LinearAmplifiers

October 30, 2018

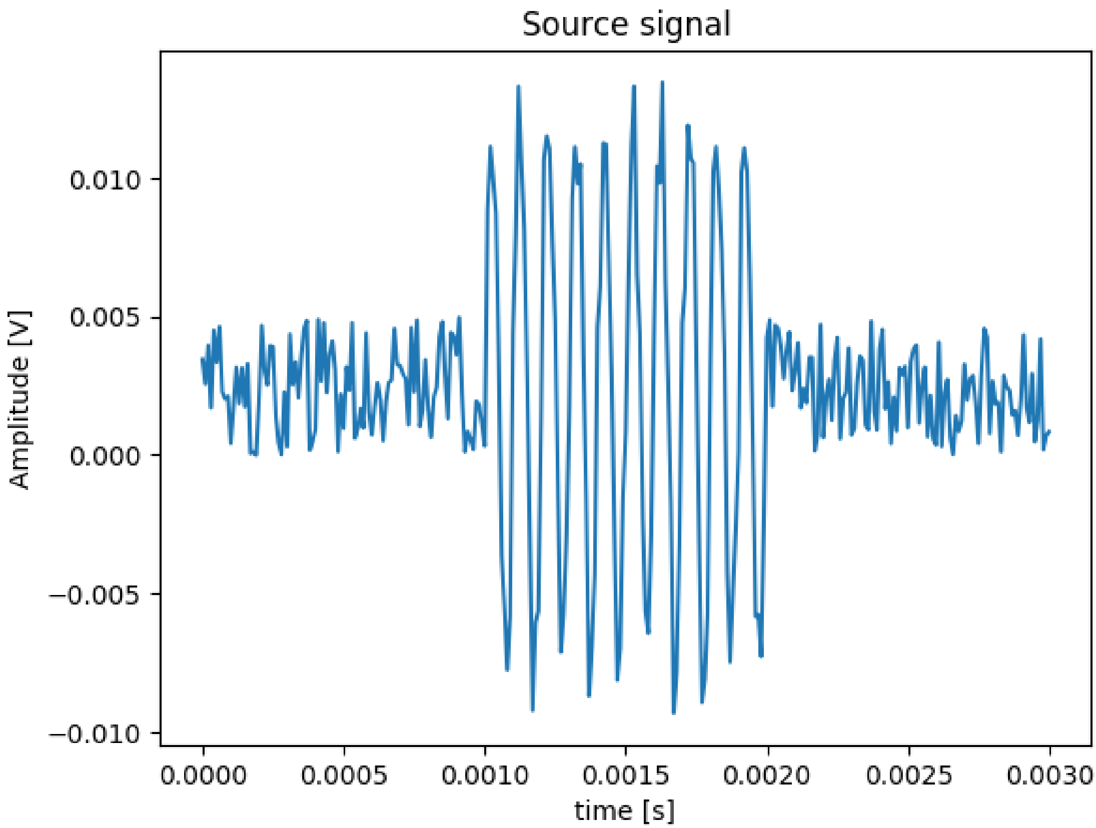
1 Linear applications of operational amplifiers

In this example a TL082 operational amplifier was used. The input signal was set to a sine wave of 10 mV amplitude and 10 kHz frequancy with additional gaussian noise.

$$E_g = Asin(\omega t) + \alpha N(t)$$
$$\omega = 2\pi f$$

In [2]:
```
using PyPlot;
```

In [3]:
```
# system definition for TL082
Aol = 100/0.001      # 80 dB
ft = 4*10^6;         # 4 MHz
Rinr = 10^12;       # input resistance
CMRR = 100          # Common Mode Rejection Ratio
PSRR = 100          # Power Supply Rejection Ratio
Vn =  25*10^(-9);   # Input noise voltage
SR = 13*10^(6);      # Slew Rate

A = 0.01;                   # amplitude
f = 10^4;                   # frequency 10 kHz
alfa  = 0.0050;              # noise amplitude
t = 0:0.00001:0.001;         # 1 ms  time vector with a resolution of 10 us
E = A*sin.(2 *pi * f *t) + alfa*rand(length(t),1);   # sinusoidal signal definition

# add noise in front and at the back of the sine signal
Eg = [alfa*rand(100,1); E; alfa*rand(100,1)];
t = 0:0.00001:0.003;
Rg = 500;               # signal source thevenin impedance
plot(t,Eg)
title("Source signal")
xlabel("time [s]");
ylabel("Amplitude [V]");
```



