EEE3096S: Practical 2 report

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I. Introduction

This practical focuses on designing a Digital-to-Analogue Converter (DAC) using Pulse Width Modulation (PWM) on an STM32 microcontroller. The DAC will convert digital signals into analogue waveforms, with a low-pass filter used to smooth the PWM signal into continuous analogue output. By generating sinusoidal, sawtooth, and triangular waveforms stored in lookup tables (LUTs), we look into the concepts of DACs, PWM, and filtering. Additionally, the project includes configuring timers for PWM generation, implementing push button interrupts to switch between waveforms, and using STM32CubeIDE with HAL libraries to program the desired results.

II. Method

Hardware:

The experiment involved setting up a Digital-to-Analog Converter (DAC) using Pulse Width Modulation (PWM) and a low-pass filter. The hardware used included:

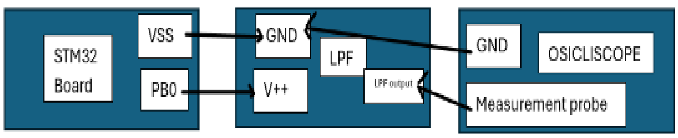
STM32 Development Board: The microcontroller platform used for generating PWM signals and handling interrupts.

Breadboard: Used for assembling the low-pass filter circuit.

Oscilloscope: To measure and verify the output waveforms.

Signal Generator: For testing and validating the filter performance.

Block Diagram:



The hardware setup is illustrated in figure above, showing the connections between the STM32 development board, the low-pass filter on the breadboard, and the oscilloscope.

Implementation:

Three lookup tables (LUTs) must be created for sinusoidal, sawtooth, and triangular waveforms, each with 128 values. In order to ensure accurate results, these LUTs must be plotted in MATLAB and then integrated into the STM32CubeIDE project. TIM2 must then be configured to cycle through the LUT values with a clock frequency of 8 MHz, and TIM3 must be set up in PWM mode on Channel 3 which correlates to PB0.Next, start the Direct Memory Access (DMA) in Interrupt mode, and use the LUTs to update the PWM duty cycle via CCR3 register. An interrupt on the PA0 pushbutton must be implemented to switch between waveforms, with debouncing handled using HAL_GetTick. A low-pass filter using a 10k Resistor and 15nF capacitor must then be constructed and tested with a signal generator and oscilloscope, confirming proper signal filtering. The output waveforms are then verified on an oscilloscope to ensure correct operation.

LUT Generation:

MATLAB code was used to generate and plot LUTs for each waveform type:

```
Command Window
>> % Parameters
Fs = 1000;             % Sampling frequency in Hz
T = 1/Fs;             % Sampling period (time between samples)
L = 1000;             % Length of signal (number of samples)
t = (0:L-1)*T;        % Time vector

% Frequency of the waveforms
f = 5;                % Frequency in Hz

% Generate waveforms
sine_wave = sin(2*pi*f*t);
sawtooth_wave = sawtooth(2*pi*f*t);
triangle_wave = sawtooth(2*pi*f*t, 0.5);
```

III. Discussion

A LUT(Look up table) is a list of predefined values , which is used to speed up the program by avoiding recalculating values. In this program, the function of the LUTs was to store values that had been predetermined to create different waveform shapes (Sine, Sawtooth, Triangle). Each LUT contains one complete cycle of each wave in a digital format which is then outputted as an analogue value.

The timers were used and played a crucial role at controlling the rate at which the development board steps through the LUTs to redesign the analogue signal waveforms from the input data in the LUTs. This was done using PWM configuration, where TIM3's PWM signal was updated using the data from the LUTs through DMA data transfers. TIM2 was used to trigger DMA transfers at frequencies corresponding to the signal frequency.

Direct Memory Access (DMA) performed a valuable role in transferring values from the appropriate LUT to TIM3. In order to avoid the incorrect DMA transfers, when one interchanged between different waveforms, the DMA transfer would first be aborted and then re-enabled once a new waveform cycle of a different wave shape began.

IV. RESULTS

In this lab, we examined triangle, sine, and sawtooth analogue waveforms generated by Digital-to-Analog Converter (DAC), which were initially simulated in MATLAB. At first, we encountered significant noise in the waveforms due to not grounding the VSS on the STM32 microcontroller. This noise interfered with accurate waveform observation. Additionally, the oscilloscope would zoom in significant when auto scaled, which made it difficult to view the waveforms clearly. Given the DAC's limited resolution, we had to zoom out significantly to properly observe the waveforms. Throughout the experiment, the waveforms were analysed through a low-pass filter, consisting of a 10 kΩ resistor and a 15 nF capacitor, which effectively attenuated signals above 1 kHz and reduced high-frequency noise. Once these issues were addressed, the triangle wave displayed a linear rise and fall, the sine wave was smooth and periodic, and the sawtooth wave showed a linear ramp with a sharp drop. These results showed the importance of proper grounding and oscilloscope scaling to accommodate the limitations of the crude DAC and ensure accurate waveform representation.

V. CONCLUSION

References

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