# Plotting and Integrating Signals in MATLAB

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1. For the first part of the project, we were asked to plot the following piecewise continues signal in MATLAB:

$$h(t)=\begin{cases}\cos(\pi t/2) & -2\le t<-1\\ 1+t^3 & -1\le t<0\\ 1 & 0\le t<1\\ 1+\sin(2\pi t) & 1\le t<2\\ 0 & elsewhere\end{cases}$$

The signal has non-zero values within the interval [-2;2]. Therefore, the range of time vector in MATLAB is 4. Since MATLAB cannot store an infinite number of data, I divided the time interval into 10000 segments. I implemented that logic with the following MATLAB code:

```
Range = 2-(-2);

step = Range/(10^4);
t = -2:step:2;
```

The signal h(t) is consist of four signals. We can represent h(t) with unit step functions. I need to define the following pulses:

u(t+2) - u(t+1) – pulse has magnitude 1 over range -2 <= t < -1. Implemented with code:

```
pulse_neg2_neg1 = (t>=(-2))&((t)<(-1)); % pulse from -2 to -1
```

u(t+1) - u(t) – pulse has magnitude 1 over range -1 <= t < 0 Implemented with code:

```
pulse_neg1_0 = (t>=(-1))&((t)<(0)); % pulse from -1 to 0
```

u(t) - u(t-1) – pulse has magnitude 1 over range 0 <= t < 1 Implemented with code:

```
pulse_0_1 = (t>=(0))&((t)<(1)); % pulse from 0 to 1
```

u(t-1) - u(t-2) – pulse has magnitude 1 over range 1 <= t < 2 Implemented with code:

```
pulse_1_2 = (t>=(1))&((t)<(2)); % pulse from 1 to 2
```

After defining those pulses, I can represent the signal as follows:

$$h(t) = \cos(\frac{\pi t}{2}) \cdot [u(t+2) - u(t+1)] + (1+t^3)[u(t+1) - u(t)] \\ + [u(t) - u(t-1)] + (1+\sin(2\pi t))[u(t-1) - u(t-2)]$$

I implemented that signal with the following code:

```
h = pulse_neg2_neg1.*cos(pi*t/2) + pulse_neg1_0.*(1+t.^3) + pulse_0_1.*1 +
pulse_1_2.*(1+sin(2*pi*t));
```

MATLAB generated the following plot:

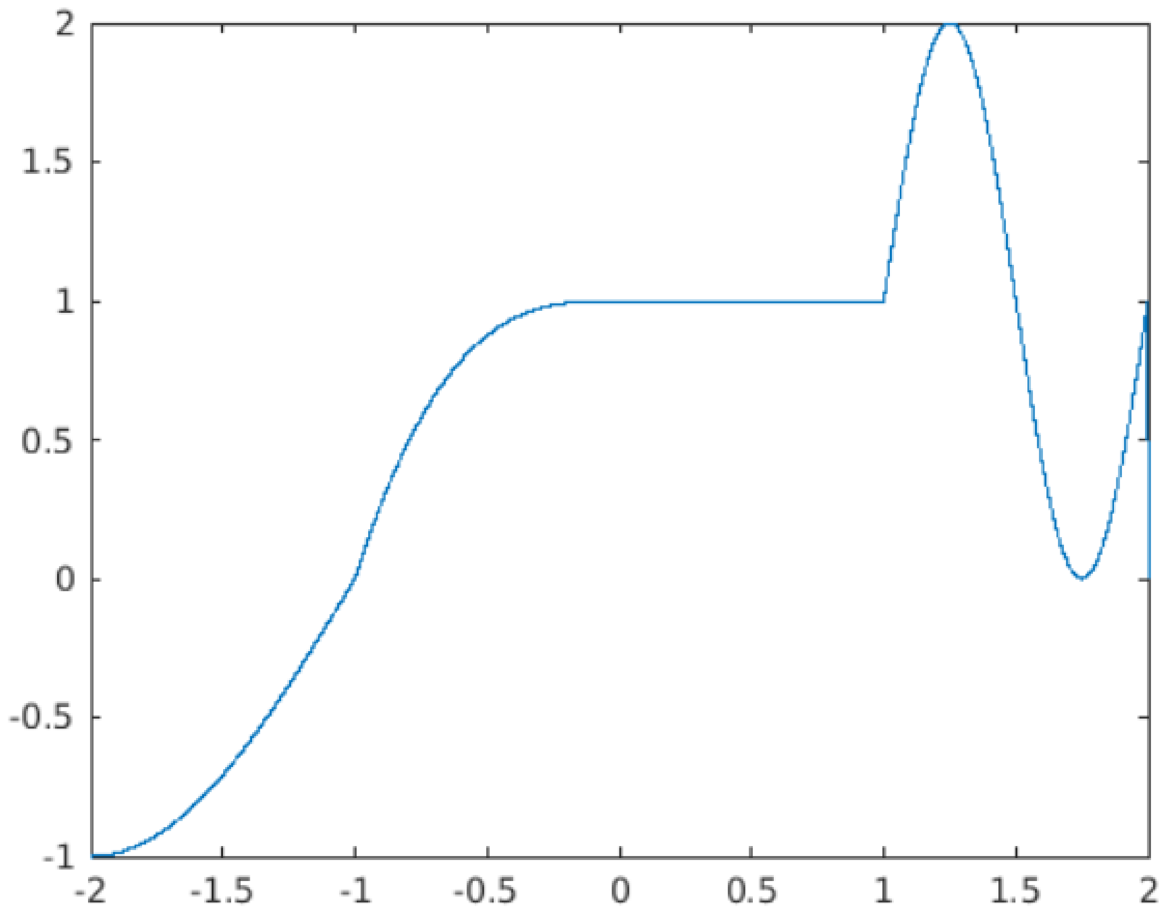


Figure 1

2. For the second part, we were asked to integrate the above-described function by hand and in MATLAB. I used trapz() command to integrate the signal in MATLAB.

a) $I1 = \int_{-2}^{1} h(t)\,dt = \int_{-2}^{-1} \cos(\frac{\pi t}{2})dt + \int_{-1}^{0}(1+t^3)\,dt + \int_{0}^{1} dt = \frac{2}{\pi}\sin\left(\frac{\pi t}{2}\right)\Big|_{-2}^{-1} + t\Big|_{-1}^{0} + \frac{t^4}{4}\Big|_{-1}^{0} + 1 = \frac{2}{\pi}\left(\sin\left(\frac{-\pi}{2}\right) - \sin(-\pi)\right) + 1 - \frac{1}{4} + 1 = 1.11338$

To evaluate that integral in MATLAB, I used the following code:

```
t1 = t(t>=(-2)&t<=(1)); % time interval [-2,1]
h1 = h(t>=(-2)&t<=(1)); % values of the function at time interval [-
2,1]
I1 = trapz(t1,h1); % integral of h over time interval [-2,1]
```

The result was 1.1134 (rounded up to 4th decimal). The discrepancy between hand and MATLAB calculation is 1.8734e-05 %

b) $I2 = \int_{-2}^{2} h(t)\,dt = \int_{-2}^{-1} \cos(\frac{\pi t}{2})dt + \int_{-1}^{0}(1+t^3)\,dt + \int_{0}^{1} dt + \int_{1}^{2}(1+\sin(2\pi t))dt = \frac{2}{\pi}\sin\left(\frac{\pi t}{2}\right)\Big|_{-2}^{-1} + t\Big|_{-1}^{0} + \frac{t^4}{4}\Big|_{-1}^{0} + 1 + 1 - \frac{1}{2\pi}\cos(2\pi t)\Big|_{1}^{2} = \frac{2}{\pi}\left(\sin\left(\frac{-\pi}{2}\right) - \sin(-\pi)\right) + 1 - \frac{1}{4} + 1 + 1 - \frac{1}{2\pi}[co\,s(4\pi) - \cos(2\pi)] = 2.11338$

To evaluate that integral in MATLAB, I used the following code:

```
t2 = t(t>=(-2)&t<=(2)); % time interval [-2,2]
h2 = h(t>=(-2)&t<=(2)); % values of the function at time interval [-
2,2]
I2 = trapz(t2,h2); % integral of h over time interval [-2,2]
```

The result was 2.1132 (rounded up to 4th decimal). The discrepancy between hand and MATLAB calculation is -0.0094536%.