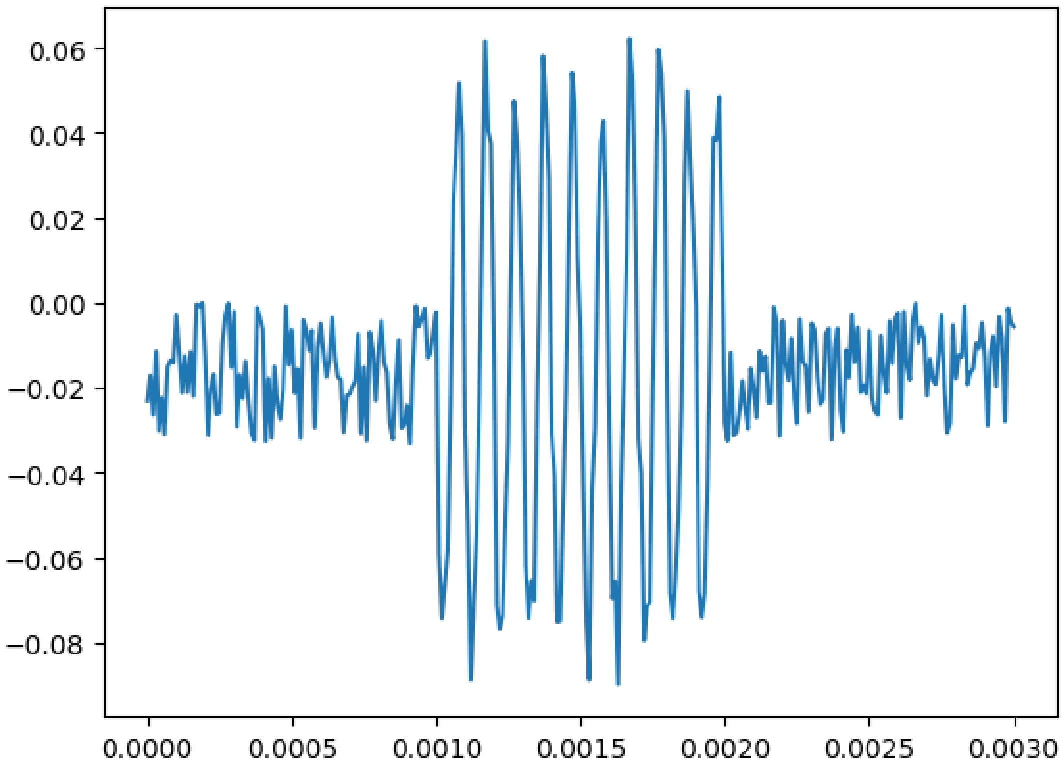
1.1 Inverting amplifier

$$A_V = -\frac{R_f}{R_{in}}$$

```
In [4]: # External resistors
        Rin = 1000;
        Rf = 10000;
        println("The value to Rin is $Rin Ohm")
        println("The value to Rin is $Rf Ohm")
        Av = -Rf/Rin;
        AvdB = floor(20log10.(abs(Av)))
        println("The value of the voltage gain is $Av V/V, what is equal to  $AvdB dB")
        Rin = Rin;
        println("The input resistance of the inverting amp is equal to $Rin");
```

```
The value to Rin is 1000 Ohm
The value to Rin is 10000 Ohm
The value of the voltage gain is -10.0 V/V, what is equal to  20.0 dB
The input resistance of the inverting amp is equal to 1000
```

In [5]:
```
Rin  = Rin;
R1  = Rin;
R2 = Rf;
Vout = Av * Eg * Rin/(Rin + Rg);
plot(t,Vout)
```



Out[5]:
```
1-element Array{PyCall.PyObject,1}:
 PyObject <matplotlib.lines.Line2D object at 0x7f43d6b8f290>
```

Gain Bandwidth

$$GB = f_T = Av \cdot f$$

In [6]:
```
fc = ft/abs(Av);
fc = round(fc/1000);
println("The cut off frequency is equal to $fc [kHz]")
```

```
The cut off frequency is equal to 400.0 [kHz]
```

