Design Proposal for RS-485 Communications Tester

EE 391
Electrical Engineering Design I, Spring 2007
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Customer:
LED Effects Inc.

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Project Description

LED Effects is a California-based company that manufactures LED lighting displays that go on the sides of multi-story buildings. Installation of these displays require thousands of LED's encased in panels to be connected to a central controller. The abundance of wires and connections in a typical installation desires a sophisticated testing routine to ensure that proper installation did indeed take place.

The EE391 design project's purpose is to design a tester for the RS485 Data Communication lines to detect errors such as crosses to AC as well as other line parameters. The tester will also have the ability to initiate and receive known communications between its components to test verify data integrity. The design will initially focus on using the DMX Protocol and later parallel firmware revisions will support alternate protocols such as LED Effects Protocol. The end usage of the device will be to test line integrity and wiring during the installation of LED Panels.

The design will consist of two units, a Roving Tester and a Data Source, that will interact with each other over the bus to verify the correct wiring of the bus and connectivity to the source unit of the bus with at correct speed, as well as checking the DC supply voltages provided to the led panels. The device must be configurable and adaptable to tolerate all current and future designs that may arise.

Specifications:

Roving tester:

- Test for overvoltage/AC on the all lines.
- Check Polarity of data lines.
- Check for both sides of twisted pair.
- Initiate Bi-Directional Communications of known test signal....
- Aggregate and display results for user
- Battery Powered

Data Source:

- Transmit known signal when prompted by roving tester, verify roving tester signal and send verification/aggregated received packet quality....
- Also needs overvoltage/ac protection with basic line quality test procedures
- Wall Outlet Powered

Both:

- RS-485 Electrical Signaling (Serial Multi-drop LVDS protocol)
- 115k Baud Max
- +5-24V DC Supply Voltage
- DMX protocol compatible with ability for expansion to others
- 1 wire pair with common ground and power (4 wires total)
- Prototype enclosures:
  1. Environmentally resistive
  2. Ability to withstand a 4 foot drop test to scaffold

Proposed Design:

The following block diagrams illustrate the functional components of the proposed design.

