Nanyang Technological University (NTU)

CE2004

Circuits & Signal Analysis

Lab Report (4 & 5)

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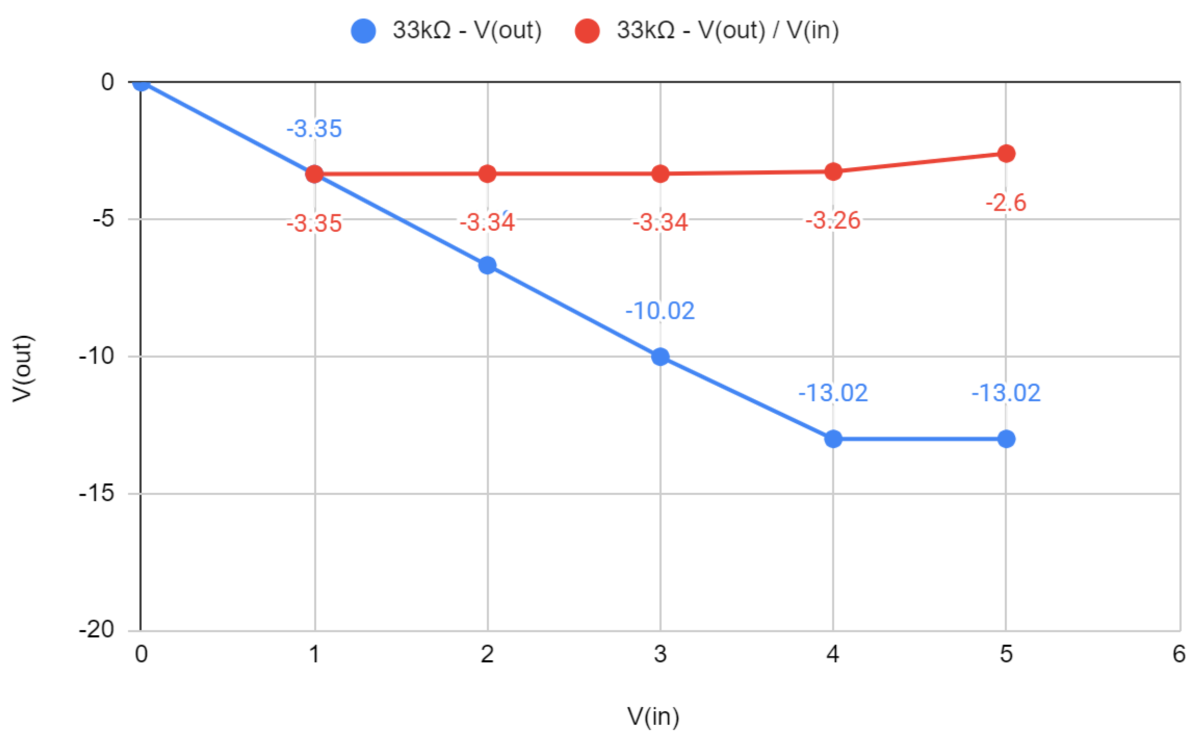
Lab 4: Linear of Op-Amp Circuits

5.1 Investing Amplifier

- V(out) can be calculated by using the formulae *-(Rf / R1) * V(in)*
- However, due to the constraint of the power supply, the voltage is capped between ±15V.

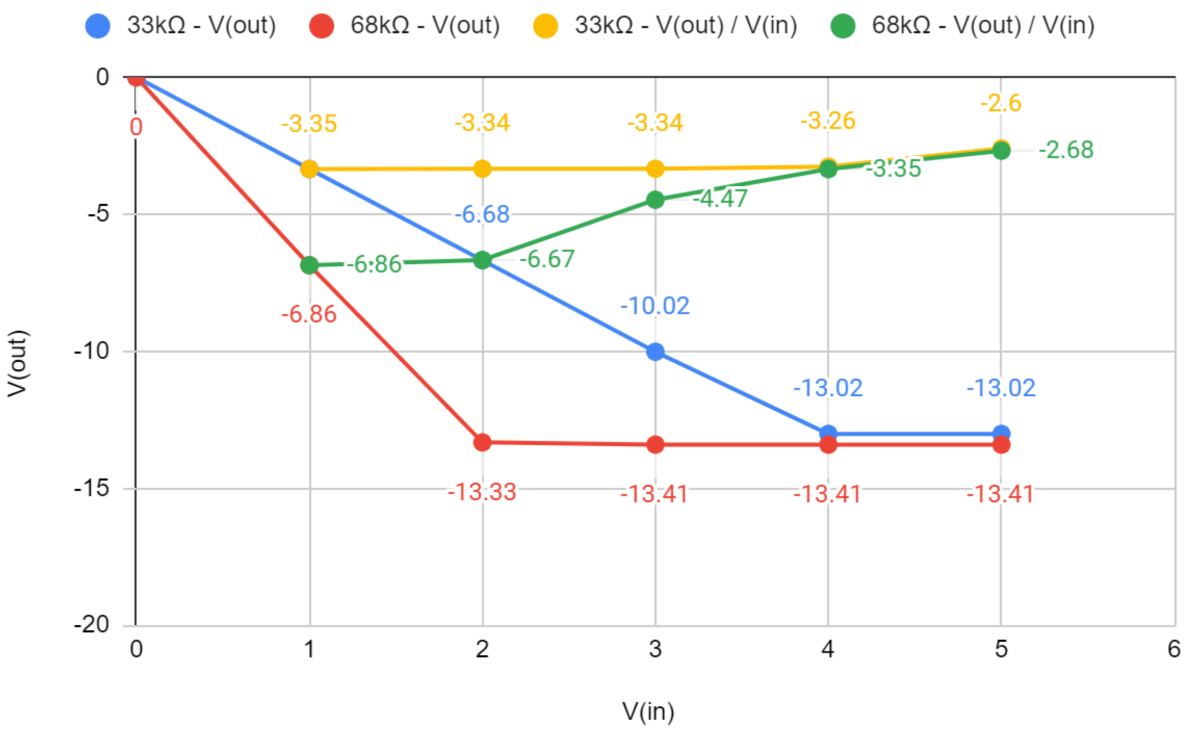
Measure VOUT and VIN for values of VIN from 0V to 5V in 1V intervals (i.e. 0V, 1V, 2V, 3V, 4V and 5V). Plot VOUT against VIN on a graph to derive the gain VOUT / VIN.