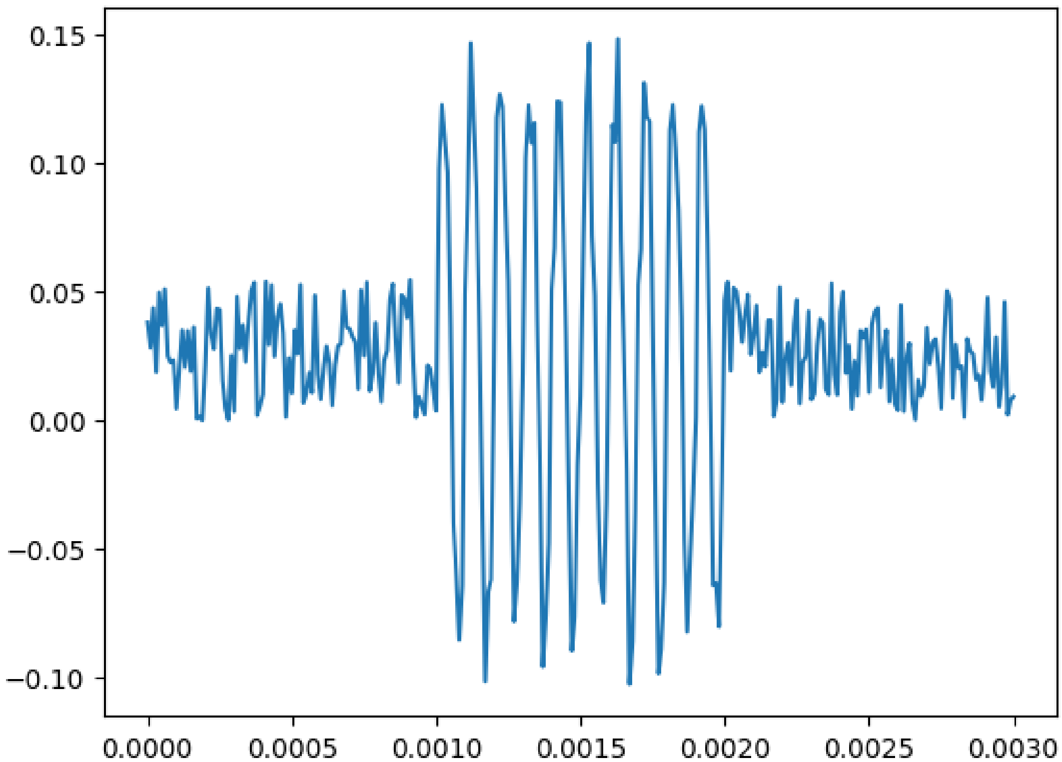
1.1.1 Non inverting amplifier

$$A_V = 1 + \frac{R_2}{R_1}$$

In [7]:
```
Av = 1 + R2/R1;
AvdB = round(20log10.(abs(Av)));
println("The value to the voltage gain is $Av V/V, what is equal to  $AvdB dB");
```

```
The value to the voltage gain is 11.0 V/V, what is equal to  21.0 dB
```

In [8]:
```
Rin = Rinr + R1*R2/(R1+R2)  ; # input resistance
println("The input resistance of the non inverting amp is equal to $Rin");
Vout = Av * Eg * Rin/(Rin + Rg) ;
plot(t,Vout)
```




```
The input resistance of the non inverting amp is equal to 1.000000000909091e12
```

Out[8]:
```
1-element Array{PyCall.PyObject,1}:
 PyObject <matplotlib.lines.Line2D object at 0x7f43d6b0f590>
```

In [9]:
```
fc = ft/Av;
fc = round(fc/1000);
println("The cut off frequency is equal to $fc [kHz]")
```