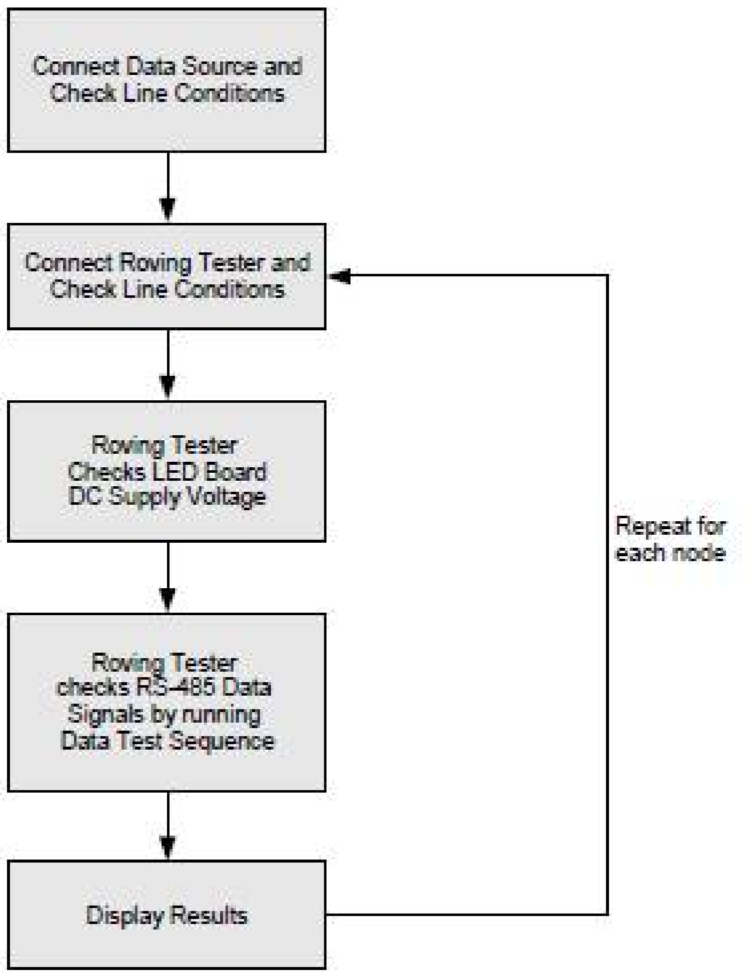

Figure 1: Master Functional Block Diagram

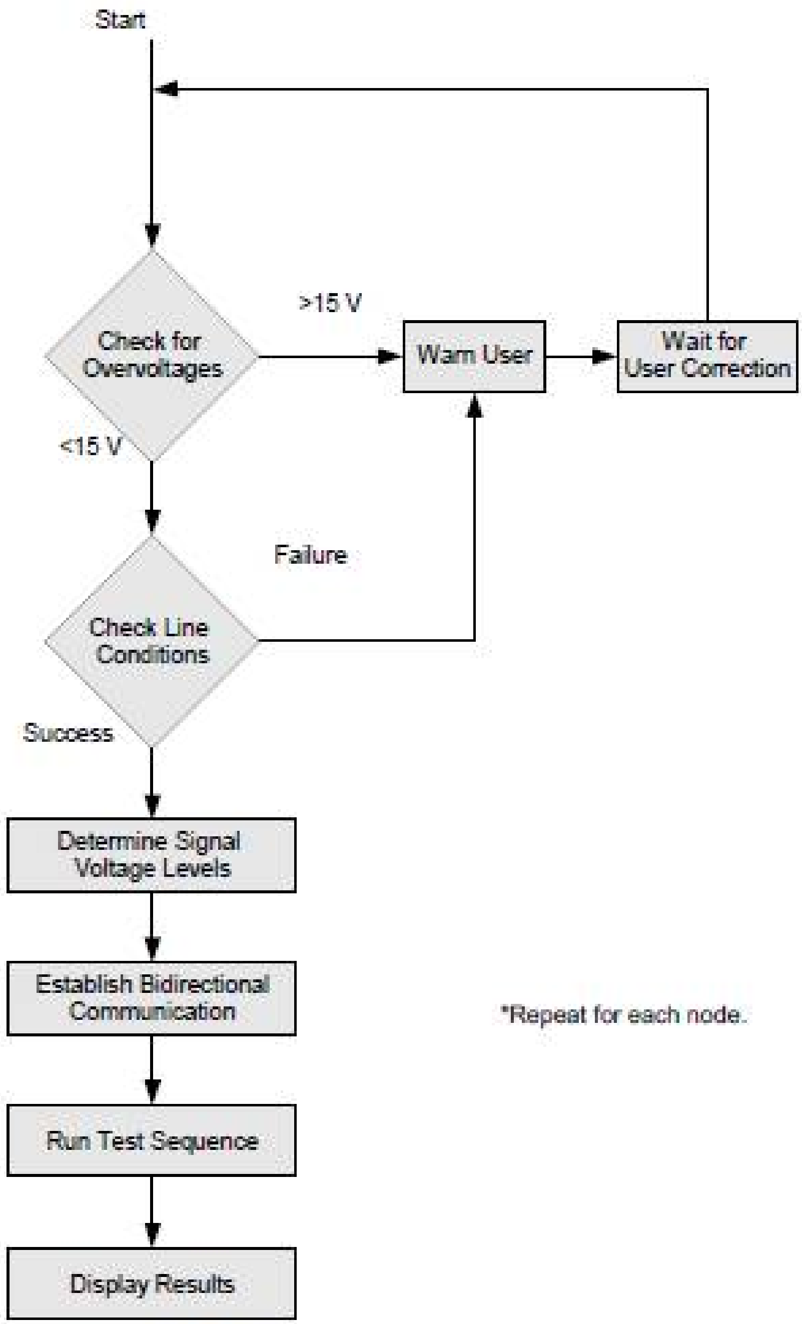

Figure 2: Roving Tester Functional Block Diagram

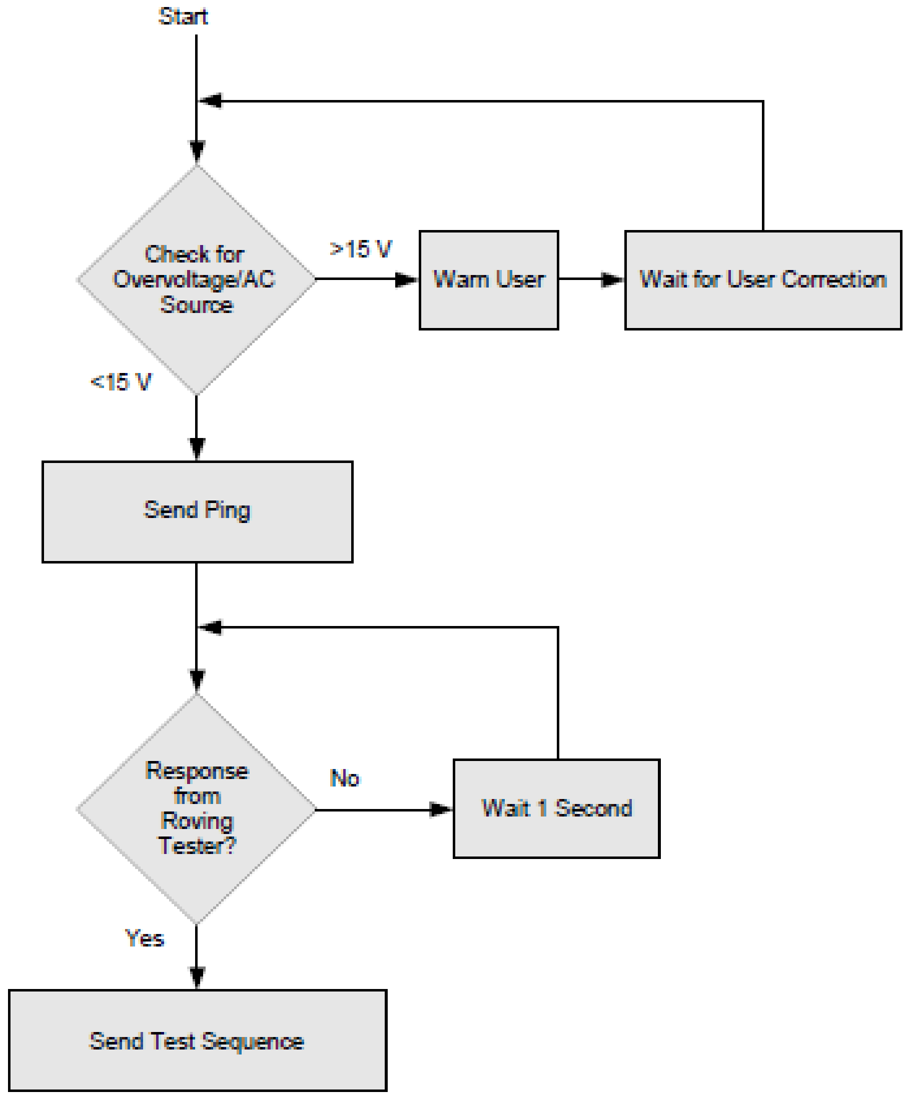

Figure 3: Data Source Functional Block Diagram

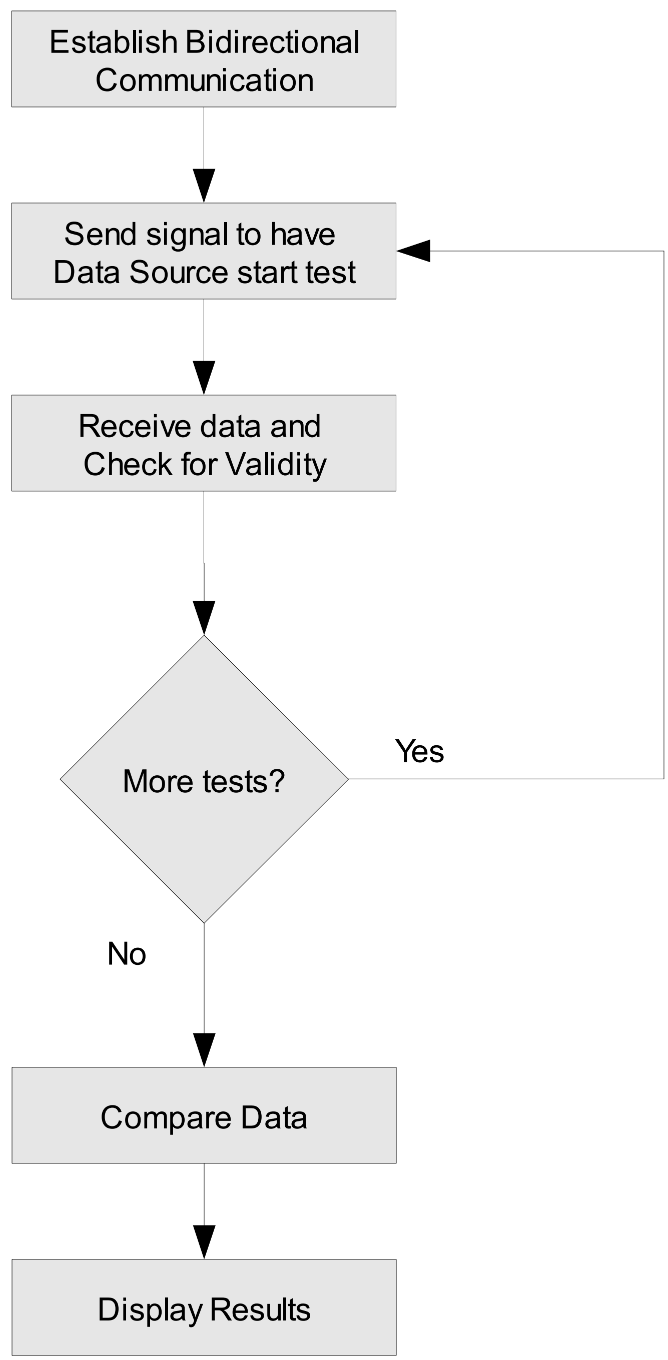

Figure 4: Test Sequence Functional Block Diagram

