Alyssa Magleby
ECE 4840
Project Proposal

Background: ATK Thiokol Propulsion*, Test Services uses B&F Signal Conditioning units to provide excitation power and shunt calibration information to the data recording systems. Gage measurements such as force, temperature, pressure, strain, etc. are recorded using this equipment. Approximately 2500 reusable instrumentation B&F Signal Conditioning units were purchased over an interval from 1978 to 1988 at a cost of around $1000 each. Through use and over time, the relay contacts on the signal conditioning mode cards have become corroded, resulting in excessive contact resistance. This causes inaccurate and inconsistent calibration data and could jeopardize the test results. These signal conditioning cards are needed for product testing for an estimated five more years, therefore, it is necessary to develop a solution to isolate the malfunctioning units for repair. The current screening method requires Test Area technicians to check cards manually, however the connections and measurements required for this process are inefficient and time consuming. To resolve this problem, funding was approved to design and build two B&F Signal Conditioner Checkout Units. Each unit will allow technicians to test relay contact resistance on signal conditioning mode cards before they are installed for data collection procedures. This tool will allow Test Area to resolve calibration accuracy problems and extend the life of the data acquisition equipment, as well as save troubleshooting time for the technicians.

Description: Each B&F Signal Conditioner Checkout unit will be designed as a portable test unit to screen for damaged relays on the B&F Signal Conditioner mode cards. The test unit will exercise the relays at a low voltage level to account for the worst-case condition of contact resistance across the relays. The unit will test the mode cards for resistance within 0.1% to1% of their minimum load for error tolerance, and for the repeatability of that resistance measurement. The unit will also provide technicians with relay measurement information to determine whether a mode card is functioning properly or not, and display which relays need to be replaced. Please see figure 1 for the system block diagram.

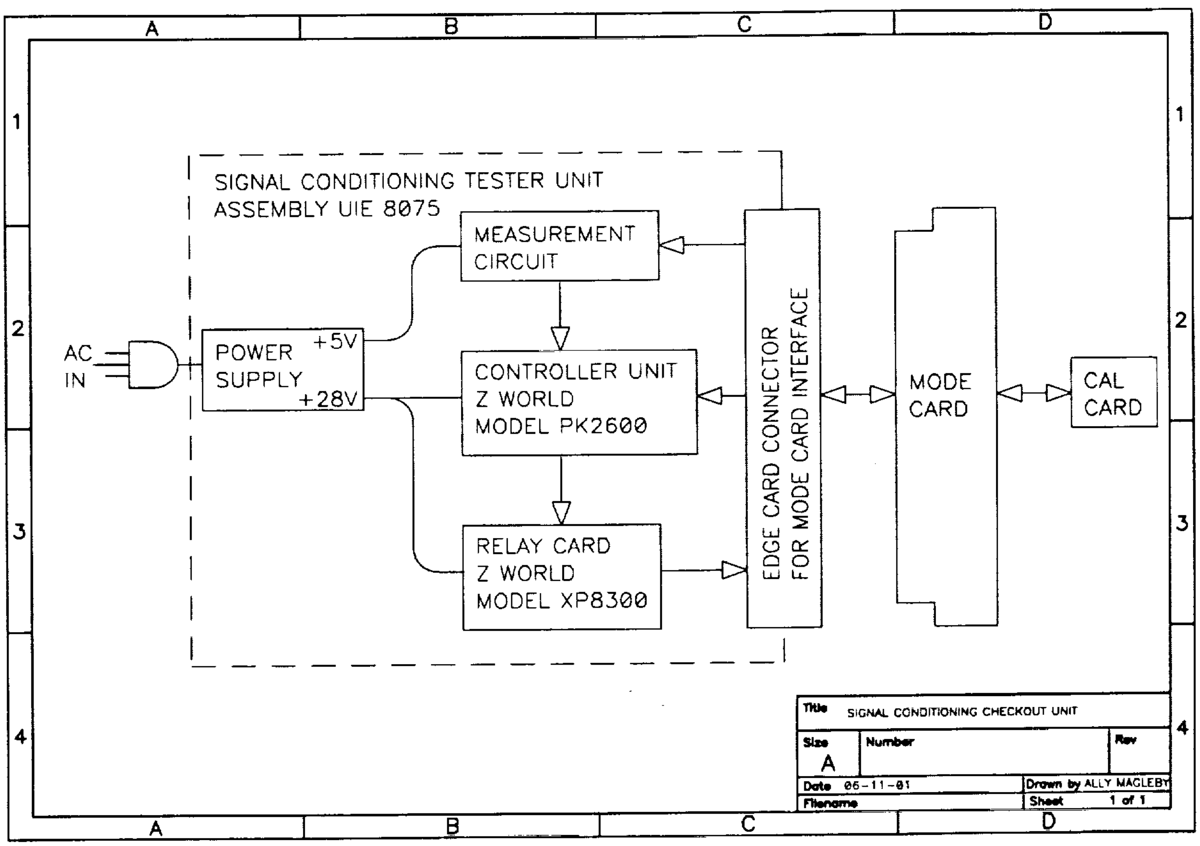

Figure 1. System Design

Specifications/Requirements: Each B&F Signal Conditioner Checkout unit needs to weigh less than 30 lbs and be enclosed in a carrying case so it can be easily transported from one test bunker to another by one Test Area technician. They need to be simple to use, with a user-friendly interface to avoid added costs of training Test Area technicians.

Test efficiency requires that the verification process should run for no longer than one minute per card. Each test unit will need the capability to test 3 different types of cards: strain gage (SG), resistive thermo-device (RTD), and thermo-coupler (TC).

