Signals Systems and Transforms
EEET-332
Lab 8

Complete the prelab to review the use of the colon (:) operator and the element-by-element operations. There is no quiz for Lab 8.

Prelab:

1) Given the Fourier series coefficient equation for a square wave below, calculate cm(3) and cm(4).

$$cm = \frac{\sin\left(\frac{m\pi}{2}\right)}{m\pi}.$$

The colon operator (:) will create a row vector containing the numbers in a range specified. For example:

```
>> t=3:10
t =
   3   4   5   6   7   8   9  10
```

Notice how the command changes when an increment of 2 is added. MATLAB starts with 3 and increments by 2. The last number is not exceeded.

```
>> t=3:2:10
t =
   3   5   7   9
```

2) Predict t below. Verify t using MATLAB.

```
>> tp=2E-3
tp =
  0.0020
>> t=0:tp/10:tp
t =
 Columns 1 through 6

     0   0.0002   ________   ________   ________   0.0010
 Columns 7 through 11

  0.0012   ________   0.0016   ________   0.0020
```

3) Predict 5:10. Verify t using MATLAB.

4) Predict 10:-1:5. Verify t using MATLAB.

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The next section reviews element-by-element operations.

Use A and B to answer the next two questions.

```
A = 1     2     3     4

B = 2     4     6     8

C = 10
```

5) Is * or .* the correct operator for multiplying A and B?

   Try A*B and A.*B in MATLAB. Which operation works? Which gives an error?

6) Is / or ./ the correct operator for dividing A and C?

   Try A / C and A ./ C in MATLAB. Show that when dividing by a constant, either operation can be used.

7) Is / or ./ the correct operator for dividing C and A?

   Try C / A and C ./ A in MATLAB. This is not the same as dividing by a constant. Which operation works? Which gives an error?

8) Is * or .* the correct operator for multiplying A and C?

   Try A * C and A .* C in MATLAB. When multiplying by a constant can either be used?

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Section 1: Fourier Coefficients

1) Calculate the Fourier series coefficients for the square wave in figure 1 using the integral

$$c_m = \frac{1}{T_o}\int_{-0.25ms}^{0.75ms} f(t)e^{-jm\omega_o t}dt \qquad \text{Equation 1}$$

   a) The square wave will have a 1 ms period, 50% duty cycle, and amplitude of 1.
   b) Rising edges are at -0.25ms, 0.75ms, 1.75ms, etc., as shown in figure 1.
   c) Common mistake: forgetting to split the integral into two integrals: one for f(t) = 1 with limits of -0.25ms to 0.25ms and, one for f(t) = 0 with limits of 0.25ms to 0.75ms.

Answer $c_m = \frac{\sin\left(m\pi/2\right)}{m\pi}$ Equation 2.

2) Use L'Hopital's rule, showing all steps, to prove that c_0 is ½.

3) Calculate c_1 by hand.

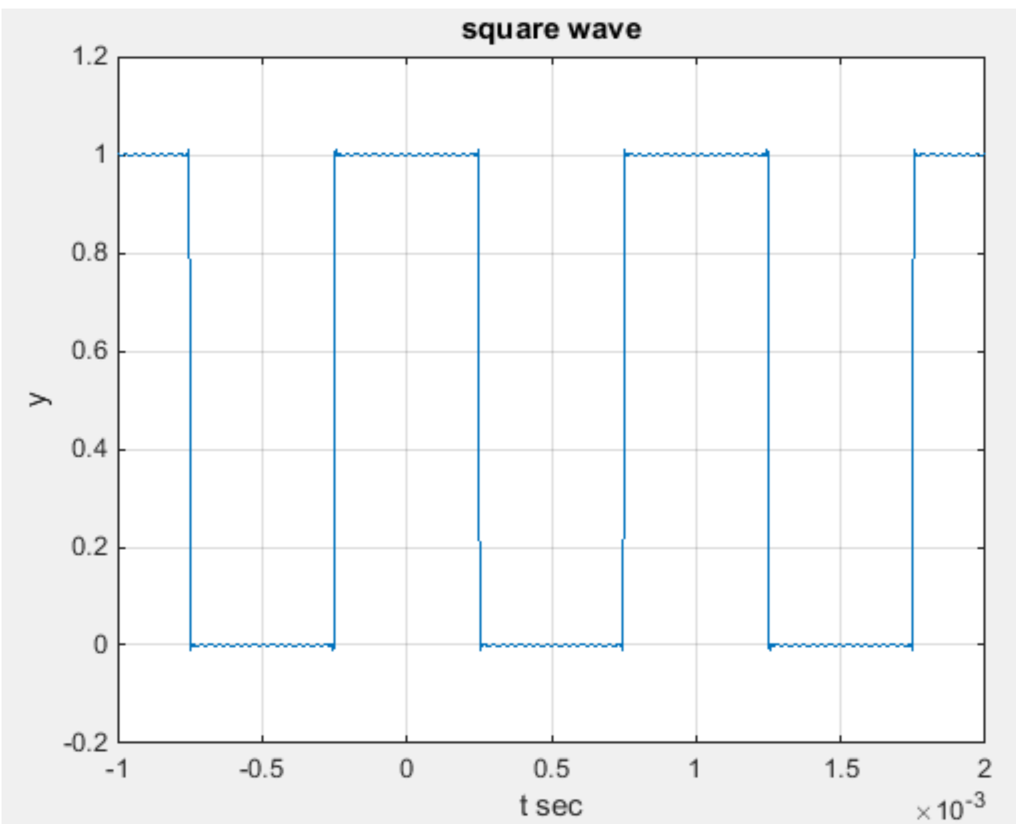

Figure 1

Submit your handwritten solution for steps 1-3 (derivation of c_m, c_0 and c_1) in your report.

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Section 2: Square wave in time and frequency domain

1) Complete the table for the 23 terms (11 harmonics, -11 ≤ m ≤ 11) in table 1 using Equation 2.

m	c_m	$m\omega_o$
-11	-0.02894	-22000π
-10	0	-20000π
-9	0.035368	-18000π
-8	0	-16000π
-7		-14000π
-6		-12000π
-5		-10000π
-4		-8000π
-3		-6000π
-2	0	-4000π
-1	0.31831	-2000π
0	0.5	0
1	0.31831	2000π
2	0	4000π
3	-0.1061	6000π
4	0	
5	0.063662	
6	0	
7	-0.04547	
8	0	16000π
9	0.035368	18000π
10	0	20000π
11	-0.02894	22000π

Table 1

Complete the partial sum of the complex Fourier series (equation 3).

$yin = \sum_{m=-11}^{11} cm * e^{jm\omega_o t} = -0.0289e^{-j22000\pi t} + 0.0354e^{-j18000\pi t} - 0.0455e^{-j14000\pi t} + 0.0637e^{-j10000\pi t} - 0.1061e^{-j6000\pi t} + 0.3183e^{-j2000\pi t} + 0.5 +$
__________ $-$ __________ $+$ __________ $-$
__________ $+$ __________ $-$ __________ Equation 3

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2) Create and complete the script below to regenerate the square wave using the first 11 harmonics and plot the spectrum. Use init.m, create_cm_series.m, cm2yt.m, make_plot.m, and make_stem.m from the last lab. Modify create_cm_series.m using Equation 2 and updating cm(m==0).

Script

```
init();
M = _______ ; % number of harmonics
T = ________; % waveform period
[m,cm] = create_cm_series(M,T); % create Fourier coefficients
t = 0:2e-3/1000:2e-3; % 1001 points from 0 to 2 ms
[y] = cm2yt(t,T,m,cm,M);
make_stem(m,cm,'Spectrum','harmonic','Fourier coefficient');
make_plot(t,y,'square wave with 11 harmonics','t sec','y');
```

Be careful of the common mistakes discussed below.

Common mistakes:

- Forgetting to use the dot operator for dividing './' in create_cm_series.m (when using Equation 2).
- Forgetting to update cm(m==0) in create_cm_series.m
- Entering time in seconds and not milliseconds (1 ms = 1e-3).

3) $c_0 = c_m$(m==0) is the DC offset of the wave. Identity, by hand, how the DC offset is shown on the time domain plot (figure 3) and on the stem plot (figure 2).

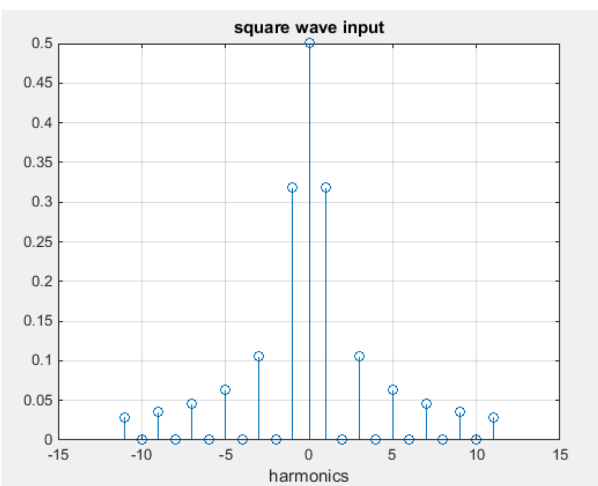

Figure 2

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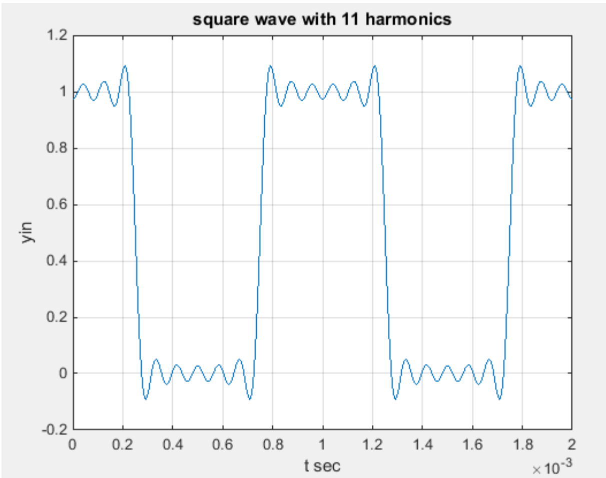

Figure 3

Prepare a completed table 1, completed equation 3, square wave plot (figure 3), and stem plot (figure 2) with DC offset identified on both and get a sign-off. Handwriting is acceptable.