V(in)	V(out) Measured	V(out) Calculated	Difference
0	0.00	0.00	0.00
1	-3.35	-3.30	0.05
2	-6.68	-6.60	0.08
3	-10.02	-9.90	0.12
4	-13.02	-13.20	0.18
5	-13.02	-15.00	1.98



Repeat the experiment with RF = 68 K, plotting the result on the same graph

V(in)	V(out) Measured	V(out) Calculated	Difference
0	0.00	0.00	0.00
1	-6.86	-6.80	0.06
2	-13.33	-13.60	0.27
3	-13.41	-15.00	1.59
4	-13.41	-15.00	1.59
5	-13.41	-15.00	1.59



Observations

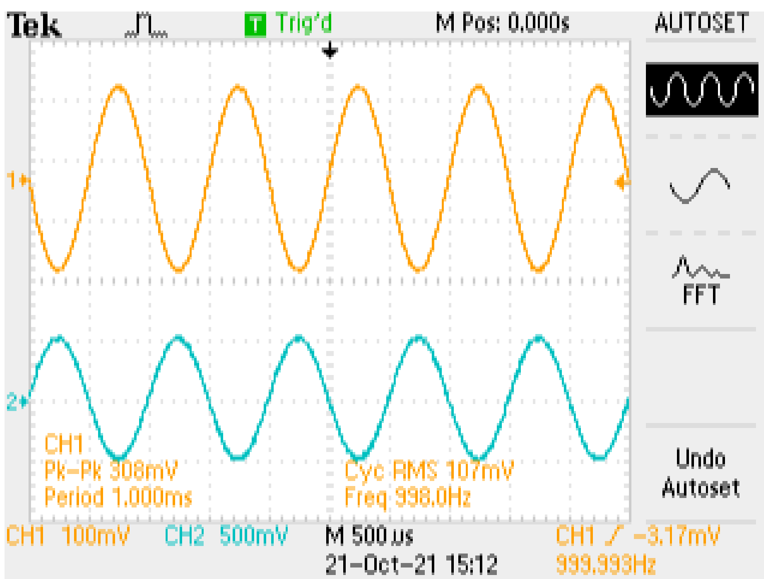
- Actual voltage gain is quite close to the theoretical gain.
  - For R(f) = 33kΩ, it is -3.35 while the calculated gain is -3.30, deviating by 1.5%.
  - For R(f) = 68kΩ, it is -6.86 while the calculated gain is -6.80, deviating by 0.9%.
  - These small deviations are due to non-ideal hardware used.
- The gain is negative, which is to be expected since we are using inverting amplifiers.
- The amplifier behaves linearly until it reaches the saturated voltage, which is expected.

- However, the actual voltage is actually capped at approximately -13.02V and -13.41V respectively instead of the theoretical value of -15V. This is because the 741 op amps used are non-ideal.

Set VS to 2V. Disconnect the potentiometer output VS from the amplifier VIN and measure VS again. Note any difference between the values measured.

- V(s) measured is 2.53V
- Since R1 is 10kΩ, the current flowing into the V(-) terminal is 2.53mA
- This means that the input impedance is not ideal as there's current flowing from the power supply, resulting in the actual V(in) being less than V(s)
- This resulted in current flowing into the V(-) and caused the voltage across R1 to drop

Set RF = 33K. Connect VIN to the output of a function generator. Connect the -ve terminal of the function generator to GND of the power supply (not to -15V). Set the function generator to supply a 1KHz sine wave of 3VPK-PK amplitude. Observe the waveforms at VIN and VOUT on the oscilloscope and sketch the waveforms



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Observations

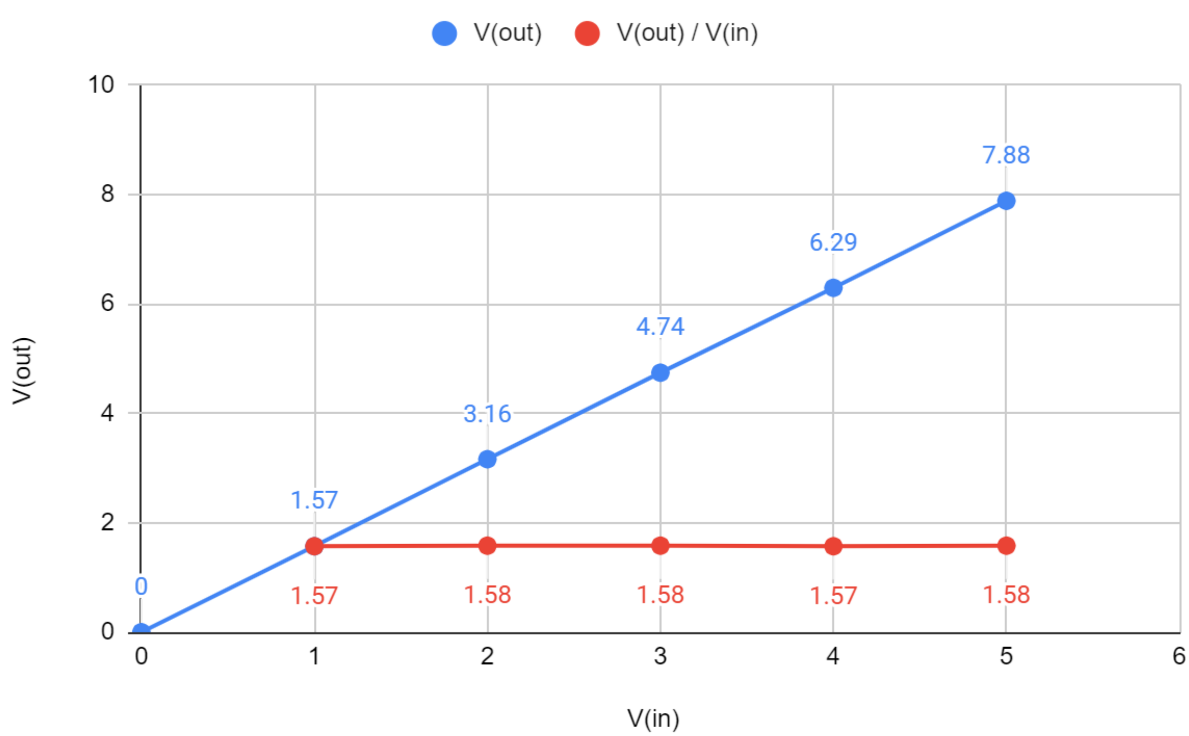
- V(in) and V(out) both have a sinusoidal waveform.
- It is quite consistent with the settings of 1kHz and approximately 3V
- V(out)'s waveform is out of phase with the V(in)'s waveform by half a cycle, which is expected behavior for an inverting amplifier.