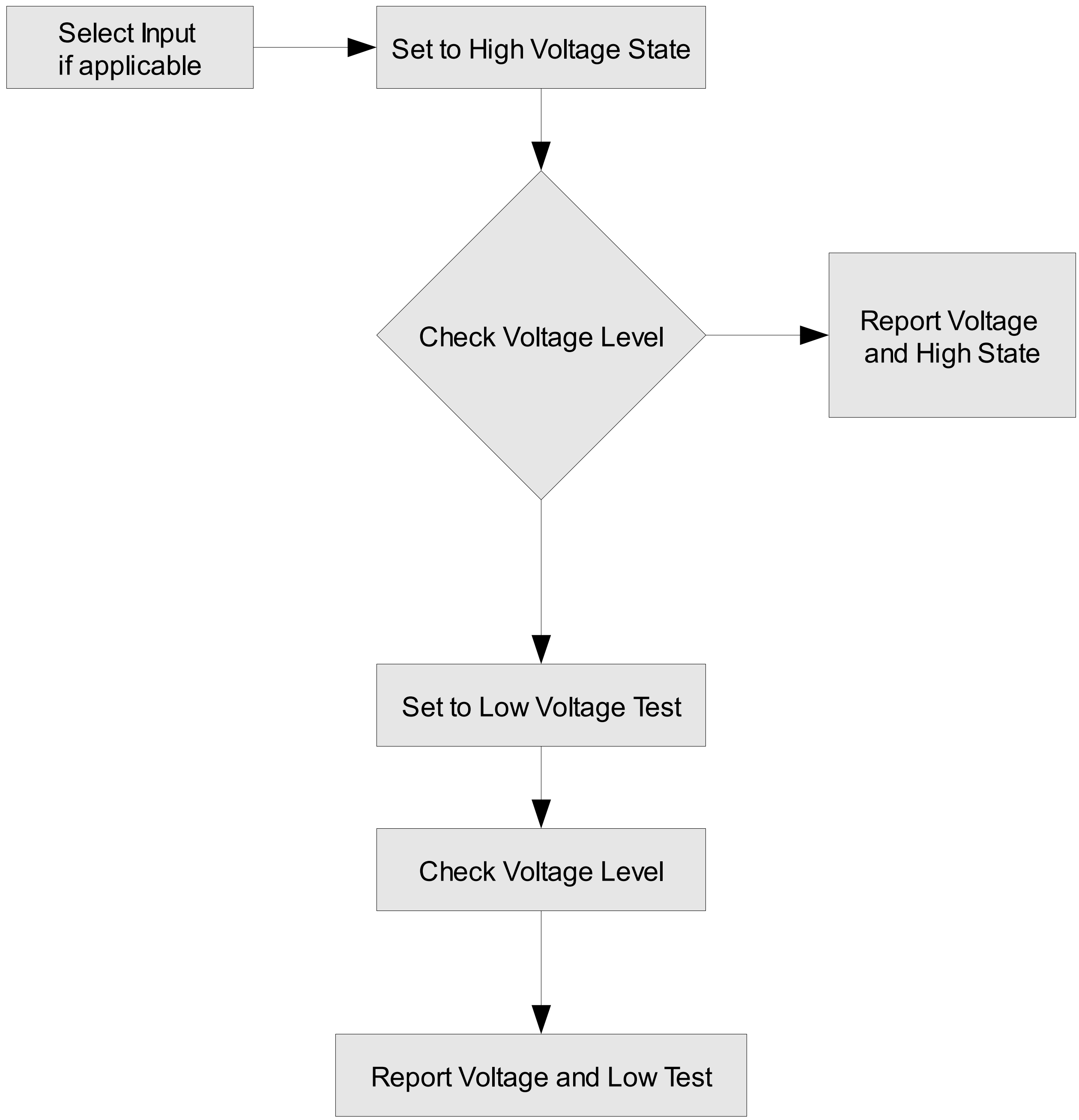

Figure 5: Check Voltage Level Block Diagram

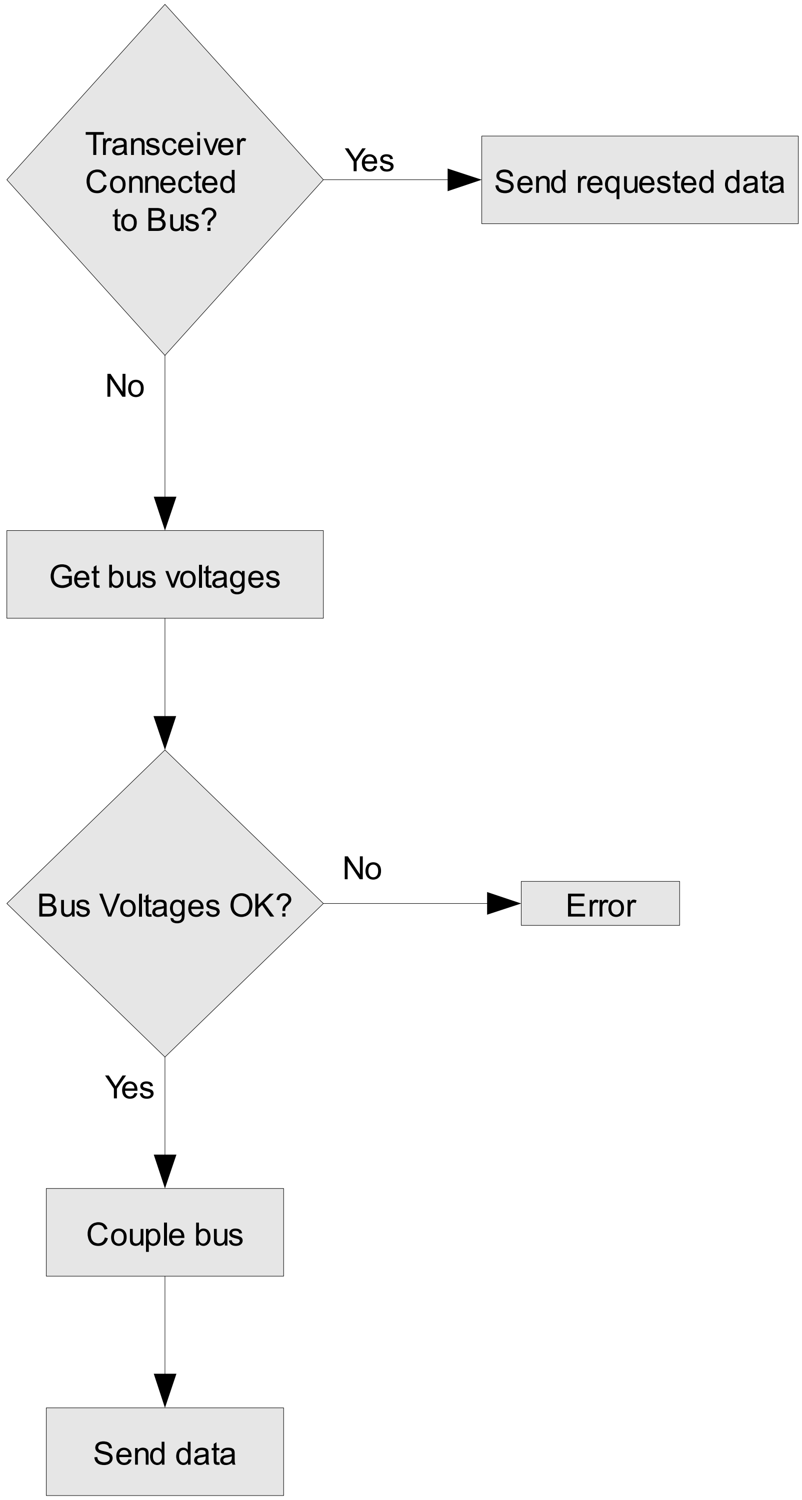

Figure 6: Transmit Functional Block Diagram

