Project Manual

Simulation Steering Wheel

ESCE 2010 - Fall 2025

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Project Resources

LTSpice Simulation File:
Google Drive Link to .asc File

CRITICAL REQUIREMENT

KEY REQUIREMENTS FOR YOUR PROJECT MANUAL:

1. **Complete schematic with ALL components labeled -** especially inputs, outputs, and frequently mentioned parts
2. **Block diagram that matches circuit functionality**
3. **Design equations for EACH building block -** show how input/output relate
4. **Justify ALL component choices** with specific reasoning
5. **Input/output plots** for each building block (measured or simulated)
6. **Integration section** explaining how blocks connect and work together
7. **At least 2 limitations per Milestone** (at least 1 must be electrical)
8. **At least 1 tradeoff per Milestone**
9. **At least 1-2 improvement suggestions**

Contents

1 Description

1.1 Complete Schematic and Block Diagram

CRITICAL REQUIREMENT

REQUIRED: Schematic must be easy to read with labeled input, output, and all important components. Block diagram functionality must match circuit schematic.

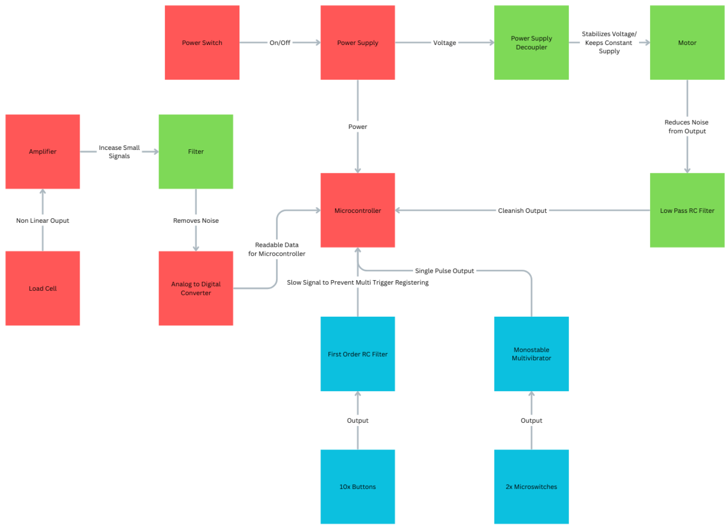

Figure 1: Complete circuit schematic - ALL major components must be clearly labeled

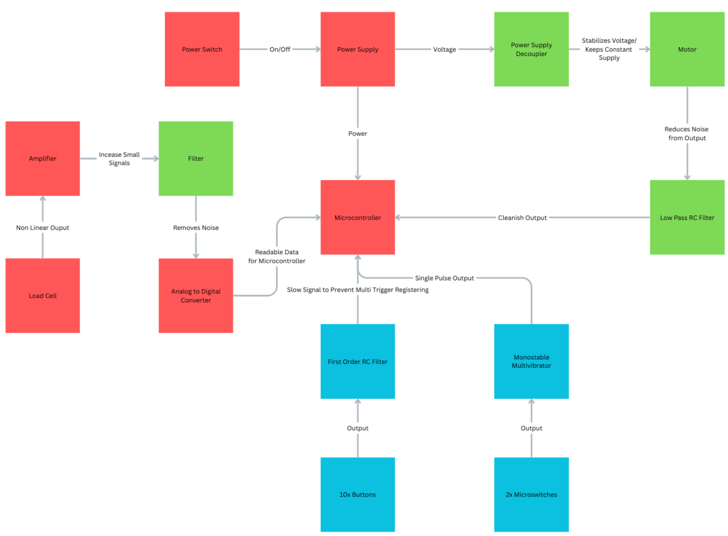

Figure 2: Block diagram showing functional relationships between stages

1.2 High-Level Description of Operation and Intended Application

[REQUIRED: Describe in layman's terms what problem you're solving]
What does your circuit do? [Explain at a high level - avoid technical jargon]
What problem are you solving? [Real-world application or use case]
How does your circuit solve it? [High-level operation of building blocks]
Example: "This circuit detects light levels and automatically controls an LED brightness. When ambient light is low, the LED brightens to provide illumination. This is useful for automatic night lights or solar-powered lighting systems."

1.3 Description of Related Pre-Existing Applications

CRITICAL REQUIREMENT

REQUIRED: Demonstrate research on your application. Show that research helped formulate your design. Highlight approaches you did NOT choose and explain why.

[Research existing solutions to your problem]
Existing Approach 1: [Describe commercial or existing solution]

- How it works: [brief description]
- Advantages: [list benefits]
- Why you didn't choose it: [cost, complexity, performance, etc.]

Existing Approach 2: [Alternative solution]

- How it works: [brief description]
- Why you didn't choose it: [reasoning]

Your Design Decision: [Explain why your approach is better/different]

2 Operation and Design

2.1 Input Block

CRITICAL REQUIREMENT

REQUIRED: Labeled schematic, design equation OR input/output plot from datasheet, and measured/simulated I/O plot. Only need to fully describe 1 input block if you have multiple.

2.1.1 Schematic

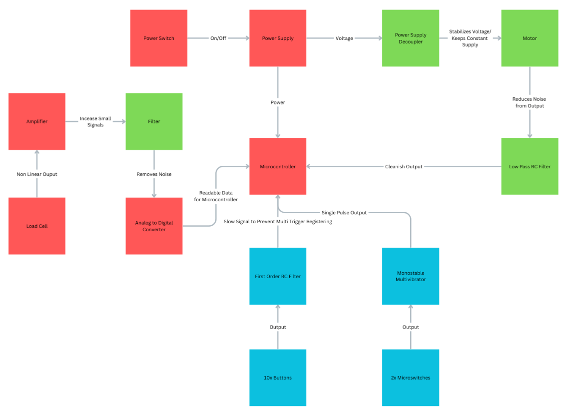

Figure 3: Input block schematic with ALL components labeled

2.1.2 Design Equation

$$V_{out} = f(V_{in}) \tag{1}$$

where all variables are defined here or in the schematic.

2.1.3 Input/Output Plot

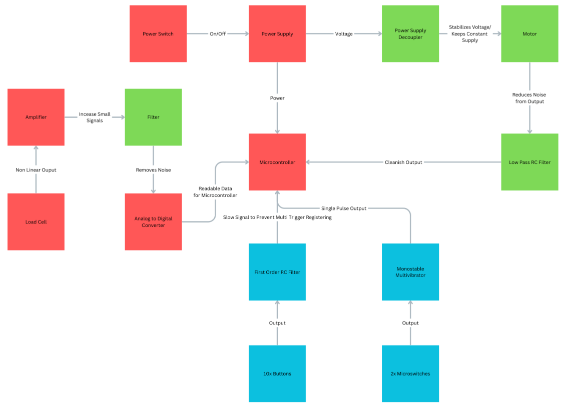

Figure 4: I/O characteristic - from measurement, simulation, or datasheet (cite source!)

2.2 MS1 Building Block 1: [Give it a descriptive name]

CRITICAL REQUIREMENT

REQUIRED FOR EACH BUILDING BLOCK:

- Labeled schematic in isolation (not connected to full circuit)
- Symbolic design equation(s) - no need to show derivations
- Discuss specific component values and WHY you chose them
- Input/output plot from measurement or simulation with labeled axes

2.2.1 Schematic

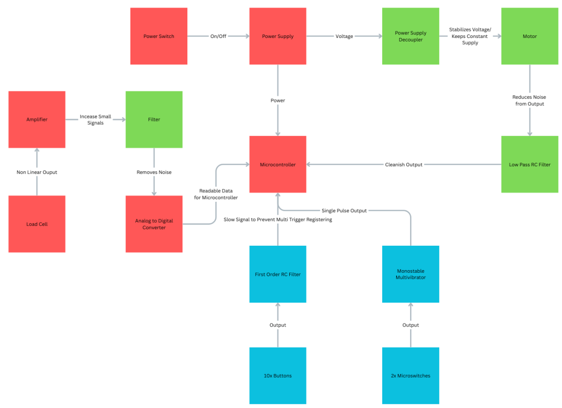

Figure 5: Building Block 1 in isolation - label ALL components in schematic or define in text

2.2.2 Design Equation

$$V_{out} = -\frac{R_f}{R_{in}} V_{in} \tag{2}$$

Define all variables:

- V_{out} = output voltage [units]
- V_{in} = input voltage [units]
- R_f = feedback resistor [value and units]
- R_{in} = input resistor [value and units]

2.2.3 Discussion of Component Choices

[CRITICAL: Justify every component value with specific reasoning]

Example format:

- $R_f = 10k\Omega$**:** "We chose this value to achieve a gain of -10, which amplifies our sensor output from 0.1V to 1V to match the range needed for the next stage."
- **Op-amp selection:** "We selected the LM741 because it has adequate bandwidth (1MHz), is readily available, and costs under $1."
- **Power supply:** "$\pm 15V$ supplies ensure $\pm 10V$ output swing without clipping."

2.2.4 Input/Output Plot

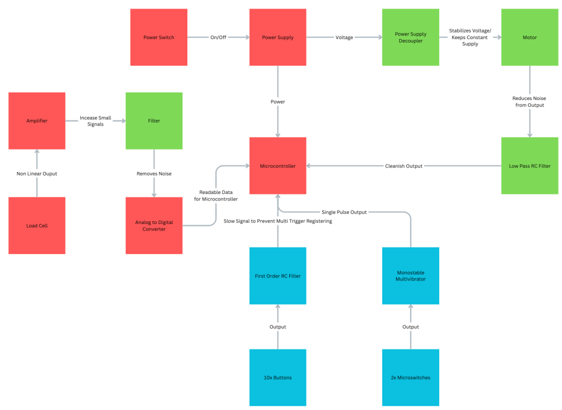

Figure 6: Measured/simulated I/O for BB1. Axes must be labeled. Relate to design equation.

2.3 MS1 Building Block 2: [Descriptive name]

CRITICAL REQUIREMENT

NOTE: If you have more than 2 building blocks in one milestone, you only need to fully describe 2 of them here. The others will be described in Integration section.

2.3.1 Schematic

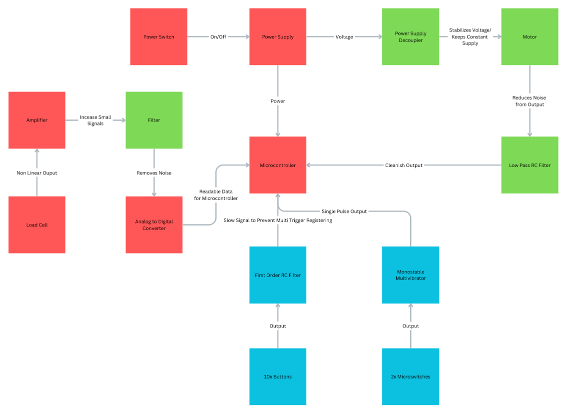

Figure 7: Building Block 2 schematic (isolated)

2.3.2 Design Equation

$$f_c = \frac{1}{2\pi RC} \tag{3}$$

2.3.3 Discussion of Component Choices

[Explain WHY you chose specific values - see example in BB1]

2.3.4 Input/Output Plot

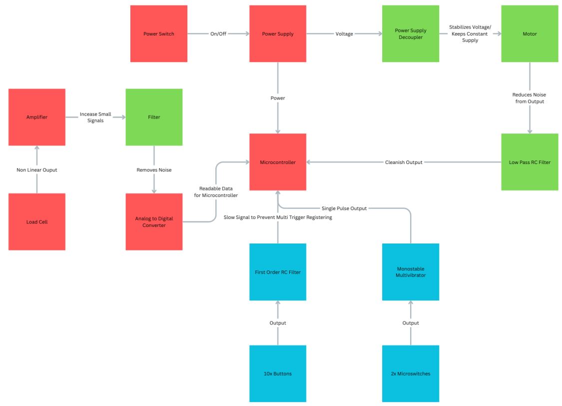

Figure 8: I/O characteristic for Building Block 2

2.4 MS2 Building Block 1: [Name]

[Add additional building blocks for Milestone 2 and 3 using same format]

2.5 MS2 Building Block 2: [Name]

[Continue pattern...]

2.6 Output Block

CRITICAL REQUIREMENT

REQUIRED: Same format as Input Block - schematic, equation, plot

2.6.1 Schematic

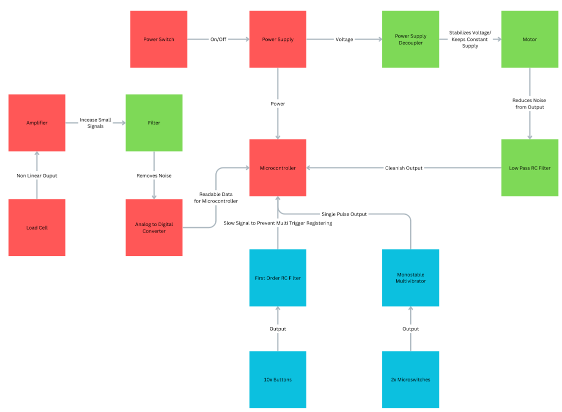

Figure 9: Output block schematic

2.6.2 Design Equation

$$I_{out} = \frac{V_{in}}{R_L} \tag{4}$$

2.6.3 Input/Output Plot

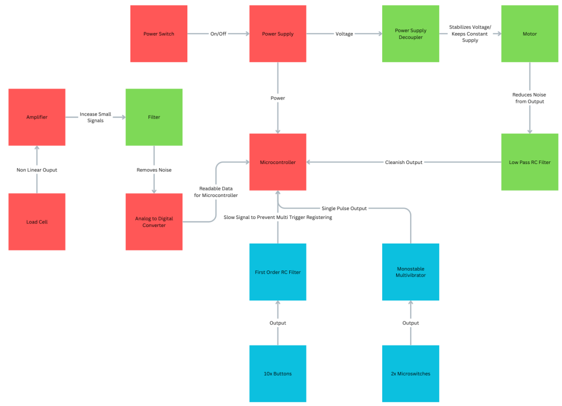

Figure 10: Output characteristic

3 Integration and Optimization

CRITICAL REQUIREMENT

REQUIRED IN THIS SECTION:

- Describe LOW-LEVEL operation (voltages, currents, frequencies)
- Start with input, step through EACH building block to output
- Explain how you designed blocks to connect together
- Reference building block equations
- Discuss any integration issues
- Plot overall input/output of integrated circuit

3.1 Signal Path and Circuit Operation

[Walk through the complete signal path from input to output]

Step 1 - Input Stage: The [sensor/source] produces [voltage range]. Using Equation 1, this signal is [processed how], resulting in [output characteristic]. We designed the output impedance to be [value] to properly drive the next stage.

Step 2 - Building Block 1: From Building Block 1, the signal [describe transformation]. According to Equation 2, the gain of [value] amplifies [input range] to [output range]. We chose component values to ensure [design consideration].

Step 3 - Building Block 2: [Continue describing each transformation, referencing equations]

[Continue for all building blocks...]

3.2 Design Decisions for Integration

[Explain how you made blocks work together]

- **Impedance matching:** [How you ensured proper loading]
- **Voltage levels:** [How you prevented saturation/clipping]
- **Frequency response:** [How you coordinated bandwidths]

3.3 Integration Issues and Solutions

Issue 1: [Problem encountered]
Cause: [Root cause]
Solution: [How you fixed it]
Result: [Improvement achieved]