5.2 Non-Inverting and Unity Gain Amplifier

Connect the circuit shown in Figure 2. Remember to connect the ±15v power rails to the op-amp. Measure VOUT and VIN for values of VIN from 0V to 5V in 1V intervals. Measure and plot VOUT against VIN on a graph to derive the gain VOUT / VIN.

- V(out) can be calculated by using the formulae (*1 + (R1 / R2)) * V(in)*
- However, due to the constraint of the power supply, the voltage is capped between ±15V.

V(in)	V(out) Measured	V(out) Calculated	Difference
0	0.00	0.00	0.00
1	1.57	1.56	0.01
2	3.16	3.11	0.05
3	4.74	4.67	0.07
4	6.29	6.22	0.07
5	7.88	7.78	0.10



Observations

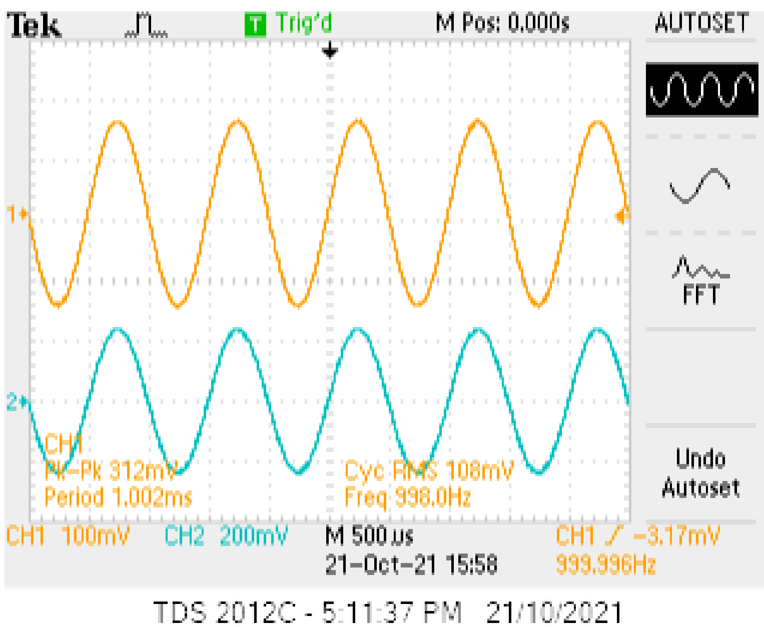
- Actual voltage gain is quite close to the theoretical gain. It is 1.575 while the calculated gain is 1.555, deviating by 1.3%.

- The gain is positive, which is to be expected since we are using inverting amplifiers.
- The amplifier behaves linearly. This is because it has yet to reach its saturation voltage of 15V, thus the behavior is expected.

Set VS to 2V. Disconnect the potentiometer from the amplifier and measure VS again. Note any difference between the values measured.

- V(s) measured is 2.00V
- As the non-inverting amplifier does not have the input resistor R1 (10kΩ), there are no current flowing into the power supply into V(+)
- Therefore, there is no difference in V(s) value before and after disconnecting the potentiometer.

Connect VIN to the output of a function generator. Set the function generator to supply a 1KHz sine wave of 3VPK-PK amplitude. Observe the waveforms at VIN and VOUT on the oscilloscope and sketch the waveforms.