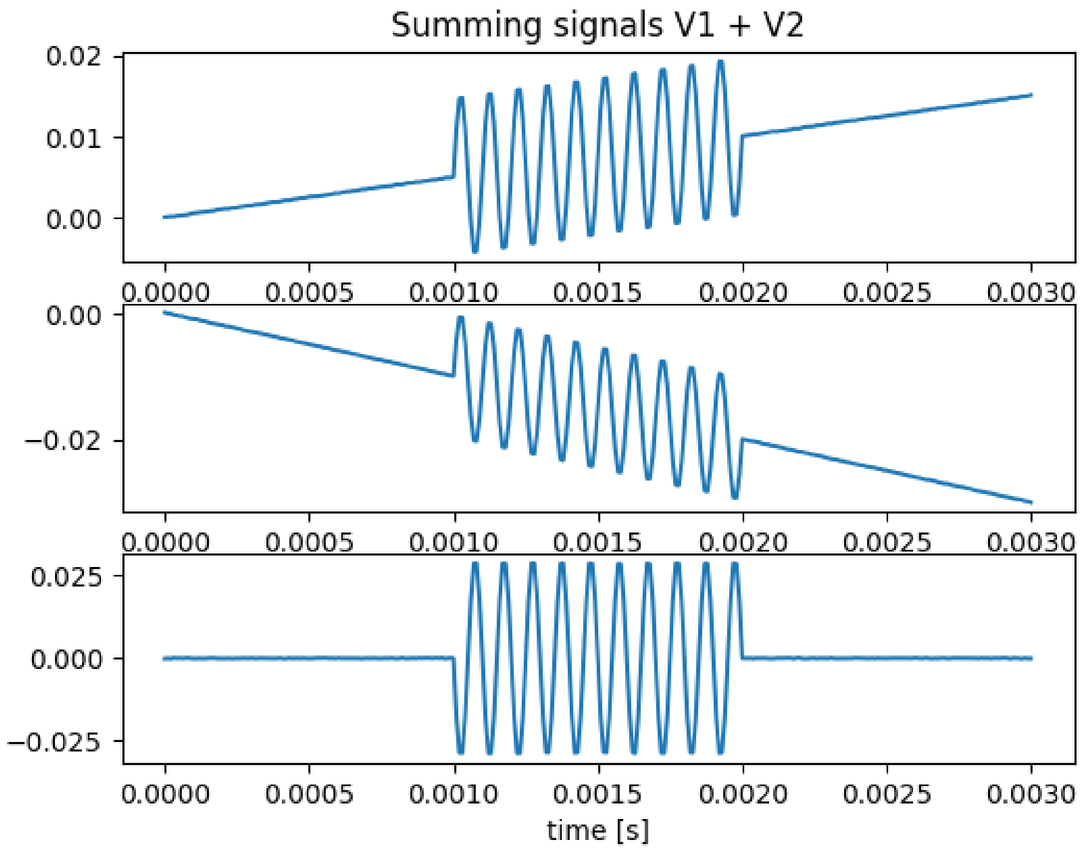
```
The cut off frequency is equal to 364.0 [kHz]
```

1.2 Summing Amp

$$V_{out} = -\sum_{k=1}^{N} \frac{R_f}{R_i} V_i$$

In [ ]:

In [10]:
```
A = 0.01;                    # amplitude
f = 10^4;                    # frequency 10 kHz
alfa  = 0.0001;               # noise amplitude
t = 0:0.00001:0.001;          # 1 ms  time vector with a resolution of 10 us
E =  A*sin.(2 *pi * f *t) + alfa*rand(length(t),1);   # sinusoidal signal definition

# add noise in front and at the back of the sine signal
V1 =  [alfa*rand(100,1); E; alfa*rand(100,1)];
V2 =  [alfa*rand(100,1); E; alfa*rand(100,1)];
t = 0:0.00001:0.003;
V1 = 5*t + V1;
V2 = -10*t + V2;
V = -(2*V1+V2);
Rg = 500;                # signal source thevenin impedance
subplot(3,1,1); plot(t,V1)
title("Summing signals V1 + V2")
subplot(3,1,2); plot(t,V2)
subplot(3,1,3); plot(t,V)
xlabel("time [s]");
```



1.3 Integrator circuit

$$V_{out} = -\frac{1}{RC}\int_{t_0}^{t_1} V_{in} dt = K_i \int_{t_0}^{t_1} V_{in} dt$$

```
In [11]: R = 10000;
         C = 10^(-8);
         Ki = -1/(R*C);
         println("Integration constant = $Ki");
```

```
Integration constant = -9999.999999999996
```

1.3.1 Example

$$V_{out} = -\frac{1}{RC}\int_{t_0}^{t_1} V_{in} dt = -K_i \int_{t_0}^{t_1} V_{in} dt$$

$$V_{in}(t) = \begin{cases} A & t \in (kT, kT+\tau) \\ -A & t \in (kT+\tau, kT+T) \end{cases}$$

$$\int_{t_0}^{T} V_{in}(t)dt = \int_{t_0}^{\tau} V_{in}(t)dt + \int_{\tau}^{T} V_{in}(t)dt$$