c) $I3 = \int_{-0.5}^{1.5} h(t)\,dt = \int_{-0.5}^{0}(1+t^3)\,dt + \int_{0}^{1} dt + \int_{1}^{1.5}(1+\sin(2\pi t))dt = t\Big|_{-0.5}^{0} + \frac{t^4}{4}\Big|_{-0.5}^{0} + 1 + 0.5 - \frac{1}{2\pi}\cos(2\pi t)\Big|_{1}^{1.5} = 0.5 - \frac{0.5^4}{4} + 1.5 - \frac{1}{2\pi}[co\,s(3\pi) - \cos(2\pi)] = 2.302684886$

To evaluate that integral in MATLAB, I used the following code:

```
t3 = t(t>=(-0.5)&t<=(1.5)); % time interval [-0.5,1.5]
h3 = h(t>=(-0.5)&t<=(1.5)); % values of the function at time interval
[-0.5,1.5]
I3 = trapz(t3,h3); % integral of h over time interval [-0.5,1.5]
```

The result was 2.3027 (rounded up to 4th decimal). The discrepancy between hand and MATLAB calculation is -7.7027e-06%.

d) $I4 = \int_{-1}^{1} h(t)\,dt = \int_{-1}^{0} (1+t^3)\,dt + \int_{0}^{1} dt = t\,\Big|_{-1}^{0} + \frac{t^4}{4}\Big|_{-1}^{0} + 1 = 1 - \frac{1}{4} + 1 = 1.75$

To evaluate that integral in MATLAB, I used the following code:

```
t4 = t(t>=(-1)&t<=(1)); % time interval [-1,1]
h4 = h(t>=(-1)&t<=(1)); % values of the function at time interval [-
1,1]
I4 = trapz(t4,h4); % integral of h over time interval [-1,1]
```

The result was 1.75 (rounded up to $4^{th}$ decimal). The discrepancy between hand and MATLAB calculation is -2.2857e-06%.

MATLAB Source Code:

```
format shortEng;
clc;
clear;


Range = 2-(-2);
step = Range/(10^4);
t = -2:step:2;


pulse_neg2_neg1 = (t>=(-2))&((t)<(-1)); % pulse from -2 to -1
pulse_neg1_0 = (t>=(-1))&((t)<(0)); % pulse from -1 to 0
pulse_0_1 = (t>=(0))&((t)<(1)); % pulse from 0 to 1
pulse_1_2 = (t>=(1))&((t)<(2)); % pulse from 1 to 2


h = pulse_neg2_neg1.*cos(pi*t/2) + pulse_neg1_0.*(1+t.^3) + pulse_0_1.*1 +
pulse_1_2.*(1+sin(2*pi*t));


figure;plot(t,h);


t1 = t(t>=(-2)&t<=(1)); % time interval [-2,1]
h1 = h(t>=(-2)&t<=(1)); % values of the function at time interval [-2,1]
I1 = trapz(t1,h1); % integral of h over time interval [-2,1]


t2 = t(t>=(-2)&t<=(2)); % time interval [-2,2]
h2 = h(t>=(-2)&t<=(2)); % values of the function at time interval [-2,2]
I2 = trapz(t2,h2); % integral of h over time interval [-2,2]
```

```
t3 = t(t>=(-0.5)&t<=(1.5)); % time interval [-0.5,1.5]
h3 = h(t>=(-0.5)&t<=(1.5)); % values of the function at time interval [-0.5,1.5]
I3 = trapz(t3,h3); % integral of h over time interval [-0.5,1.5]


t4 = t(t>=(-1)&t<=(1)); % time interval [-1,1]
h4 = h(t>=(-1)&t<=(1)); % values of the function at time interval [-1,1]
I4 = trapz(t4,h4); % integral of h over time interval [-1,1]


I_matlab = [I1 I2 I3 I4];
I_hand = [1.11338 2.11338 2.302684886 1.75];
diff = I_matlab - I_hand;
diff = diff./I_hand;
diff = diff*100;
["Integral from -2 to 1" "Integral from -2 to 2" "Integral from -0.5 to 1.5"
"Integral from -1 to 1"];
I=[ans(:) I_matlab(:) I_hand(:) diff(:)];
I=["time interval" "MATLAB calc" "Hand calc" "% diff"; I] % rounded to 4 decimal
```