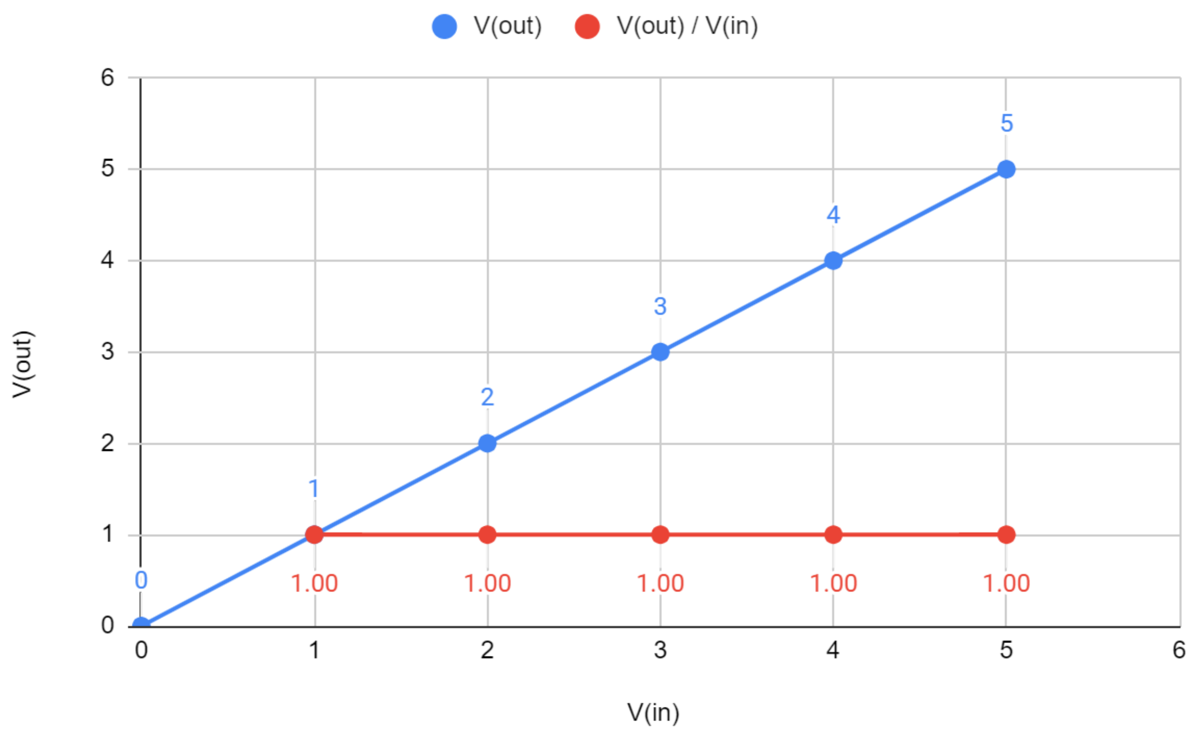
Observations

- V(in) and V(out) both have a sinusoidal waveform.
- It is quite consistent with the settings of 1kHz and approximately 3V
- The waveforms are also in phase, which is expected of that of a non-inverting amplifier.

Replace R1 with a short-circuit, and remove R2 to form a Unity Gain amplifier as shown in Figure 3. Measure VOUT and VIN for values of VIN from 0V to 5V in 1V intervals. Plot the VOUT against VIN graph.

- V(out) should be the same as V(in) as a unity gain amplifier does not amplify the voltage.
- However, due to the constraint of the power supply, the voltage is capped between ±15V.

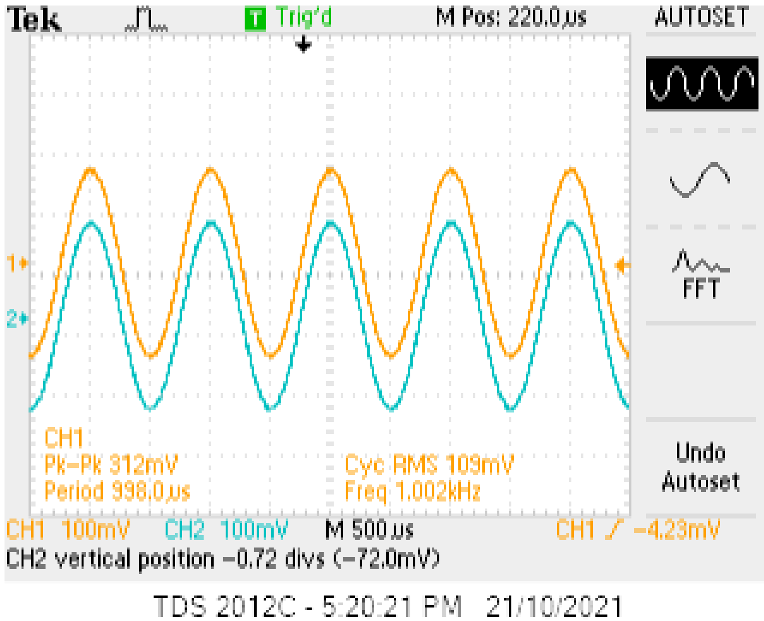
V(in)	V(out) Measured	V(out) Calculated	Difference
0	0.00	0.00	0.00
1	1.00	1.00	0.00
2	2.00	2.00	0.00
3	3.00	3.00	0.00
4	4.00	4.00	0.00
5	5.00	5.00	0.00



Observations

- Actual voltage gain is actually the same as the theoretical gain of 1, which is to be expected since we are using a unity gain amplifier.
- The amplifier behaves linearly. This is because it has yet to reach its saturation voltage of 15V, thus the behavior is expected.

Connect VIN to the output of a function generator. Set the function generator to supply a 1KHz sine wave of 3VPK-PK amplitude. Observe the waveforms at VIN and VOUT on the oscilloscope and sketch the waveforms.



Observations

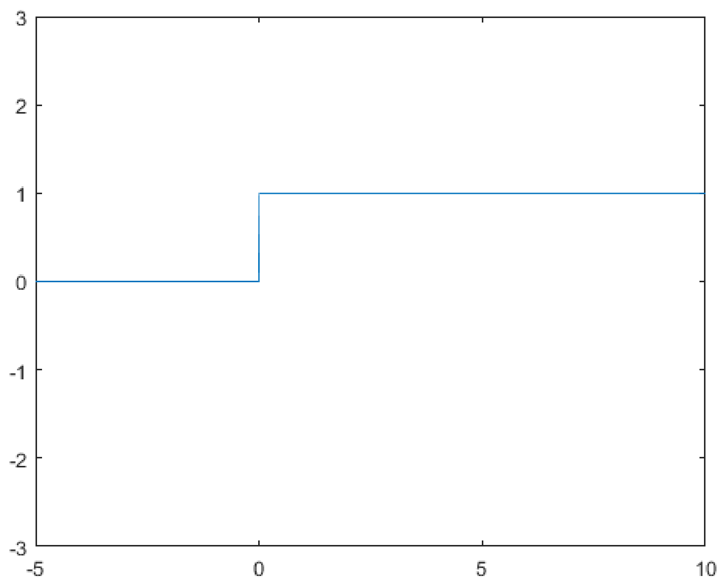
- V(in) and V(out) both have a sinusoidal waveform.
- It is quite consistent with the settings of 1kHz and approximately 3V
- The waveforms are also in phase, which is expected of that of a unity gain amplifier.
- The amplitude of both waves are also the same as a result.

