Signal Processing and Analysis Module Projects

Electronics I · Circuit Theory II · Signals and Systems

Sivas University of Science and Technology

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Contents

The following table lists the projects integrated across the three module courses:

Project 1: Water Level Indicator

Overview

Design and implement a system to monitor water level, providing a digital output (LEDs) and an acoustic warning signal when a critical level is reached.

Electronics I Tasks

- **E1) Sensor Interface & Switching:** Design a transistor-based switching circuit to interface the low-voltage level sensors with the digital logic/display section. Determine appropriate current-limiting resistors and transistor types.
- **E2) Output Driver:** Design an audio amplifier stage, using an Op-Amp or discrete transistor, to drive a small speaker or buzzer for the acoustic alarm.

Circuit Theory II Tasks

- **D1) Transient Analysis:** Model the capacitance or impedance change of the water probes in the tank. If using an RC timing circuit for debouncing the sensor signal, analyze its step response and calculate the RC time constant RC for a required delay.
- **D2) Frequency Filtering:** Design a simple passive RLC or active RC filter (e.g., a low-pass filter) to eliminate high-frequency noise induced by the sensor wires before the signal enters the logic stage. Calculate the cutoff frequency.

Signals and Systems Tasks

- **S1) Signal Modeling:** Model the acoustic alarm signal as a discrete-time sequence $x[n]$ (e.g., a pulse train or a sampled sinusoid). Define its frequency and period in the discrete-time domain.
- **S2) System Response:** If a digital chip is used, analyze how a continuous-time water level signal $x(t)$ would be sampled and quantized, discussing the effects of aliasing based on the chosen sampling rate T_s.

Project 2: Mobile Phone Charger

Overview

Design a step-down (buck) converter circuit to transform a higher input voltage (e.g., 12V) into a regulated 5V output for mobile phone charging.

Electronics I Tasks

- **E1) Power Semiconductor Selection:** Select the appropriate switching element (MOSFET/BJT) for the buck converter, considering parameters like saturation voltage, switching speed, and current rating.
- **E2) Control Circuit:** Design the basic feedback network using an Op-Amp or comparator to regulate the output voltage against load changes.

Circuit Theory II Tasks

- **D1) RLC Output Filter Design:** Determine the values of the inductor L and capacitor C in the output filter of the buck converter to meet specifications for maximum output voltage ripple ΔV_{out} and minimum load current.
- **D2) Steady-State Analysis:** Derive the relationship between the duty cycle D and the input/output voltages ($V_{out} = DV_{in}$) and calculate the converter's power efficiency (η) based on component losses (ESR of C, resistance of L).

Signals and Systems Tasks

- **S1) Pulse Width Modulation (PWM) Signal:** Model the PWM signal driving the MOSFET as a periodic signal x(t) and compute its Fourier Series coefficients. Discuss which harmonics contribute to the output ripple.
- **S2) System Transfer Function:** Approximate the buck converter's filter stage (LC filter) as a linear system and find its transfer function $H(s)$ in the s-domain. Use this to analyze the system's stability and frequency response.

Project 3: FM Radio (Intermediate Frequency Filter)

Overview

Design the key stages of a simple FM receiver, focusing on tuning, filtering, and demodulation.

Electronics I Tasks

- **E1) RF Amplifier Stage:** Design a basic **high-frequency amplifier** using a BJT or FET to boost the weak antenna signal. Analyze its small-signal gain A_v.
- **E2) Mixer/Local Oscillator:** Explain the principle of down-converting the RF signal to an Intermediate Frequency ***IF*** using a non-linear element (mixer) and a local oscillator.

Circuit Theory II Tasks

- **D1) LC Tuning Circuit:** Design the **LC** tank circuit used for station selection, ensuring it resonates at the desired RF carrier frequency f_c. Calculate the required L and C values for a target frequency (e.g., 90 MHz).
- **D2) IF Filter Analysis:** Analyze the transfer function H(s) of the IF filter (e.g., a bandpass filter centered at 10.7 MHz). Determine its Quality Factor (Q) and Bandwidth (BW) to ensure adequate selectivity.

Signals and Systems Tasks

- **S1) Frequency Modulation (FM) Model:** Write the mathematical expression for the FM signal x(t) given a modulating message signal m(t) and carrier frequency w_c. Sketch its approximate magnitude spectrum in the frequency domain.
- **S2) Filtering Impact:** Analyze the effect of the IF bandpass filter (viewed as a linear time-invariant system) on the FM signal using the concept of **convolution** in the time domain or multiplication in the frequency domain.