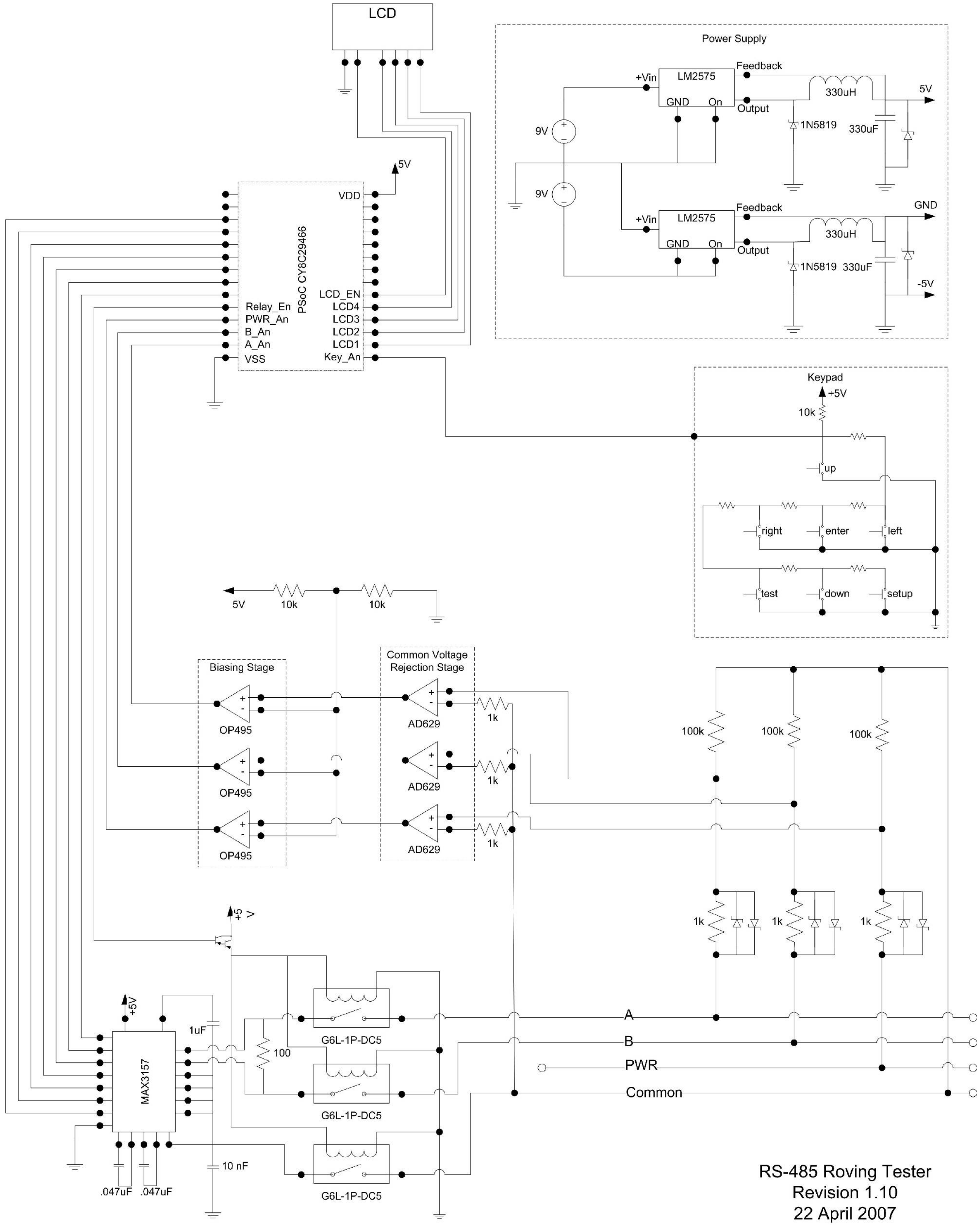

Figure 7: Roving Tester Schematic

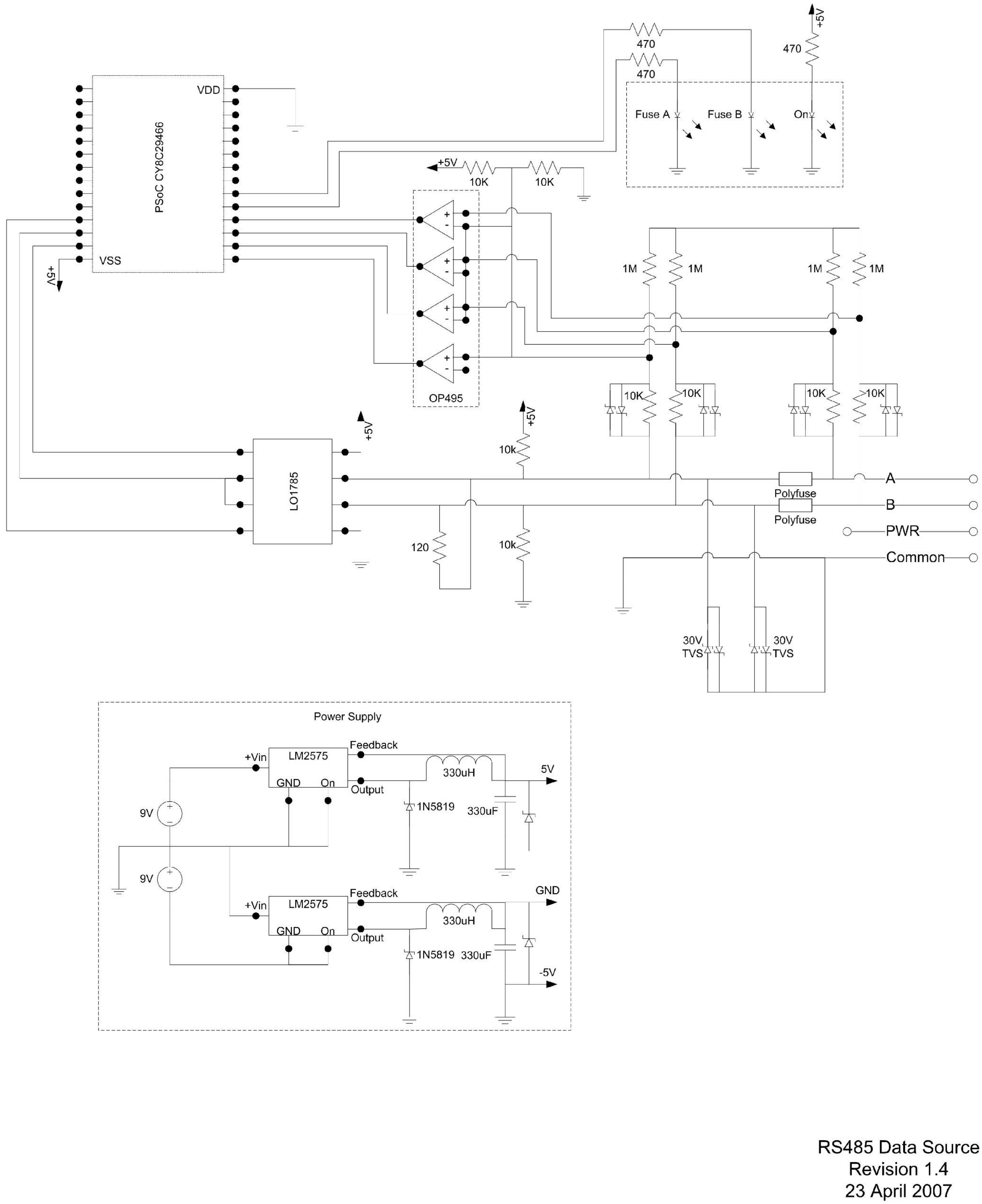

Figure 8: Data Source Schematic

Theories Of Operation:

Roving Tester

Selectable High Impedance Voltage Divider

This element allows for the selection of different voltage divider ratios to detect voltage levels. Initially it should be held in a testing state for high voltages an only later moved to the lower ranges if deemed safe to do so despite the zener as a second layer of protection to insure that voltages greater then 5V and less the 0 be sent to the uP. High value resistors are used to insure to limit the effect on the circuit and additional current drain with high tolerances to insure accuracy of the measurements

This works by having the MOSFET act as a switch between the resistors. If the bjt is powered by the uP, current is allowed to pass which allows for the resistors to act in parallel reducing their effective resistance. While unpowered no current (effectively) is allowed to pass and only one resistor to act in the divider.

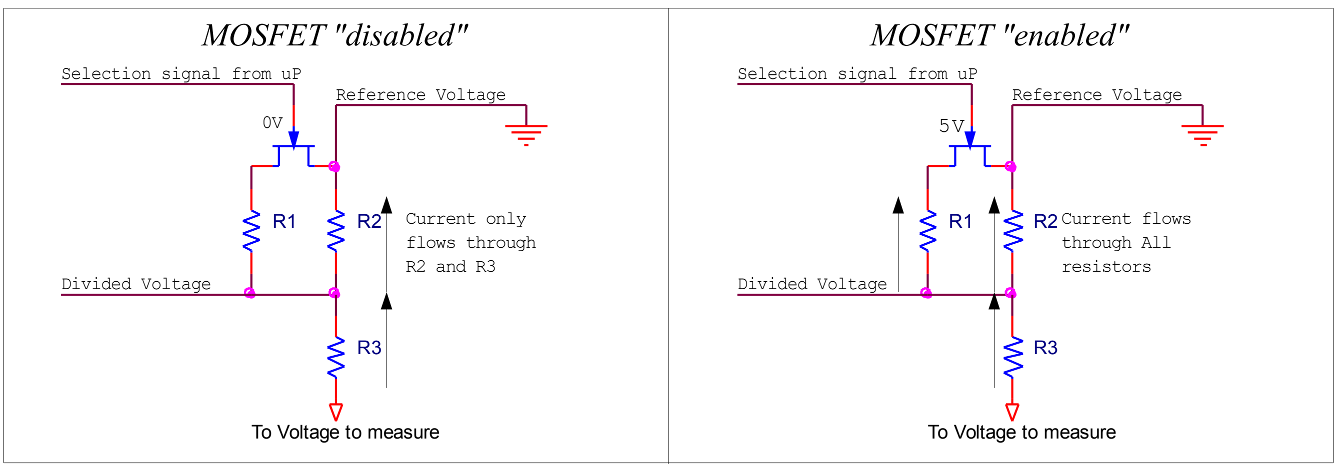

Figure 9: Selectable High Impedance Voltage Divider

Voltage Stabilizer

A relativity high accuracy of the VCC supplied to the microprocessor is very desirable within the design as VCC provides the reference for the ADC Conversions. Using 14 bit ADC's within the microcontroller, small errors in reference could cause reductions in accuracy. A LM7805 is used for this as it has 2% voltage accuracy, and it inexpensive and fairly easy to obtain, as well as providing ample current. It is able to achieve 5V with up to a 35V DC Source (Maximum Rating). This may be replaced with a LM2575 simple switching supply with the same functionality and almost identical specifications but has a higher efficiency.

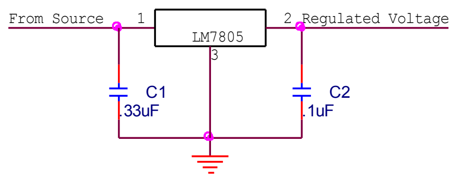

Figure 10: Voltage Regulator

MOSFET Controlled Power Switch

A "soft" power switch is designed for use in the circuit as it will allow for better power saving features to be implemented and has virtually no current draw upon the battery while off.

This works by having a momentary switch bypass the MOSFET for a period of time allowing for the uP to initialize. Upon initialization of the uP, it will assert a signal to the mosfet allowing for a current path independent of the switch. When this has occurred, the switch can be depressed and the circuit will remain powered. A DPST switch should be used that will allow for a separate signal to be sent to the uP as well. This signal can be used to detect when the switch is depressed again and have the uP stop powering the MOSFET turning off the device. This can also be operated on a watchdog timer to turn of the device after a set number of minutes of inactivity to save battery power.

This will be implemented between the battery and the power supply with a mosfet capable of conducting the total current specified by the design.

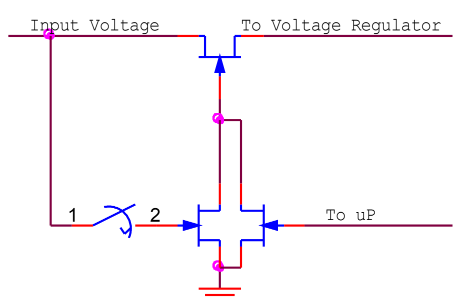

Figure 11: MOSFET "Soft" Power Switch

User Interface Switches

The user interface will be controlled by use of switches with directions. This can be implemented by using momentary switches with resistors between them and read using a ADC. The voltage present will correspond to a unique switch and can be acted upon. This has advantages over use of a parallel read touchpad by using only 1 input on the microcontroller, but losses in that it must be connected to one of the limited number of ADCs[1]. Resistor values are chosen to allow for a relatively even number of adc tics between the different buttons.