Lab 5: Signals

5.1 Defining and plotting step functions

u(t)

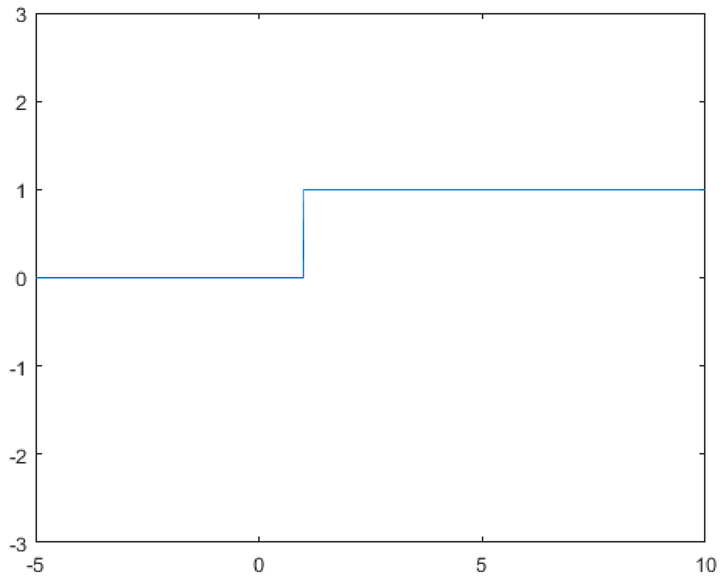
```
function y=step(t)
    y=0.5+0.5*sign(t);
end
```



- As defined, function is equal to 1 for t ≥ 0, else equal to 0

u(t-1)

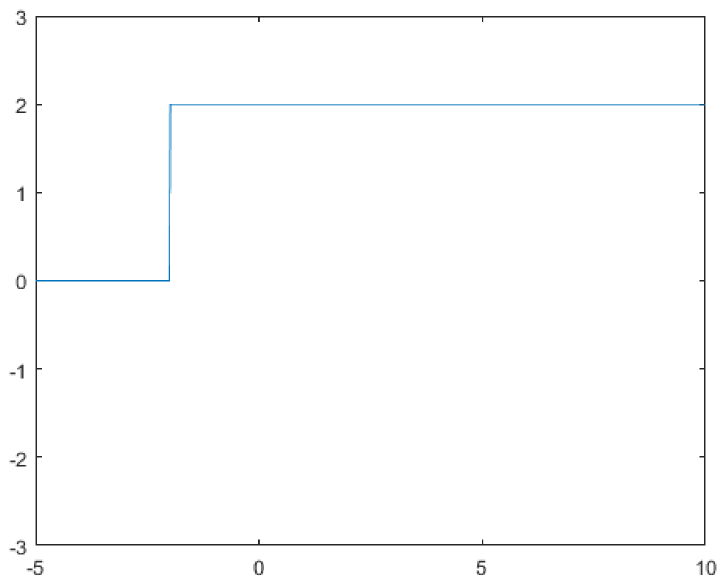
```
t=-5:0.01:10;
plot(t, step(t))
axis([-5 10 -3 3])
```



- The shape is a result of
    - Time shifting: Delayed by 1

2 x u(t+2)

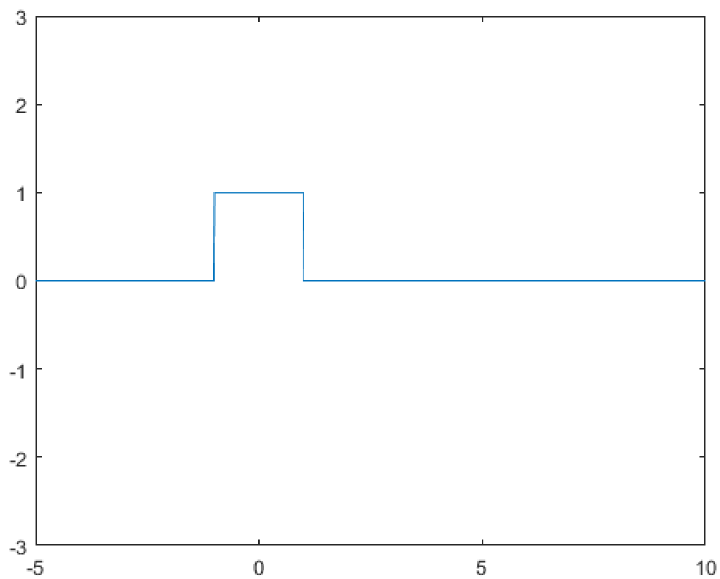
```
t=-5:0.01:10;
plot(t, step(t-1))
axis([-5 10 -3 3])
```



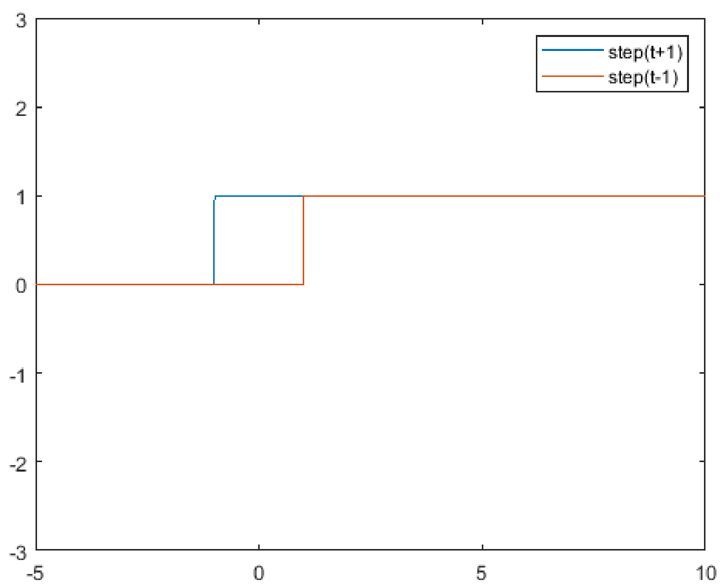
- The shape is a result of
    - Time shifting: Delayed by 2
    - Amplitude manipulation: Amplified by 2

u(t+1) - u(t-1)

```
t=-5:0.01:10;
plot(t, step(t+1)-step(t-1))
axis([-5 10 -3 3])
```



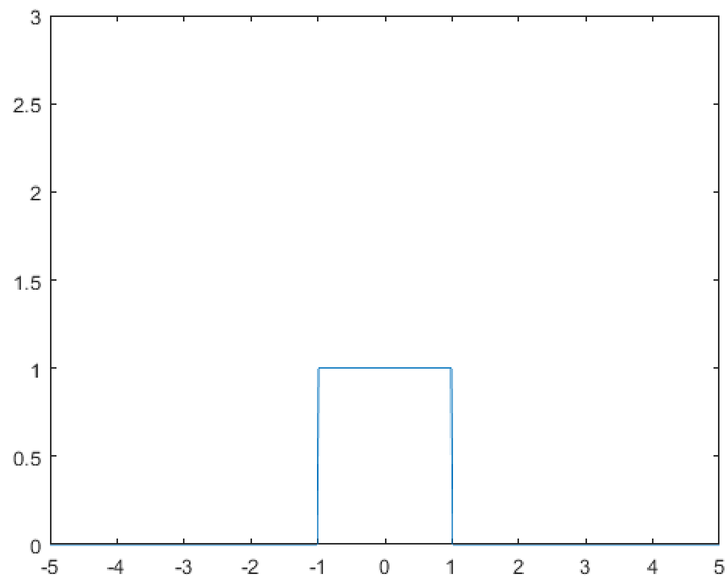
- This shape is a result of combining the 2 separate expressions together. That means that the value at t=x can be derived by summing up the value of each of the expressions at t=x together



5.2 Defining and plotting rectangular functions

step(t)

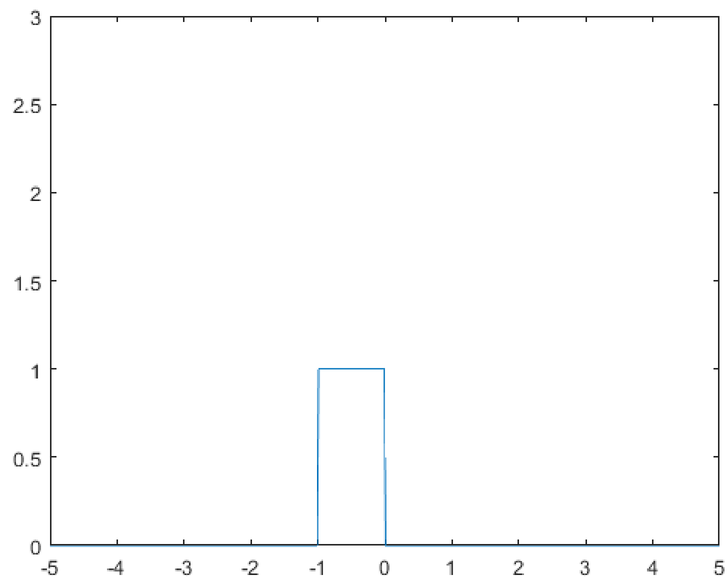
```
function y=step(t)
    y=0.5+0.5*sign(t);
end
```



- As defined, function is equal to 1 when $-0.5 \leq t \leq 0.5$, else equal to 0

step(2t-1)

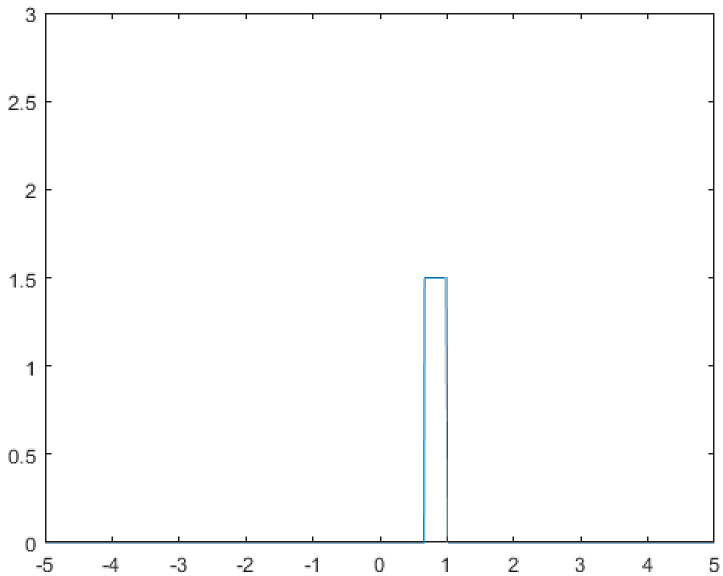
```
t=-5:0.01:5;
plot(t, square((2*t) + 1))
axis([-5 5 0 3])
```



- The shape is a result of
  - Time scaling: Compression with a factor of 2
  - Time shifting: Advancement by 1

1.5 x step(-6t+5)

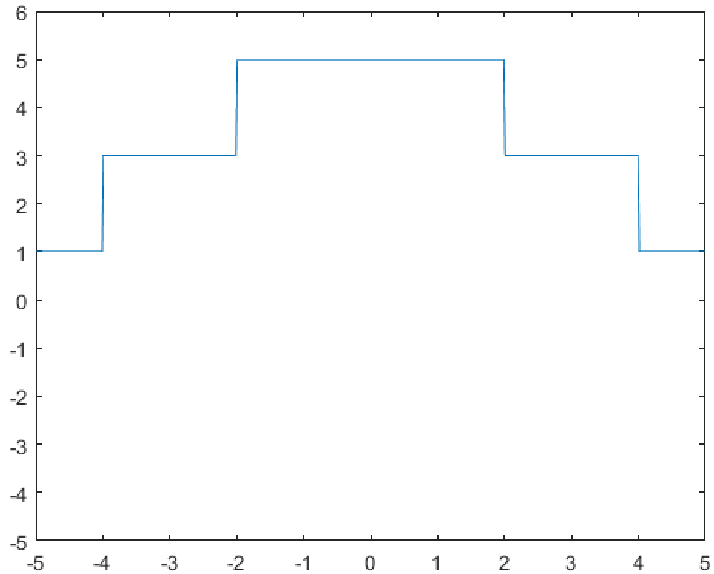
```
t=-5:0.01:5;
plot(t, 1.5 * square((-6 * t) + 5))
axis([-5 5 0 3])
```



