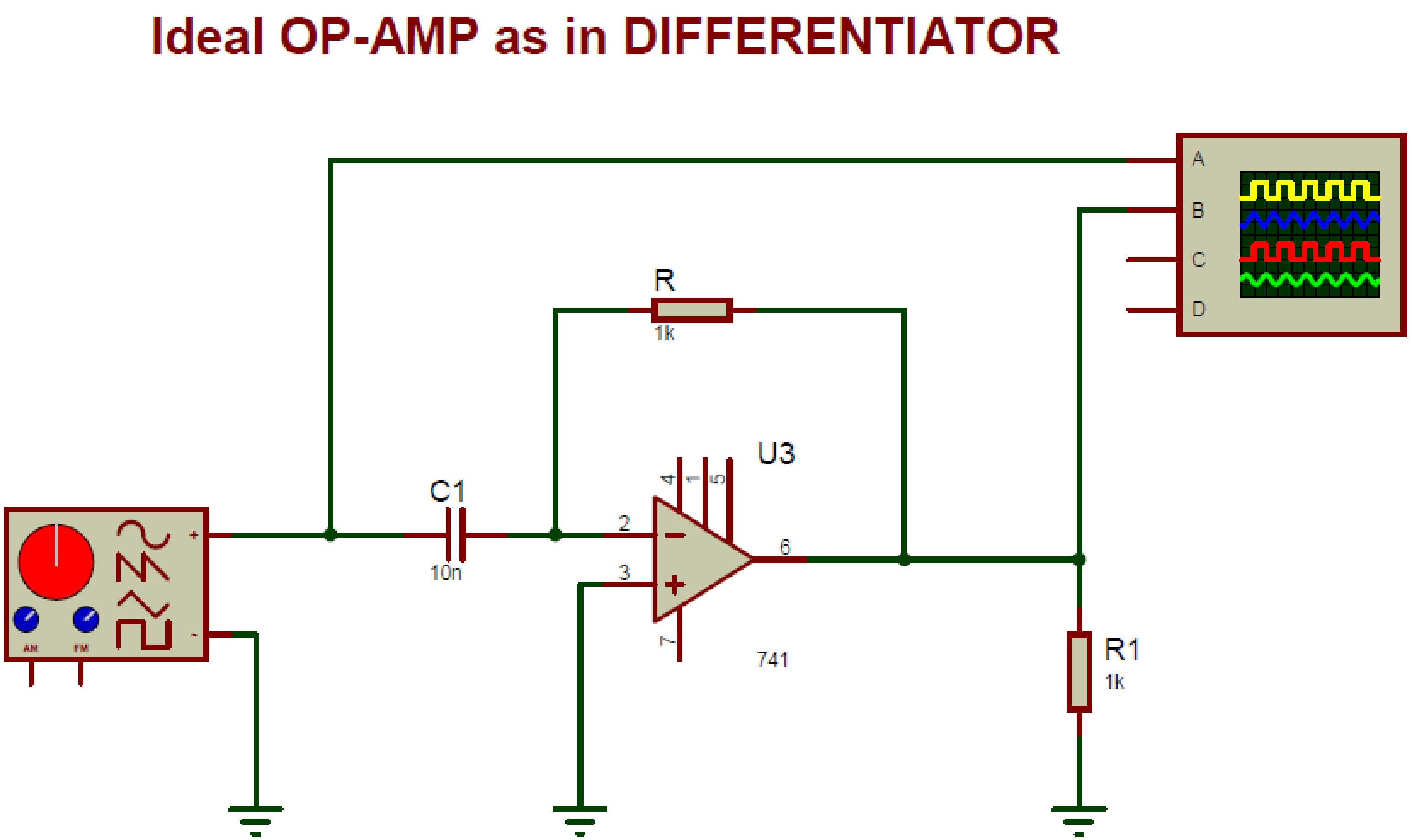
	Channel A	Channel B		Horizontal
V/Div	10.00 mV	5.00 mV	Source	Trace
Offset	0.00 V	0.00 V	Position	100.00 uS
Invert	Normal	Normal	S/Div	10.00 uS
Coupling	AC	AC		

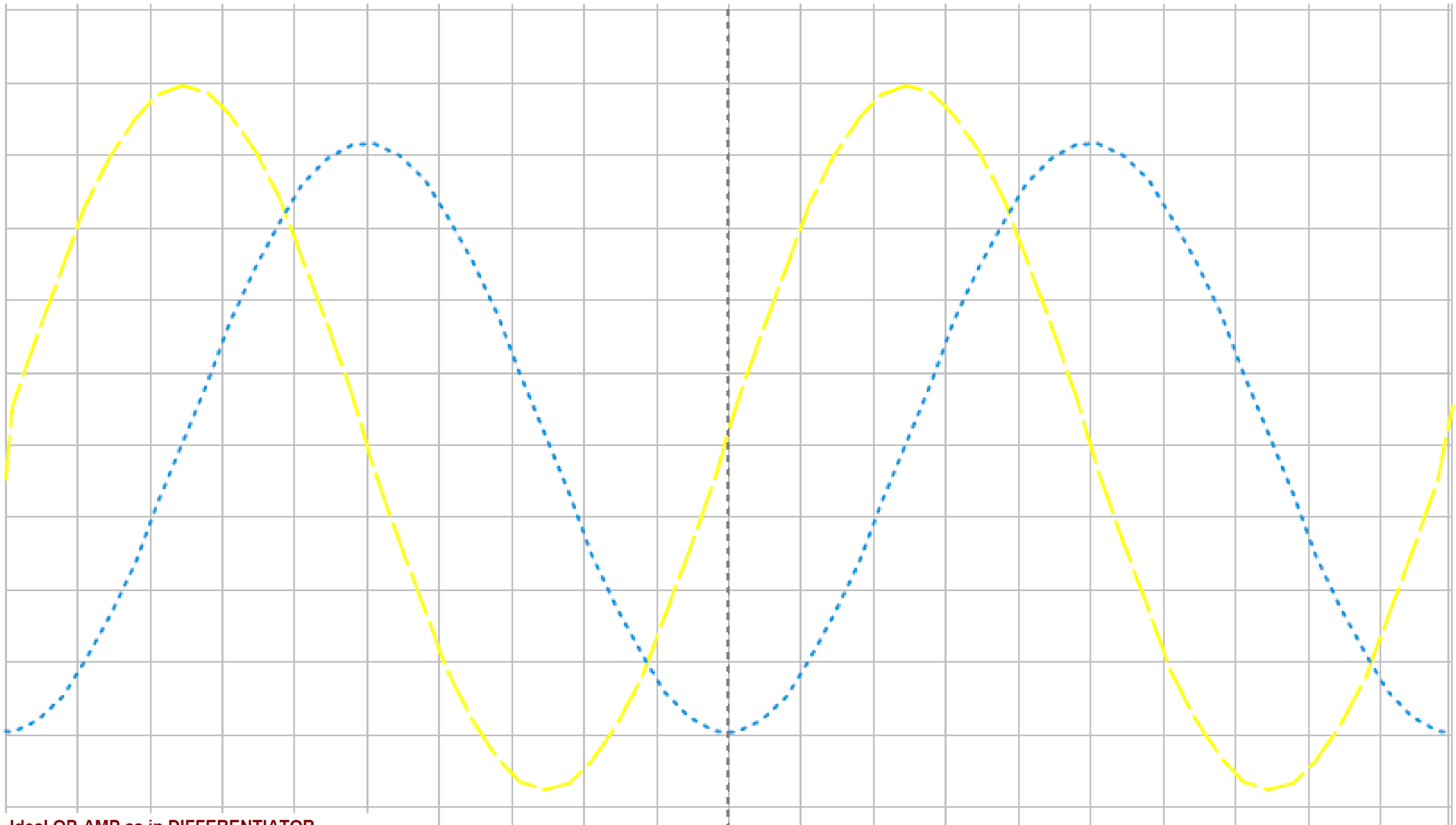
Inverting differentiator circuit



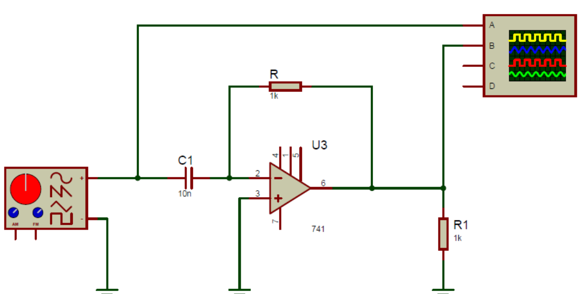
$$V_{\text{out}} = -RC\,\frac{\mathrm{d}\,V_{\text{in}}}{\mathrm{d}\,t}$$

Inverting differentiator simulate





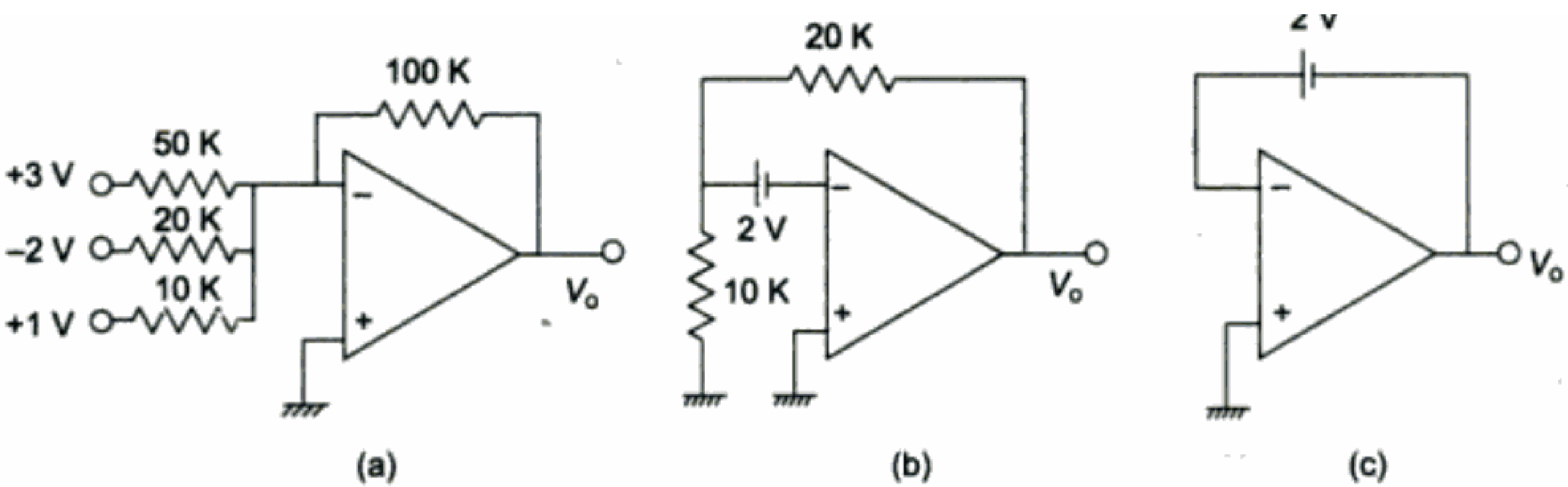
Ideal OP-AMP as in DIFFERENTIATOR



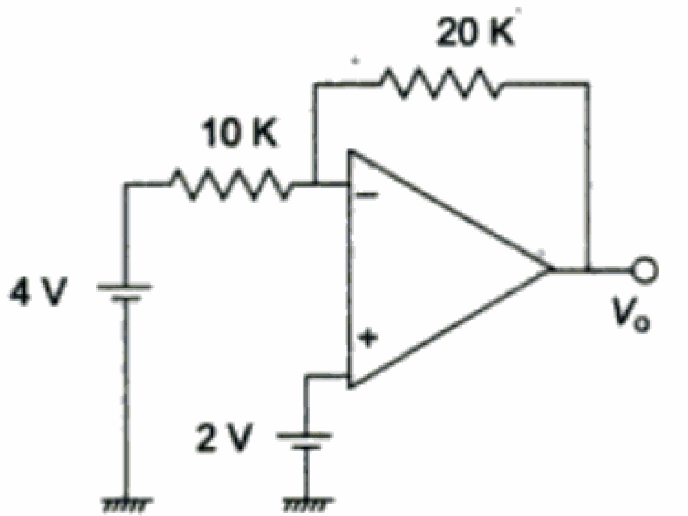
	Channel A	Channel B
V/Div	65.83 mV	5.00 mV
Offset	13.17 mV	1.00 mV
Invert	Normal	Normal
Coupling	AC	AC

	Horizontal
Source	Trace
Position	1.00 mS
S/Div	100.00 uS

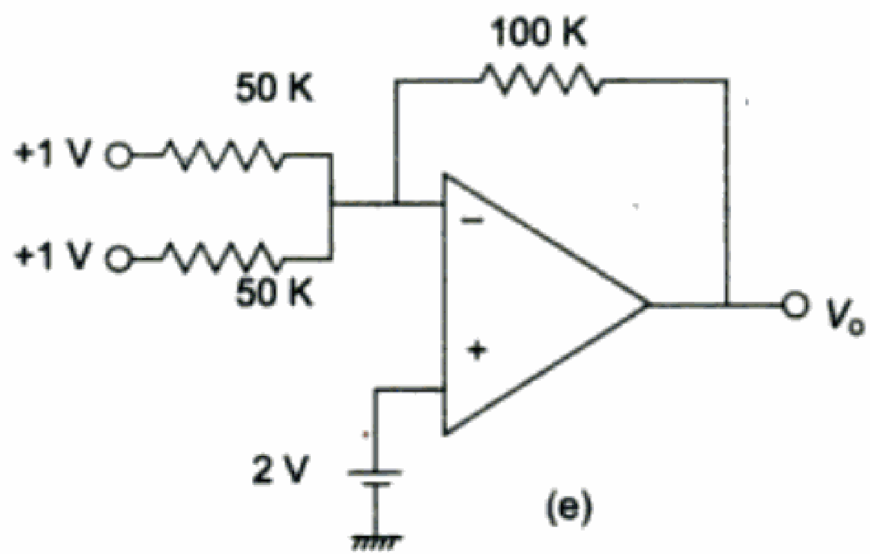
11. Assuming the operational amplifier to be ideal, calculate V_o for circuits a to g.



11. Assuming the operational amplifier to be ideal, calculate V_o for circuits a to g.

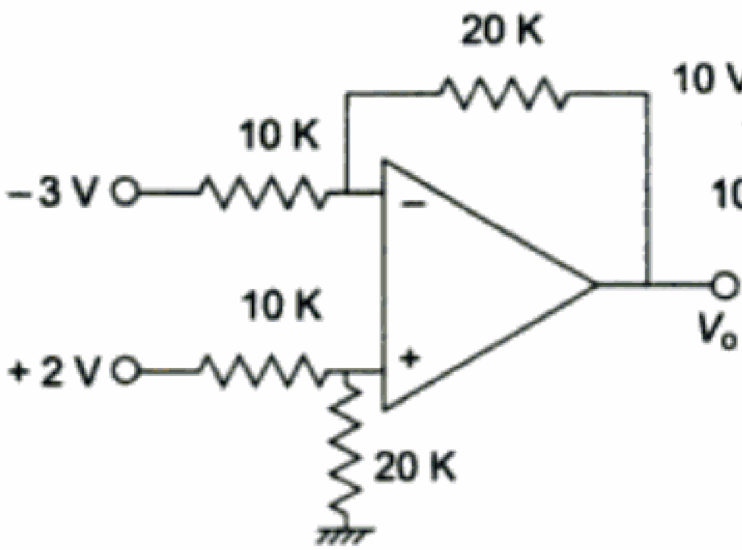


(d)

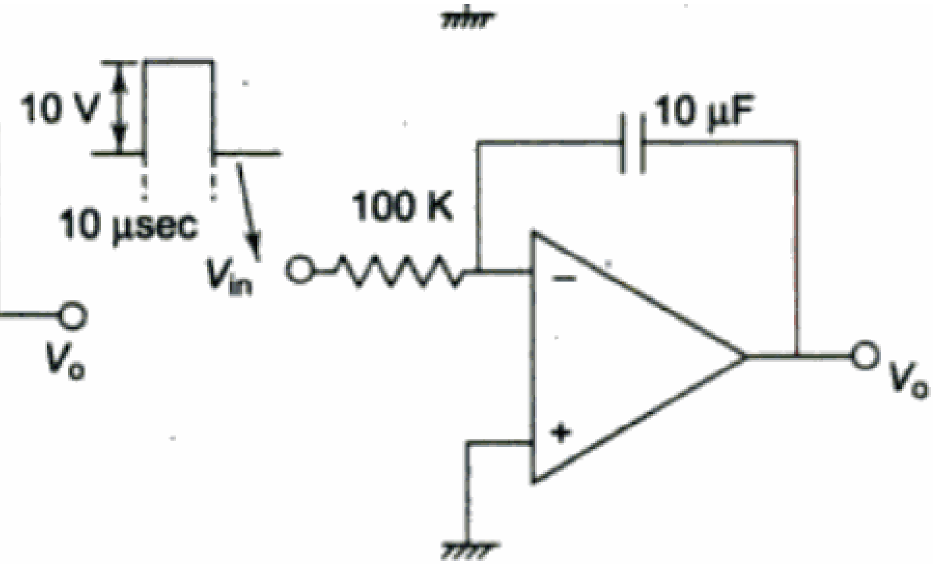


(e)

11. Assuming the operational amplifier to be ideal, calculate V_o for circuits a to g.



(f)



(g)

12. Assuming the operational amplifier to be ideal, find the values of circuit for (i), (ii) and (iii).

(i) Amp voltage gain = – 5 and input resistance 100 K

(ii) Amp voltage gain = – 20 and input resistance 2 K

(iii) Voltage gain = + 100 and high gain input resistance