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Lab 2 Manual
EECE1195: Digital Electronics II

Objectives

This lab extends your knowledge from Lab 1 – Digital Combination Lock by integrating its output with a DC motor soft-starter circuit.
You will design and simulate a combinational logic system with a latching sequential system to control a three-stage DC motor soft start, driven by relay control.

System Description

1. Integration with Lab 1

- The Unlock LED output from your Lab 1 Combination Lock is used as the Enable input for this soft-starter.
- When the correct 3-digit code is entered and the Test button is pressed, the Unlock LED goes HIGH.
- That HIGH signal enables the Start/Stop latch in this Lab 2 circuit.
- Once the motor is running, changes in the code do not affect operation until the Stop button is pressed.
  - After the motor is stopped, the system again checks the Lab 1 Enable signal before any new Start can occur.
  - This ensures security: the motor can only start when the correct code is entered, but accidental code changes during operation will not interrupt running equipment.

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2. Functional Blocks

A. Start/Stop Control –Latch

- Two momentary pushbuttons: Start (Set) and Stop (Reset).
- The latch output (RUN signal) remains HIGH after Start is pressed and LOW after Stop.
- RUN LED indicates motor ON state.
- RUN output feeds the relay-driver logic that close the motor circuit and start running the motor.
- The latch operates only if the Enable (from Lab 1) = HIGH.

B. Soft-Start Sequence – Three Resistor Stages

- The motor is powered through three series resistors (R_1, R_2, R_3) at startup.
- Relay 1, Relay 2, Relay 3 each have a normally open (NO) contact across one resistor.
- When the system starts, relays energize one by one, gradually bypassing the resistors to increase voltage and speed:
    1. Stage 1: All three resistors in series → minimum current (motor begins turning).
    2. Stage 2: Relay 1 ON → R_1 bypassed.
    3. Stage 3: Relay 2 ON → R_2 bypassed.
    4. Stage 4: Relay 3 ON → R_3 bypassed → motor at full voltage.
- Voltage across the motor and the current through the motor must be measured using Digital Multimeters.

C. Relay Driver –Transistor / Transistor Array

- Each relay coil is driven by a transistor or one channel of a ULN2003 transistor array.
- The transistor input or ULN2003 inputs receive logic signals from your circuit, and its outputs energize the relay coils.
- Fly-back diodes across the relay coils are needed to protect your logic circuit from inductive spikes.

D. Power Components

- Select a 12 V DC motor (obtain its datasheet).
- Determine R_1, R_2, R_3 values based on motor rated current.
    - Example: $R = \frac{V_{drop}}{I_{motor}}$
    - Ensure $P = I^2R \geq$ resistor power rating.
- Choose 12 V relays with coil current < 500 mA.

Process Sequence (System Operation)

1. **Code Entry (Lab 1):**
    - Student enters their 3-digit code using DIP switches.
    - Press Test → If code matches → Unlock LED = HIGH (Enable = 1).
2. **Ready State:**
    - Enable = 1 and system awaiting Start.
    - RUN LED OFF.
3. **Start Sequence:**
    - Press Start → latch sets → RUN LED ON → Run Relay closes the motor circuit.
    - Relays activate sequentially: R_1→bypassed, then R_2→bypassed, then R_3→bypassed.
    - Motor voltage rises gradually to 12 V (soft start achieved).
4. **Running State:**

- Motor at full speed.
- If student changes DIP-switch code, system continues running (Enable is not re-checked until stop).

5. **Stop Sequence:**
    - Press Stop → latch resets → RUN LED OFF → Run Relay OFF and opens the motor circuit → motor stops.
    - All relays de-energize → resistors re-inserted.
    - Enable is checked again before any next Start.

Design Requirements

1. **Software: Use Multisim.**
2. **Inputs:**
    - Start pushbutton
    - Stop pushbutton
    - Enable signal (from Lab 1 Unlock LED)
3. **Outputs:**
    - RUN LED (& Run relay control)
    - Three relay controls
4. **Power Stage:**
    - Transistors → Relays → Motor + Resistors.
5. **Simulation:** Include realistic relay models and 12 V motor.
6. **Labels:** All signals must be named clearly in the simulation.

Deliverables

Each student (or pair for bonus) must submit a ZIP folder containing:

1. **Multisim file (.ms14) – fully labeled circuit.**
2. **Demonstration Video (1–3 minutes) (MUST with verbal description)**
    - Show Lab 1 Enable going HIGH.
    - Demonstrate Start/Stop operation.
    - Display relays energizing sequentially (soft start).
3. **Design Report (PDF):**
    - Circuit description and sequence of operation.
    - Latch truth table.
    - Logic expressions for relay control.
    - Power and resistance calculations.
    - Screenshots of simulation results.

4. **Component List and Cost Analysis (Table):**
    - List all components (motor, relays, transistors, resistors, LEDs, ICs, pushbuttons, etc.)
    - Include unit cost and total project cost (Digikey online prices).
5. **Optional Relay LED Indicators (for visual confirmation).**

Bonus (+25%) – Hardware Implementation

Students may work in pairs for hardware construction.

Requirements:

1. Assemble the circuit on breadboard or PCB.
2. Demonstrate Start → soft start → Stop sequence.
3. Use actual ULN2003 chip to drive relays.
4. Record a 2 minute video showing the real operation.
5. Hardware report must include a photo of the assembled circuit and measurements (voltages or currents).

Submission Details

- Due Date: Thursday, February 11, 2026 @ 11:59 PM
- Submission: file via eConestoga including simulation, video, report
- Group Work: Allowed only for hardware implementation (max 2 students)

Extra Notes Paper