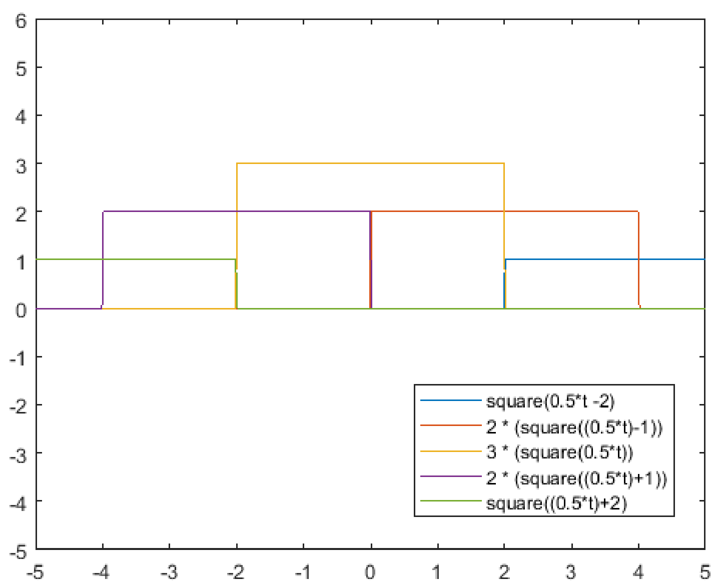
- The shape is a result of
  - Time scaling: Compression with a factor of 6
  - Time shifting: Delayed by 5
  - Amplitude manipulation: Amplified by 1.5

step(0.5t-2) + 2step(0.5t-1) + 3step(0.5t) + 2step(0.5t-1) + step(0.5t+2)

```
t=-5:0.01:5;
plot(t, square(0.5*t -2) + 2 * (square((0.5*t)-1)) + 3 *
(square(0.5*t)) + 2 * (square((0.5*t)+1) + square((0.5*t)+2)
axis([-5 5 -5 6])
```



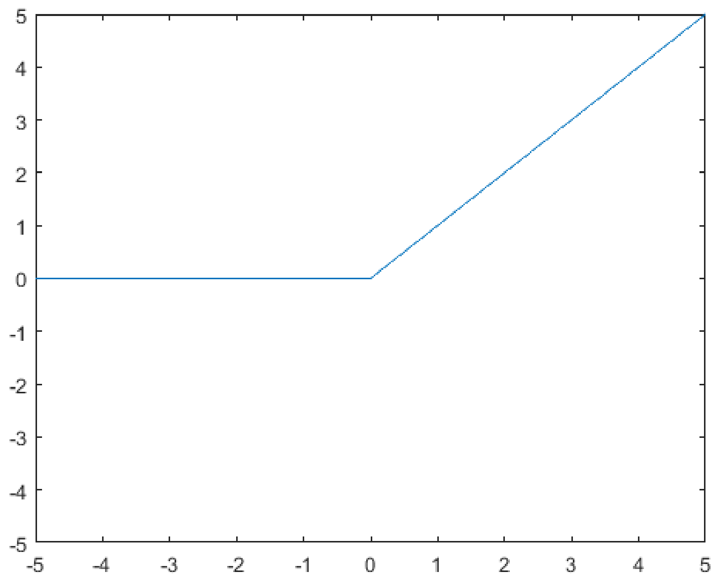
- This shape is a result of combining the 5 separate expressions together. That means that the value at t=x can be derived by summing up the value of each of the expressions at t=x together.



5.3 Defining and plotting ramp functions

r(t)

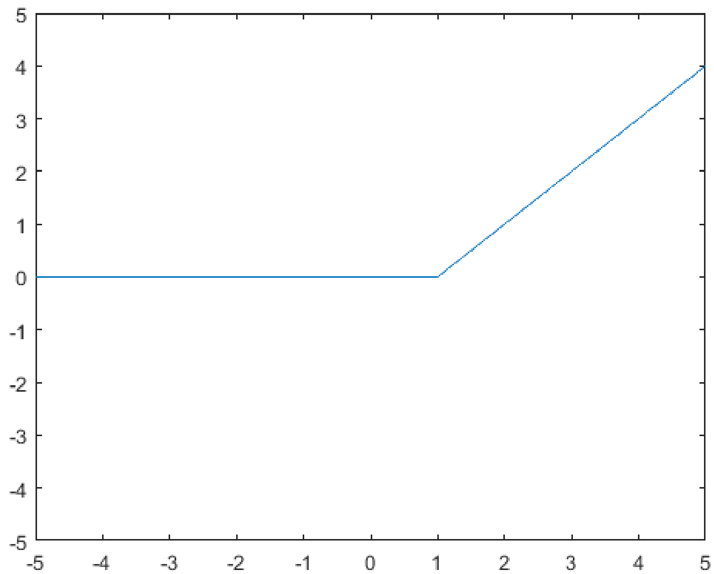
```
function y=ramp_fn(t)
    y= (0.5*t) + (0.5*abs(t));
end
```



- As defined, function is equal to t when t≥0, else equal to 0

r(t-1)

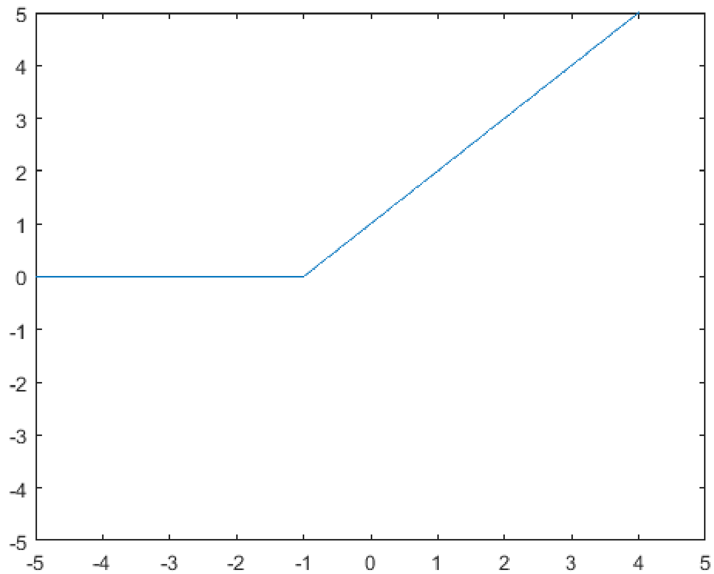
```
t=-5:0.01:5;
plot(t, ramp_fn(t-1))
axis([-5 5 -5 5])
```