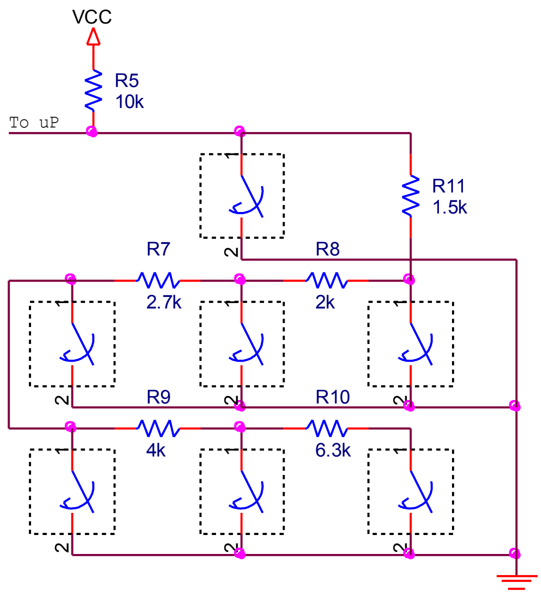

Figure 12: User Interface Switches

LCD

For this project a 16 char, 4 line display is planned for. This will allow for the space to display detailed test results to the user and simplify user interfaces reducing the time required to analyze the results. As UI design progresses, this may be swapped for a 3 line to reduce costs if possible without compromising utility.

Common Voltage Rejection Components

Components have been selected for the interface between the microcontroller sections of the circuit and the line itself that allow for common voltage rejection. By using these parts the two sides are effectively running on grounds allowing for the testers ground to float from the line, simplifying the testing of the common ground line. If the common ground were used as the tester ground problems could arrise if the common line were shorted to ac or if simply decoupled, from the transient resulting in the from the tester circuit matching the common ground voltage.

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1 Technique from: *Freescale App Note AN1775, Expanding Digital Input with an A/D Converter*

Battery Life

Optimization of battery performances is important to prevent the need to replace batteries on a frequent bases in the Roving Tester Component. Currently worst case numbers suggest a current draw after the power sources to be about 123.5mA. With 82% efficiency supplies this amounts to a 150mA draw on the batteries. Alkaline batteries are specified due to relatively insignificant cost increase to the consumer and greatly improved live over carbon batteries. By these calculations the battery life would be:

Type	Assumed typical mAHr (average)	Battery Life assuming (full battery can be used)
AAA (6)	1000	6.66 hrs
AA (6)	2225	14.853 hrs
9V	565	3.766 hrs
9V (2)	1130	7.53 hrs

Data Source

Overvoltage Protection (Thermal Fused)

The data source utilizes a RS-485 transceiver with higher voltage tolerances (60V as opposed to 15V) which allowed for a simpler voltage protection method to be implemented, however it may be counterbalanced with a longer reset time.

The overvoltage protection to the circuit is implemented by use of a trans-orbs connected with respect to ground to the RS-485 Data Bus. When the trans-orbs voltage level is exceed (at approximately 30V), it allows a higher current to pass limited only by a 47Ohm resistor. This heats a thermal fuse causing it to trip and protect the transceiver from the effects of the high voltages.

Additional circuitry and software will be implemented to detect the tripping of the fuse and its subsequent reset. This is performed by monitoring the voltage on either side of the fuse with a simple high impedance voltage divider that is offset through an op-amp allowing for the monitoring of the voltages on either side of the line. In the case the fuse being tripped the voltages will not match.

This design reduces the complexity of the design and eliminates the need for relays and constant polling as this line should be in a constant receive mode. As a downfall, the recovery time is as of yet unknown, and will likely depend on ambient temperatures.

High Impedance Voltage Divider

The Data source implements a simplified version of the voltage divider from the Roving tester to check voltages on the bus. It is a much simplified version, mainly to insure the voltages on the buses are approximately correct and error if otherwise. This can be accomplished using a simple divider circuit with the op-amp series on the outputs.

LED Warnings

When the Data Source isn't running tests and displaying complex outputs, their is little need for an expensive LCD display. Instead LED's will be lit to display minimal information as to the health of the bus. LED's are currently present for "ON", "FUSE_A", and "FUSE_B" trips. LED's may also be added to detect shorts should they be deemed useful.

Software Functionality:

<u>Roving Tester Routines</u>

High Range Voltage Test, RS-485 Line:

A Method to initially test the voltages of the line on the two RS-485 wires with the range select on high setting. Method should read multiple times to check for AC Waveforms as well as voltages that could damage the transceiver. When completed should set condition flags for an "AC_Detect", "Ok_To_Transmit", as well as analog readout of voltage detected.

Low Range Voltage Test, RS-485 Line:

A method called after the high voltage test to test for voltages with low range selected. Should also read multiple times to verify dc voltages only, and should modify AC flag and analog readout with more accurate measurements.

Voltage Test, PWR Line:

Method to check the voltage on the power line supplied with the RS-485 tester. Test should first be run in high voltage range and move to low voltage if within its range. Test should be run multiple time to verify DC signal. After test completed should compare value to user selected option and tolerances. Method should set flags for AC, OK, as well as actual voltage detected on the line.

Open Bus:

Method most likely called by Transmission method prior to first transmit. This method should verify that all the data bus is safe to couple to the transceiver and assert the line to close the relays. May also connect ground and PWR lines into the circuit and delay for transient to die out.

Transmit Signal:

Method that will activate the transceiver and send data as requested by other methods using a compatible TTL signal to the RS-485 specs.

Receive Signal:

Method activated after initial handshaking with data source to receive data from the data source and check it against expected signals.

