Experiment #1 – Time Division Multiplexing

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# EEL4515 Fundamental of Digital Communications

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# **Experiment Description**

The objective of this experiment is to transmit signals using Time Division Multiplexing. TDM is method of transmitting data when bandwidth is constrained, by allowing one signal to be sent over the channel for brief amount of time.

# **2.0 About Laboratory Day and Equipment List**

# The laboratory session took place on the Thursday section between 9:00am and 11:50am on January 18, 2024. My lab partner was Isiah. The equipment for the is experiment is listed below,

1. USB Flash Drive
2. Rohde & Schwarz RTM 3034 Oscilloscope
3. Tektronix AFG3022 Function Generator
4. DC Power Supply
5. CD4051
6. LM393NG

# **3.0 Experimental Procedure**

For the TDM switch to operate, it requires signal to control switching, for this experiment the lab manual instruct for us to construct a square-wave generator using the following schematic.

A diagram of a circuit

Description automatically generated

Clock Schematic

For this experiment, we used the function generator to generate two sine waves to test this transmission method. The frequencies of the sine waves were: 200 Hz and 400 Hz.

To generate the TDM signal and recover the transmitted signal, we used the CD4051 IC chip in the following configuration,

A circuit diagram of a device

Description automatically generated

Time Division Multiplexing and Demultiplexing Schematic

A circuit board with wires and wires

Description automatically generated

Realized Circuits in Laboratory

# **3.5 Experimental Measurements**

A screenshot of a computer

Description automatically generated

Measured PWM Clock

A screen shot of a computer

Description automatically generated

TDM Signal

A screenshot of a computer

Description automatically generated

Demodulated Signals

Since we were able to complete this laboratory early, we tried to improve the resolution of the demodulated signals. One method of improvement is increasing the switching speed to have fewer flat edges. This can be done by reducing the charging/discharging time of the capacitor in clock circuit. We reduced the capacitor size by 10 (from 0.1 µF to 0.01µF). The following is faster clock signal:

A screenshot of a computer

Description automatically generated

Faster PWM Clock

The 10x reduction in capacitance lead to 10x increase in frequency. Using the faster clock lead to great improvement in signal quality,

A screen shot of a computer

Description automatically generated

Demodulated Signal using Faster clock.

# **4.0 Learned Objectives**

1. Discuss the role of each element of the TDM system.

|  |  |
| --- | --- |
| Component | Purpose |
| PWM Clock | Used to select signal. |
| LM393NG | Used to generate PWM Clock. |
| CD4051 (1) | Switches the current signal to transmit using the PWM clock |
| CD4051 (2) | Outputs message 1 and message 2 from TDM signal by switching output using the PWM Clock |
| Low Pass filter | Used to smooth the output signal and help reduce the stair-edge effect |

2. How to increase the quality of the demultiplexed signals?   
Increase the frequency of the PWM clock as shown above.

3. How to change the frequency of the square wave generated by Figure 1.2(b)?   
By decreasing the time required to charge/discharge the capacitor. This can be done by changing the capacitor value or the resistors values.

4. For each one of the 6 signals plotted in Figure 1.1 (a) & (b), approximately sketch its corresponding spectrum (frequency domain).







# **5.0 MATLAB Code**

Used to generate figure(s)

clear;

clc;

close all;

syms t n

%% Define message signals

m1(t) = cos(2\*pi\*200\*t);

m2(t) = cos(2\*pi\*400\*t);

%% Define clock parameters

Ap = 1;

An = -1;

a(n) = 2\*((Ap\*sin(pi \* n / 2))/(pi \* n) - (An\*sin(pi \* n / 2))/(pi \* n));

f0 = 4000;

a0 = Ap/2 + An/2;

n = 1:2:1001;

a\_eval = eval(a);

a\_terms = a\_eval .\* cos(2\*pi\*f0\*n.\*t);

c(t) = a0 + sum(a\_terms);

fig = figure;

fig.Position = [0, 0, 1280, 720];

centerfig(fig);

t = 0:1/(100\*f0):0.01;

m1\_eval = eval(m1);

m2\_eval = eval(m2);

c\_eval = eval(c);

subplot(2,2,1),plot(t\*1e3, m1\_eval); grid on;

title("200 Hz Signal", "FontSize", 14);

subplot(2,2,2),plot(t\*1e3, m2\_eval); grid on;

title("400 Hz Signal", "FontSize", 14);

subplot(2,2,3);

stem([-200, 200], [1/2, 1/2]);

xlim([-500, 500]);

title("Frequency Spectrum of 200 Hz Signal", "FontSize", 14);

xlabel("Frequency (Hz)", "FontSize", 13);

ylabel("Amplitude", "FontSize", 13);

grid on;

subplot(2,2,4);

stem([-400, 400], [1/2, 1/2]);

xlim([-500, 500]);

title("Frequency Spectrum of 400 Hz Signal", "FontSize", 14);

xlabel("Frequency (Hz)", "FontSize", 13);

ylabel("Amplitude", "FontSize", 13);

grid on;