- The shape is a result of
  - Time shifting: Delayed by 1

r(t+1)

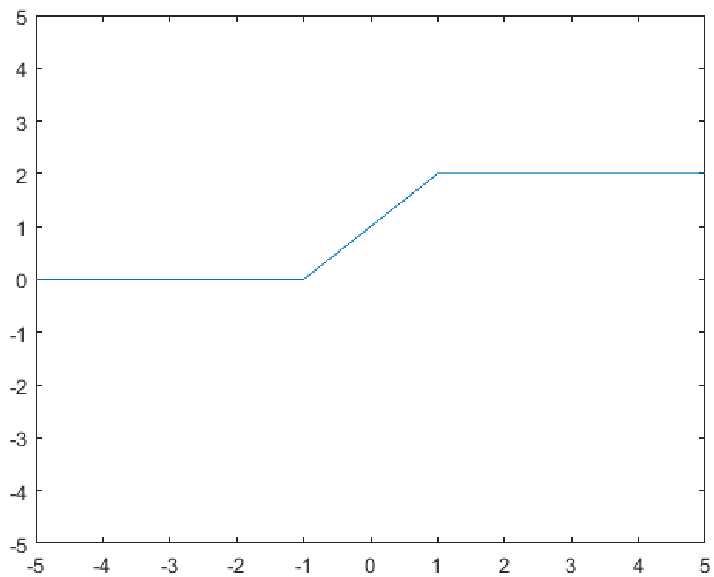
```
t=-5:0.01:5;
plot(t, ramp_fn(t+1))
axis([-5 5 -5 5])
```



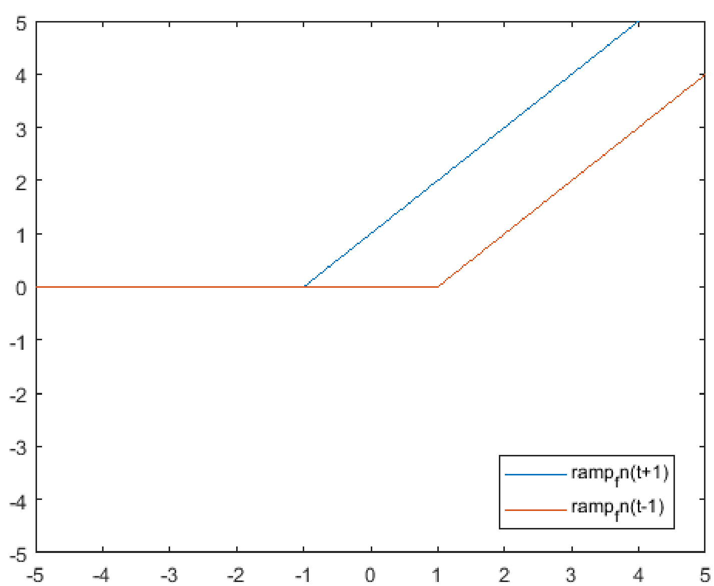
- The shape is a result of
    - Time shifting: Advancement by 1

r(t+1) - r(t-1)

```
t=-5:0.01:5;
plot(t, ramp_fn(t+1) - ramp_fn(t-1))
axis([-5 5 -5 5])
```



- This shape is a result of combining the 2 separate expressions together. That means that the value at t=x can be derived by summing up the value of each of the expressions at t=x together.



5.4 Defining delta function and verifying its properties

The delta function is often also referred to as the Dirac delta function.

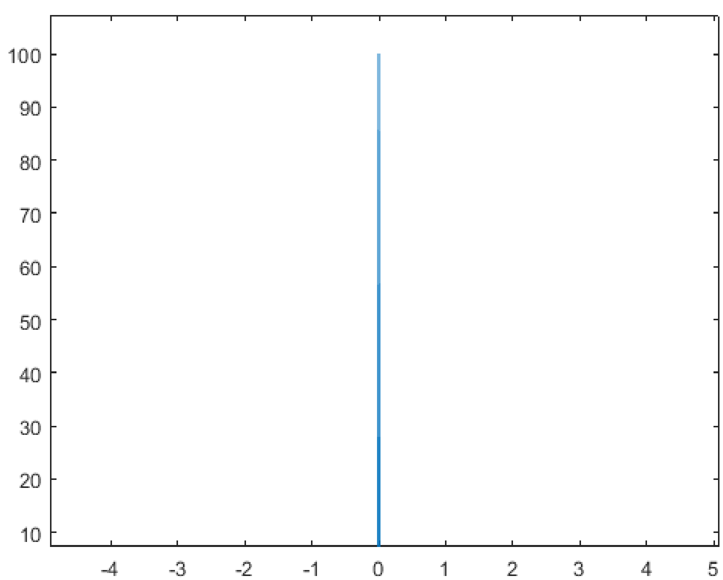
The main property of the delta function is that it reaches infinity at a single point and is zero at any other point. Its most important property is that its integral is always one:

$$\int_{-\infty}^{\infty} \delta(x)\, dx = 1$$

As this function is hypothetical and not possible to plot in practice, we can only think of the delta function as the approximation of a rectangular function with the pulse width approaching zero. It can be defined as the following with alpha approaching a very large number.

$$-\frac{1}{\alpha} \leq x \leq \frac{1}{\alpha}$$

```
function y=delta(t)
    a = 100;
    y= a * square(2 * a * t);
end
```



```
t=-5:0.01:5;
plot(t, delta(t));
hold on;
plot(t, exp(t) .* delta(t-1));
```