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Section 3: Time delay (tp) – shifting on the x-axis.

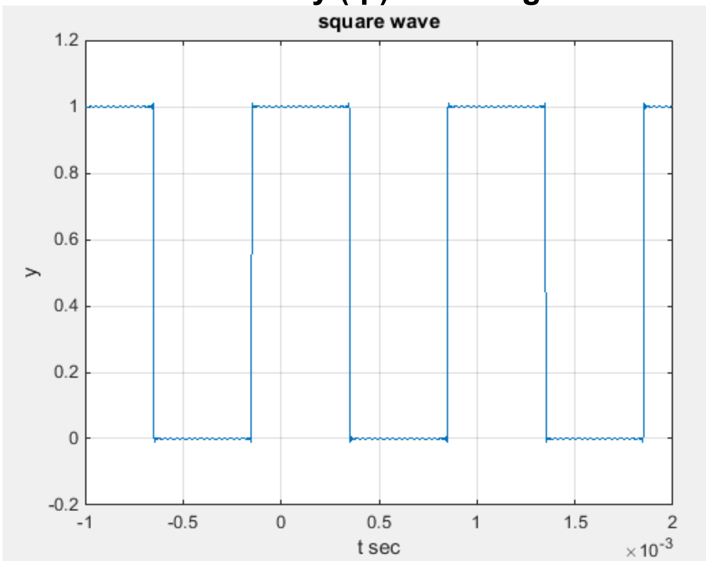

Figure 4 Shifted square wave (NOT partial sum)

1) Complete the Fourier series calculation for a square wave in figure 4 using a square wave that is the same as figure 1 except for a slight shift (delay, tp) to the right. To do this, fill in the blanks for the derivation of cm below.

$$c_m = \frac{1}{T_o}\int_{-0.25ms+tp}^{0.75ms+tp} f(t)e^{-jm\omega_o t}dt$$ Equation 1 repeated with slight delay

a) The integral is separated into two parts because f(t) has two different values (0 and 1) over a full period. Fill in the period and f(t).

$$c_m = \frac{1}{\_\_\_\_\_\_}\int_{-0.25ms+tp}^{0.25ms+tp} \_\_\_\_\_\_\_\_\_\_ e^{-jm\omega_o t}dt + \frac{1}{T}\int_{0.25ms+tp}^{0.75ms+tp} 0 * e^{-jm\omega_o t}dt$$

b) The second integral is zero.

$$c_m = \frac{1}{1E-3}\left(\frac{e^{-jm\omega_o(\_\_\_\_\_\_\_\_)}}{-jm\omega_o} - \frac{e^{-jm\omega_o(\_\_\_\_\_\_\_\_)}}{-jm\omega_o}\right)$$

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d) Separate each exponent into two exponents and replace ω_o with $2\pi/T$ in all cases except the term with the delay, tp.

$$c_m = \frac{1}{-jm2\pi}\left(e^{\_\_\_\_\_\_\_\_\_} - e^{jm2\pi(0.25)}\right)e^{-jm\omega_o tp}$$

e) Separate the denominator and multiply top and bottom by -1 so Euler can be used.

$$c_m = \frac{1}{m\pi}\left(\frac{e^{\_\_\_\_\_\_\_\_\_} - e^{-jm\pi/2}}{\_\_\_\_\_\_\_\_\_}\right)e^{-jm\omega_o tp}$$

f) Write the cm equation from figure 1. Explain what is new or different.

Figure 1: cm =

Figure 4: $c_m = \frac{1}{m\pi}\sin\left(m\,\pi/2\right)e^{-jm\omega_o tp}$

2) The delay in figure 4 is 0.1ms. Fill in the blanks and use them to modify create_cm_series.m (or *.mlx) to make a delayed square wave. Do not forget to use the dot operator for element-by-element dividing and multiplying.

```
wo = 2*pi/T;

tp=___________________________;

cm = (sin(m*pi/2)./(m*pi)).*(exp(-1j*m*_______________*tp)); cm(m == 0) = 0.5;
```

Modify the script from section 3 as follows:

```
t = -1e-3:2e-3/1000:2e-3; % 1001 points from -1 to 2 ms
```

Run the script using the first 11 harmonics to generate the shifted square wave.

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Note: the partial sum you create will be a delayed version of figure 3, not figure 4. If you want the crisp edges shown in figure 4, increase the M value to a few hundred. Any M value can be submitted in the report (you are the engineer, you decide).

Submit figure 4 with tp identified and derivation of cm in your report; a handwritten solution is acceptable.

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Submissions:

Create your own cover page.
Submit your cover page, the requested solutions for sections 1 and 3, and this sign-off sheet.

Sign-offs

Name ______________________

Section 2: Table 1, completed equation 3, square wave plot (figure 3), and stem plot (figure 2) with DC offset identified.

	/ /
Signature	Date