Project 4: Simple Function Generator

Overview

Design a circuit capable of generating square, triangular, and sinusoidal waveforms at a selectable frequency, using Op-Amps.

Electronics I Tasks

- **E1) Square/Triangular Wave Generator:** Design an Op-Amp relaxation oscillator and an integrator circuit to produce simultaneous square and triangular waves. Specify the required Op-Amp characteristics.
- **E2) Sine Wave Shaping:** Design a basic diode-clipper/shaper circuit to convert the triangular wave into an approximation of a sinusoidal wave.

Circuit Theory II Tasks

- **D1) Oscillation Frequency Derivation:** For the square wave generator, use circuit analysis (e.g., node analysis) to derive the formula for the oscillation period **T** based on the RC components and Op-Amp saturation voltages.
- **D2) Stability Analysis:** Analyze the stability of the sinusoidal output stage (if using a separate oscillator like Wien Bridge) by examining the poles and zeros of the loop transfer function H(s).

Signals and Systems Tasks

- **S1) Fourier Series & Synthesis:** Write the Fourier Series expansion for the ideal square wave and triangular wave outputs. Use this to discuss the minimum bandwidth required for an amplifier to pass the waveforms without significant distortion.
- **S2) System Block Diagram:** Represent the entire function generator as an interconnected block diagram of linear and non-linear systems (integrator, comparator, filter/shaper).

Project 5: Bus Card Detector

Overview

Design a system that detects the presence of a card, simulated by a metallic object or a coupled coil, using inductive principles, displaying the result visually.

Electronics I Tasks

- **E1) RF Excitation Circuit:** Design a simple, fixed-frequency LC oscillator/driver circuit to generate the RF magnetic field necessary for inductive coupling.
- **E2) Detection/Rectification:** Design a diode-based peak detector/rectifier circuit to convert the tiny RF voltage induced or coupled onto the receiver coil into a measurable DC level change, which can then trigger an LED/logic.

Circuit Theory II Tasks

- **D1) Mutual Inductance and RLC Model:** Model the transmitter and receiver coils as a coupled system with mutual inductance **M**. Analyze how the card's presence changes the equivalent impedance of the transmitter coil Z_{eq}.
- **D2) Frequency Response:** Analyze the frequency response $|Z(jw)|$ of the primary LC tank circuit, detector coil. Determine how its bandwidth and quality factor Q influence the sensitivity of the detection.

Signals and Systems Tasks

- **S1) Modulated Response:** If the card causes a periodic change in the coil's quality factor, model the induced voltage as a continuous-time signal y(t) and analyze how the card's movement frequency is reflected in the signal's frequency spectrum.
- **S2) Low-Pass Filtering:** Design a simple digital filter using difference equations to smooth the noisy DC output of the peak detector, outlining the filter's effect on the system's response time, latency.

Project 6: Toy Piano

Overview

Design a circuit that produces distinct musical tones with notes upon button presses and drives a small speaker.

Electronics I Tasks

- **E1) Tone Generation/Oscillator:** Design a 555 Timer circuit (or similar Op-Amp based oscillator) to generate the square wave tones for one octave. Calculate the RC values required for at least two specific musical notes, frequencies.
- **E2) Audio Amplification:** Design a push-pull or single-ended audio power amplifier stage to interface the low-power tone signal with the low-impedance speaker.

Circuit Theory II Tasks

- **D1) Frequency Calculation:** For the tone generation circuit, derive the formula linking the component values, such as resistors, capacitors, to the output frequency **f** of the square wave. Use this to create a component table for all required notes.
- **D2) RL Load Analysis:** Model the speaker as a series RL load and analyze the transient response of the amplifier output when a note starts, for instance, when the square wave instantaneously changes level.

Signals and Systems Tasks

- **S1) Discrete-Time Tone Generation:** Model a generated note with square wave as a periodic discrete-time signal **x[n]** and define its fundamental period N and frequency w.
- **S2) Speaker as a Filter:** Approximate the speaker's physical response which is acoustic output, as a linear system **H(w)**. Discuss how the speaker's frequency response shapes the perceived sound, namely, how the sharp harmonics of the square wave are attenuated.

Project Groups

Grup-1(Project-1)	Grup-2(Project-5)	Grup-3(Project-2)	Grup-4(Project-6)
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***Report submission deadline**: 12.01.2026

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* The presentations will be held during the final exam week, and the exact date will be announced at a later time.