%% Compute TDM Signal

TDM = zeros(1, length(t));

m1\_rcv = zeros(1, length(t));

m2\_rcv = zeros(1, length(t));

for i=1:1:length(t)

    if c\_eval(i) > 0

        TDM(i) = m1\_eval(i);

        m1\_rcv(i) = TDM(i);

        m2\_rcv(i) = 0;

    else

        TDM(i) = m2\_eval(i);

        m2\_rcv(i) = TDM(i);

        m1\_rcv(i) = 0;

    end

end

fig2 = figure;

fig2.Position = [0, 0, 1280, 720];

centerfig(fig2);

subplot(2,2,1), plot(t\*1e3, c\_eval);

grid on;

xlabel("time (ms)", "FontSize", 13);

title("Clock Signal (2.5 kHz)", "FontSize", 14);

subplot(2,2,2), plot(t\*1e3, TDM);

grid on;

xlabel("time (ms)", "FontSize", 13);

title("TDM Signal", "FontSize", 14);

subplot(2,2,3);

c\_fft = fft(c\_eval);

L = length(c\_eval);

Fs = 100\*f0;

frequencies = linspace(-Fs/2, Fs/2, L);

plot(frequencies, abs(fftshift(c\_fft)));

xlabel("Frequency (Hz)", "FontSize", 13);

ylabel("Magnitude", "FontSize", 13);

title("FFT of c(t)", "FontSize", 14);

grid on;

subplot(2,2,4);

TDM\_fft = fft(TDM);

L = length(TDM);

Fs = 100\*f0;

frequencies = linspace(-Fs/2, Fs/2, L);

plot(frequencies, abs(fftshift(TDM\_fft)));

xlabel("Frequency (Hz)", "FontSize", 13);

ylabel("Magnitude", "FontSize", 13);

title("FFT of TDM Signal", "FontSize", 14);

grid on;

figure

subplot(2,2,1), plot(t\*1e3, m1\_rcv);

title("m\_{1}(t) Signal --- 200 Hz", "FontSize", 14);

xlabel("time (ms)", "FontSize", 13);

subplot(2,2,2), plot(t\*1e3, m2\_rcv);

title("m\_{2}(t) Signal --- 400 Hz", "FontSize", 14);

xlabel("time (ms)", "FontSize", 13);

Fs = 100\*f0; % sampling frequency

m1\_rcv\_fft = fft(m1\_rcv); % fft

L = length(m1\_rcv); % length of signal

frequencies = linspace(-Fs/2, Fs/2, L);

subplot(2,2,3);

plot(frequencies, abs(fftshift(m1\_rcv\_fft)));

xlabel('Frequency (Hz)', "FontSize", 13);

ylabel('Magnitude', "FontSize", 13);

title('FFT of m\_{1}(t) Signal', "FontSize", 14);

grid on;

subplot(2,2,4);

m2\_rcv\_fft = fft(m2\_rcv); % fft

plot(frequencies, abs(fftshift(m2\_rcv\_fft)));

xlabel('Frequency (Hz)', "FontSize", 13);

ylabel('Magnitude', "FontSize", 13);

title('FFT of m\_{2}(t) Signal', "FontSize", 14);

grid on;

# **6.0 Learned Objectives**

* TDM Multiplexing/Demultiplexing
* Method of Generating PWM Signals
* Usage of CD4051
* Usage of Comparator

# **7.0 Conclusion**

In conclusion, the Time Division Multiplexing (TDM) experiment conducted in the Fundamental of Digital Communications laboratory proved to be both informative and practical. The primary goal of transmitting signals under bandwidth constraints using TDM was effectively accomplished through the construction of a square-wave generator for the PWM clock and the use of the CD4051 IC chip for multiplexing and demultiplexing. Experimental measurements, including the PWM clock, TDM signal, and demodulated signals, offered valuable insights. Notably, the decision to optimize signal resolution by increasing the switching speed, achieved through reducing the capacitor size in the clock circuit, yielded a significant enhancement in signal quality, showcasing a practical method for improvement. In summary, the successful execution of the experiment contributes to a deeper understanding of digital communication principles, reinforcing the practical application of TDM in scenarios with limited bandwidth.