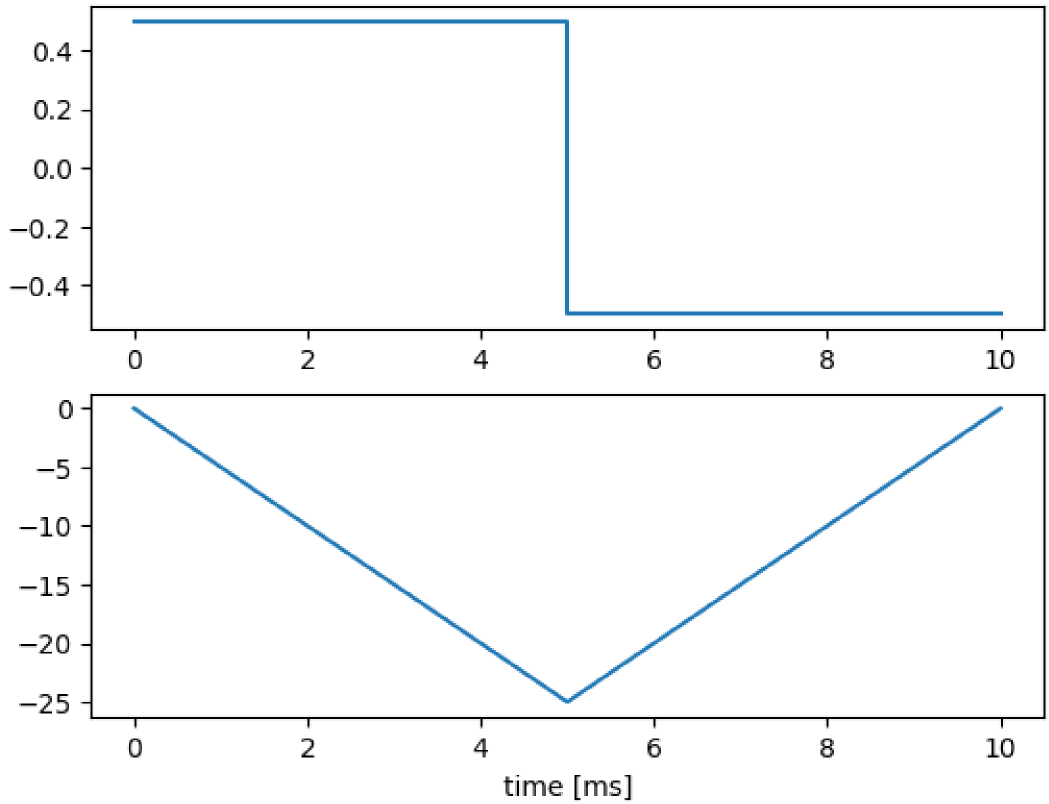
$$\int_{t_0}^{\tau} V_{in}(t)dt + \int_{\tau}^{T} V_{in}(t)dt = \int_{t_0}^{\tau} Adt + \int_{\tau}^{T} -Adt$$

$$\int_{t_0}^{\tau} Adt + \int_{\tau}^{T} -Adt = At|_{t0}^{\tau} - At|_{\tau}^{T}$$

$$-K_i \int_{t_0}^{\tau} Adt + -K_i \int_{\tau}^{T} -Adt = -K_i At|_{t0}^{\tau} + K_i At|_{\tau}^{T}$$

In [12]:
```
A = 0.5;
f = 100;
T = 1/f;
tau = 0.5*T;

#for positive amplitude
min = A*Ki*tau;
# for negative amplitude
max = -A*Ki*T - (-A*Ki*tau);
```

In [13]:
```
t1 = 0:0.01*tau:tau;
t2 = tau:0.01*tau:T;
t = [t1; t2];


x1 = A*ones(length(t1),1 );
x2 = -A*ones(length(t2),1 );
x = [x1; x2]


y1 =  A*Ki*t1;
y2 =  -A*Ki*t2;
y2 =  y2.-2*max;
y  =  [y1; y2]

subplot(2,1,1); plot(1000*t,x)
subplot(2,1,2); plot(1000*t,y)
xlabel("time [ms]");
```



1.4 Derivative circuit

$$V_{out}(t) = -RC\frac{V_{in}(t)}{dt}$$

1.4.1 Example

Triangular wave derivative

$$V_{in}(t) = \begin{cases} \alpha t & t \in (kT, kT+\tau) \\ -\alpha t & t \in (kT+\tau, kT+T) \end{cases}$$

```
In [14]: T = 0.001;
         tau = 0.5*T
         f = 1/T;
         R = 10000;  # 10k
         C = 10*10^(-9);  # 10n
         Kd = -R*C;
         println("Derivation constant = $Kd");
         A = 10;
         alpha = A/(0.25*T);
         println("Slope = $alpha");
```

```
    sol = -Kd*d;
    println("Solution Kd*d = $sol [V]");
```

```
Derivation constant = -0.00010000000000000005
Slope = 40000.0
```

```
UndefVarError: d not defined

Stacktrace:

 [1] top-level scope at In[14]:11
```

In [ ]:

In [ ]: