EEE3096S-2023

Tutorial 3

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1 Question 1

1.1 Question 1.1: Resolution in bits of the ADC:

Methodology:

- We obtained unique ADC values from the captured data.
- We checked the step sizes (differences) between these consecutive unique ADC values.

```
import pandas as pd

# Load the data from the CSV file
data = pd.read_csv("ramp.csv")

# Get the unique values and their counts
unique_values, counts = data.iloc[:, 0].value_counts().index.to_numpy(), data.iloc[:, 0].value_c

# Sort unique values and their counts
sorted_indices = unique_values.argsort()
unique_values_sorted = unique_values[sorted_indices]
counts_sorted = counts[sorted_indices]

# Calculate the step sizes (differences) between consecutive unique ADC values
step_sizes = unique_values_sorted[1:] - unique_values_sorted[:-1]

unique_values_sorted, counts_sorted, step_sizes
```

Findings:

- The unique ADC values ranged from 14 to 244.
- The total number of unique values are:

$$244 - 14 = 231$$

- Calculating the bit resolution:

$$\log_2(231) = 7.85 \approx 8$$

- An ADC cannot have a resolution that is not an integer therefore we round it up to 8.
- There is a consistent step size of 1 between consecutive unique ADC values.
- Thus, the effective resolution of the ADC is 8 bits.

1.2 Question 1.2: Q (Quantizing) Resolution in Volts:

Methodology:

- For an 8-bit ADC, the maximum value it can represent is 255.
- Given the voltage range from 0 to 2.50 V for this ADC, we calculated the voltage difference represented by a single increment in the ADC value.

Findings & Calculation: The Q (Quantizing) Resolution in volts is given by:

$$\text{Quantizing Resolution (in Volts)} = \frac{\text{Full Scale Range}}{\text{number of voltage intervals}} = \frac{2.50 \text{ V}}{255} \approx 0.0098 \text{ V}$$

- This result means that for every increase of approximately 0.0098 V (or 9.8 mV) in the input signal, the ADC value will increase by 1.

2 Question 2

2.1 Question 2.1: DC Offset Error

Methodology:

- Load the data from `zero.csv`.
- Calculate the mean (average) of the ADC values. This will give us the average value the ADC reads when it should be reading 0 V.
- Convert this mean ADC value to volts using the Q (Quantizing) Resolution that we previously calculated.

```
# Load the data from zero.csv
zero_data = pd.read_csv("zero.csv")

# Calculate the mean ADC value from the zero_data
mean_adc_value = zero_data.iloc[:, 0].mean()

# Convert the mean ADC value to volts using the previously calculated Q
dc_offset_error_volts = mean_adc_value * quantizing_resolution

mean_adc_value, dc_offset_error_volts
```

Findings:

- The mean ADC value, when the input is approximately 0 V, is approximately 14.87.
- The DC offset error of the ADC, when converted to volts using our previously calculated Q (Quantizing) Resolution, is approximately 0.1458 V or 145.8 mV.

2.2 Question 2.2: Spurious-free Dynamic Range (SFDR)

Methodology:

- Identify the peak corresponding to the 80kHz signal (fundamental frequency).
- Identify the highest spurious peak in the spectrum
- SFDR is calculated as the difference in dB between the fundamental frequency and the highest spurious peak.

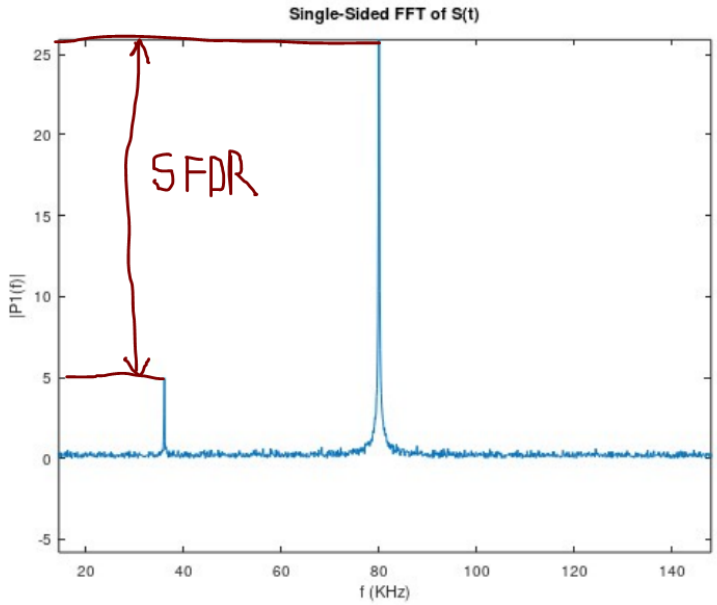

Figure 3: Testing with 80 kHz input, a zoomed in view of frequency plot

Figure 1: FFT Spectrum for SFDR Calculation

Findings:

- In the FFT spectrum, the fundamental frequency (80 kHz signal) was clearly identifiable as a distinct peak at approximately 25.3 dB.
- Among the spurious signals, we identified the highest peak (in magnitude) as 5 dB and used it to compute the SFDR.

$$SFDR = 25.3 - 5 = 20.3 \text{ dB}$$

- The computed SFDR, which represents the difference in dB between the fundamental frequency and the highest spurious peak, came out to be approximately 20.3 dB.

3 Question 3

3.1 Question 3.1: Difference between PWM frequency and its duty cycle

- **PWM Frequency** represents the number of PWM pulses per second.
- **Duty Cycle** represents the percentage of time the PWM signal is high during a cycle.

3.2 Question 3.2: Increasing the brightness of an LED driven by a PWM signal

The brightness of the LED can be increased by **increasing the duty cycle**.

3.3 Question 3.3: Persistence of vision in the context of PWM

- **Persistence of Vision**: It's a phenomenon where the human eye retains an image for a brief moment even after its source has been removed.
- **Why it's useful**: PWM takes advantage of the persistence of vision to simplify circuit designs. Instead of needing complex analog circuitry to control the brightness of an LED, for instance, we can just toggle the LED on and off very quickly, and our eyes will perceive the average brightness. This method simplifies designs and can be more energy-efficient.

3.4 Question 3.4: 555 timer-based circuit for generating a PWM signal

An astable circuit was designed with the 555 timer with the following values:

- $R1 : 1k\ \Omega$
- $R2 : 10k\ \Omega$
- $C1 : 1\ \mu F$
- $C2 : 10\ nF$

$$
\begin{aligned}
f &= \frac{1.44}{(R_1 + 2R_2)C_1} = 68.57 \text{ Hz} \\
T &= \frac{1}{f} = 14.57 \text{ ms} \\
T_{\text{high}} &= 0.694(R_1 + R_2)C_1 = 7.634 \text{ ms} \\
\text{Duty Cycle} &= \frac{T_{\text{high}}}{T} = 52.38\ \%
\end{aligned}
$$

The Duty cycle can be changed by using a variable resistor in place of R2

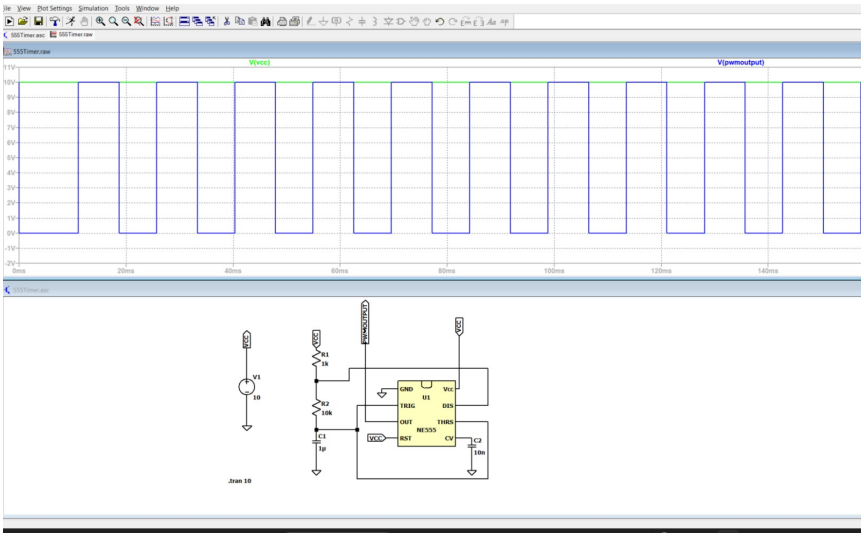

Figure 2: Circuit Design with Simulated Output in LT-SPICE