3.4 Overall System Performance

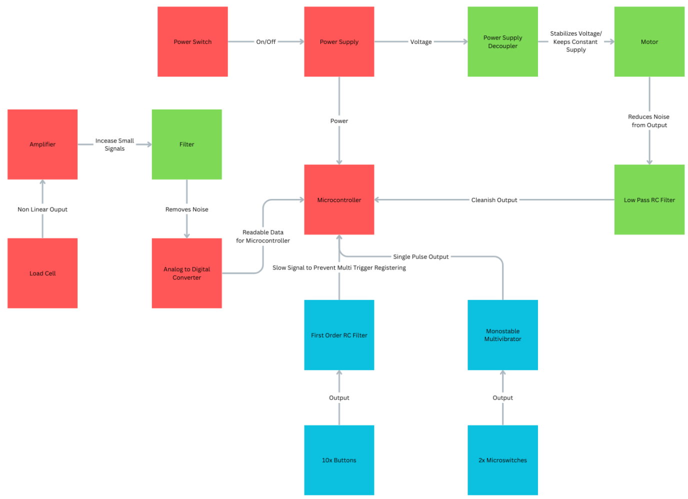

Figure 11: Overall input-output of integrated circuit

4 Operating Conditions

4.1 Circuit Limitations

CRITICAL REQUIREMENT

REQUIREMENTS:

- At least 2 limitations per Milestone
- At least 1 MUST be electrical and demonstrate circuit understanding
- Write about 1 paragraph per limitation
- CAN discuss situations where circuit doesn't work but you don't fully understand why (with educated guess)
- DO NOT say obvious things like "cannot be used in water"
- DO NOT discuss irrelevant specs like op-amp voltage ratings if they don't affect your application

4.1.1 Limitation 1: [Title - Make it electrical/circuit-related]

[Example: Frequency Response Limitations]

The circuit exhibits [specific behavior] when [conditions]. This limitation arises from [electrical explanation - e.g., op-amp gain-bandwidth product, RC time constants, slew rate, etc.].

[Explain the electrical/circuit reason in detail - about 1 paragraph]

This restricts the circuit's use to [operational range] because [consequences]. For example, [specific example of when it fails].

4.1.2 Limitation 2: [Title]

[Another electrical or application limitation]

[Paragraph explaining the limitation, its cause, and impact]

4.1.3 Limitation 3: [Optional additional limitation]

[If you observed something doesn't work but aren't sure why:]

"Sometimes [describe behavior]. We believe this may be due to [educated guess based on circuit theory - e.g., thermal effects, component tolerance, noise coupling, etc.]."

4.2 Design Tradeoffs

CRITICAL REQUIREMENT

REQUIRED: At least 1 tradeoff per Milestone. A tradeoff is when two desirable features conflict.
Example: "Increasing laser distance requires more current, but this increases power consumption and reduces battery life."

4.2.1 Tradeoff 1: [Title describing the competing objectives]

[Example: Gain vs. Bandwidth Tradeoff]

Our design faces a fundamental tradeoff between [feature A] and [feature B].

The conflict: Increasing [feature A] requires [action], but this causes [feature B] to [decrease/worsen] because [circuit theory explanation].

Mathematical relationship:

$$[Showequationthatdemonstratesthetradeoff] \tag{5}$$

Our decision: We chose [your compromise] because [reasoning based on application requirements]. This provides [benefit] while accepting [limitation].

Alternative not chosen: We could have [other option], which would give [different benefit] but would sacrifice [what you'd lose].

4.3 Potential Improvements

CRITICAL REQUIREMENT

REQUIRED: Discuss 1-2 ways the circuit could be improved, even if not achievable due to time/cost constraints.

4.3.1 Improvement 1: [Title]

The [current limitation or performance metric] could be improved by [specific technical solution].

How it would work: [Explain the technical approach]

Expected benefit: [Quantify improvement if possible - e.g., "would reduce noise by 10dB" or "extend bandwidth to 1MHz"]

Why not implemented: [Cost, time, complexity, or other constraints]

4.3.2 Improvement 2: [Title]

[Another concrete improvement with technical details]

Appendix: Component List

Table 1: Bill of Materials

Component	**Value/Part**	**Qty**	**Notes**
Op-Amp	LM741	2	General purpose
Resistor	$1k\Omega$	3	5% tolerance
Resistor	$10k\Omega$	2	5% tolerance
Capacitor	$1\mu F$	2	Electrolytic
LED	Red 5mm	1	Standard