Setup Menu:

A group of methods that will allow for the modification of parameters such as expected DC Voltages, and tolerances, as well as possibly data protocol, existence of PWR and bus speed. These options will be saved in Static Ram allowing for them to remain after power to the unit is lost.

Data Source Routines

Test LVDS Voltages

Method to read the voltages from the LVDS Bus and set flags/physical indicators if tripped. Will check multiple samples for the existence of AC on the line.

Fuse Indicators

Method that will activate upon tripping of a thermal fuse in an overvoltage case. Upon removal of the overvoltage signal, this method will send a signal through the rs-485 lines to determine when the fuses have reset and turn of the indicator.

Wait

Method that will wait while listening to the lvds bus for a request to initiate bi-directional communications. This request may contain configuration options for the test that will need to be parsed and applied. Ideally this might be a low power mode with interrupt, if recovery time permits.

Receive

Method to receive and interpret requests from the bus. This will normally be listening for a response to the ping packet.

Transmit

Method to transmit data to the RS-485 bus. This will be run at determined intervals to "ping" for the tester on the bus.

Run Test Sequence

Method that will send pre-arranged signals to the transmit routine to run data quality tests after the tester has responded to the ping.

Project Management

Progress reports will be made to appropriate parties via email and as necessary phone and/or face to face communications. Current work will be kept as up to date and accessible as possible via "http://studentweb.montana.edu/rweber/" to allow for easy monitoring of progress. These materials will include schematics, source code and any other relevant work.

Table 1: Project Task Schedule for Fall 2007

Date	Bo	Ray	Team
Summer	Learn PADS/Cadence software, enclosure considerations.	Work on Microprocessor code and prototype hardware.	
August			Final Design Review
September	3rd week: ship out 1st layout order, order parts. PCB layout	Work on algorithms	
October	Assemble first PCB		1st week: Subsystem completion Final code verification (i.e. test sequences)
November	3rd week: Project completion Final project demo of successful operation Finalize poster and materials for the design fair		
December	Design Fair Presentation, Final Report Submission		

Parts and Materials Costs:

All anticipated expenses, and include the cost of "no cost" items if your project will use donated items (note these as donated, and then show two budget totals - one for the actual project estimated cost and the other for the total estimated cost if all parts were purchased).

Bill of Materials

Roving Tester Side

Part Number:	***Description:***	***Approx Price:***	***Qty:***
MAX3157	High CMMR, RS485 Transceiver	$4.59	1
CY8C29466	Psoc CY8C29466, Mixed Signal Array	$8.78	1
LCM-S01604DSR	16x4 LCD, Parallel interface	$22.02	1
LM7805	5V Voltage Regulator	$0.72	1
2N7000	N Channel Mosfet	$0.26	3
G6L-1P-DC5	5V Relays	$1.75	3
1N4733A	5.1V Zener Diode	$0.25	8
T350A334K035AT	.33uF capacitor (for regulator)	$0.48	1
TAP104K050SCS	.1uF capacitor (for regulator)	$0.52	1
AD629	High CMMR, Differential Amplifier	$5.18	3
OP495GP-ND	OP495 Op-Amp (Quad Rail to Rail), DIP Package	$7.78	1
2N4124BU	NPN BJT (for relay current)	$0.11	1
44764-0601	6 Position Connector (through hole)	$3.67	1
	Large Resistors values for dividers, 1% or lower	$0.05	9
	120 ohm termination resistor	$0.05	1
	Assorted 1/4W Resistors	$0.05	11
	Pushbutton Switch with keycaps		7

Data Source Side

LT1785CN8	Fault Protected Rs485 Transceiver, 60V	$4.00	1
CY8C29466	Psoc CY8C29466, Mixed Signal Array	$8.78	1
LM7805	5V Voltage Regulator	$0.72	1
T350A334K035AT	.33uF capacitor (for regulator)	$0.48	1
TAP104K050SCS	.1uF capacitor (for regulator)	$0.52	1
1N4733A	5.1V Zener Diode	$0.25	10
OP495GP-ND	OP495 Op-Amp (Quad Rail to Rail), DIP Package	$7.78	1
44764-0601	6 Position Connector (through hole)	$3.67	1
	Large Resistors values for dividers, 1% or lower	$0.05	9
	Assorted 1/4W Resistors	$0.05	15
	120 ohm termination resistor		1

Both designs will also use .1uF bypass capacitors not included in this bill of materials

The estimated cost associated with commercial fabrication of printed circuit boards for this project is approximately $100 per pcb design as a minimum, depending on final size and complexity.

Project Deliverables

- Working prototype with PCB (printed circuit board)
- Design documentation including schematics
- User Manual documenting operation and user specifications for the design
- Disc of microcontroller source code

Impacts Associated with Engineering Design

The following constraints and issues affecting this design project are addressed below.

- **Economic**

  Since this is a very low volume product, minimizing cost isn't a major factor in choosing components for this project. The goal for the project is for the company to use in their installation of panels and possibly also rent it to customers doing their own installations.

- **Environmental**

  Since the Roving Tester component of this design will be used outside in unknown weather conditions, the enclosure of the Roving Tester will have to be water-resistant, pass a four foot drop test (i.e. To the scaffolding), and in general be rugged enough to withstand usage on the installation site.

- **Sustainability**

  This project will undergo changes in the future at the firmware level, but otherwise will remain largely unchanged otherwise. It is generally desirable for this project to be maintained over a long period of time, although this prototype in particular is not required to meet the end specifications for durability.

- **Manufacturability**

  Citing the same low volume projections for this product, there is no need to require an optimal (time and cost-wise) manufacturing process.

- **Ethical, Health and Safety, Social, and Political**

  Heath and safety plays a part in this project in insuring that the the design will not fail catastrophically in the case of worst case failures, or cause injury to the user such as accidental connection to 220AC must not come into any contact with the user.