Work to be Completed: A method of measurement needs to be developed to measure the resistance across relay contacts with extreme accuracy, to four decimal places, for each of the three types of cards. An electrical schematic will need to be drafted. Parts must be acquired and an assembly drawing will need to be made. Two boxes will be built to allow for multiple location use and backup purposes. An instruction manual detailing maintenance and operation procedures will need to be written as a reference document for Test Area technicians.

Project Management: This project will require the work of one engineer, a designer for the schematics and mechanical assembly drawings, and a Test Area technician for hardware assembly. This project should total no more than 600 hours of labor. Materials will be acquired from various companies in industry and should total no more than $10,000. Please see Table 1 for the proposed tasks and schedule.

Table 1. Project Schedule

Task:	To be completed:
Phase 1: Preliminary Design	
Preliminary research	June 6, 2001
Write abstract and proposal	May 23, 2001
System design:	
Preliminary Design Review	May 23, 2001
Generate ideas	June 6, 2001
Select Power Supply	June 6, 2001
Select Control Method	June 6, 2001
Select Interface design	June 6, 2001
Select meter	June 6, 2001
Select box	June 6, 2001
Phase 2: System Design	
Target Specs	June 6, 2001
Circuitry Specs	June 6, 2001
Research resources	June 13, 2001
Acquire materials	July 25, 2001
Define Test method	June 20, 2001
Critical Design Review	June 20, 2001
Phase 3: Detailed Design	
Finalize specs	June 20, 2001
Electrical layout	June 20, 2001
Electrical Assembly	Aug. 8, 2001
Write and debug code	Aug. 1, 2001
Bill of Materials	Aug. 15, 2001
Cost sheet	Aug. 22, 2001
Phase 4: Test and Refine	
Testing	Oct. 20, 2001
Refinements	Oct. 20, 2001
Phase 5: Documentation	
Procedure Manual (TEOP)	Oct. 3, 2001
Final Design review	Oct. 25, 2001
Release written report	Oct. 25, 2001

Alyssa Magleby
ECE 4850
Technical Report

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1. *PROJECT BACKGROUND

1.1 ATK Thiokol Propulsion—Internship/Coop:

This project was completed at an internship at ATK Thiokol Propulsion Corp. during the summer of 2001. Both the design and the assembled units are property of ATK Thiokol Propulsion Corp. I have been given permission to use the project as my senior project, and also to publish this report concerning the project.

1.2 Why the B&F Signal Conditioner Test Unit is needed:

1.2.1 History of Signal Conditioner Mode Cards

ATK Thiokol Propulsion, Test Services uses B&F Signal Conditioning units to provide excitation power and shunt calibration information to the data recording systems. Gage measurements such as force, temperature, pressure, strain, etc. are recorded using this equipment. Approximately 2500 reusable instrumentation B&F Signal Conditioning units were purchased over an interval from 1978 to 1988 at a cost of around $1000 each. Through use and over time, the relay contacts on the signal conditioning mode cards have become corroded, resulting in excessive contact resistance. This causes inaccurate and inconsistent calibration data and could jeopardize the test results. These signal conditioning cards are needed for product testing for an estimated five more years, therefore, it is necessary to develop a solution to isolate the malfunctioning units for repair. The current screening method requires Test Area technicians to check cards manually, however the connections and measurements required for this process are inefficient and time consuming. To resolve this problem, funding was approved to design and build two B&F Signal Conditioner Checkout Units. Each unit will allow technicians to test relay contact resistance on signal conditioning mode cards before they are installed for data collection procedures. This tool will allow Test Area to resolve calibration accuracy problems and extend the life of the data acquisition equipment, as well as save troubleshooting time for the technicians.

1.2.2 Problem Analysis

Initial problem analysis was performed to uncover the cause of the problem and determine how best to solve it. Several hypotheses of the problem were tested before one was found to be the root cause. The first hypothesis assumed that the inconsistencies might be due to the contacts not having enough settling time before the signal was read. This hypothesis proved false when timing was measured and it was found that the relays were closed for ample time to get the signal through without being affected by the bouncing of the contact. The next assumption was that the contacts were dirty. To investigate, contacts were cleaned and tested but no improvement was found. Finally, it was decided that the contacts were too corroded to be cleaned and would have to be replaced. This hypothesis was proved to be true when bad relays were replaced with new ones resulting in great improvement of data accuracy.

1.2.3 Solution

Since relay corrosion was determined to be the cause of mode card failure, it was necessary to develop a method to test for defective relays on each mode card. The technicians attempted to test individual relays on each card by hand. Each relay has at least two switches to be tested, which technicians connected to an ohmmeter, and then they would connect the leads to energize the coil to a power supply. The technicians would then step through testing each contact with the ohmmeter. This proved to be time consuming and difficult. It was then determined that a test unit should be built to test individual relay contact resistance and alert the technician when the relays needed to be replaced in an easy to decipher and timely manner.

2. PROJECT OVERVIEW

2.1 DESIGN REQUIREMENTS:

2.1.1 Quick

For optimum test efficiency, it was required that each test run for no longer than one minute per card.

2.1.2 Portable

Each unit would have to weigh less than 30 lbs, and be enclosed in an ergonomic carrying case so that it could be easily transported from one test bunker to another by an individual Test Area technician.

2.1.3 Consistent

Each unit needed the capability to test 3 different types of cards consistently so the test unit could be relied upon for accurate evaluation of relays.

2.1.4 Simple User Interface

The test unit also needed to be simple to use with a user-friendly interface to avoid added costs of training Test Area technicians on how to use the new equipment.

2.2 SYSTEM DESIGN AND FUNCTIONALITY:

The top-level hardware system design is broken into sub-levels. These consist of: a power supply, a measurement circuit, a controller, a relay card, a user interface with an interface to the mode card and cal card, and an enclosure. Please see Figure 1 for the block diagram of the hardware system.

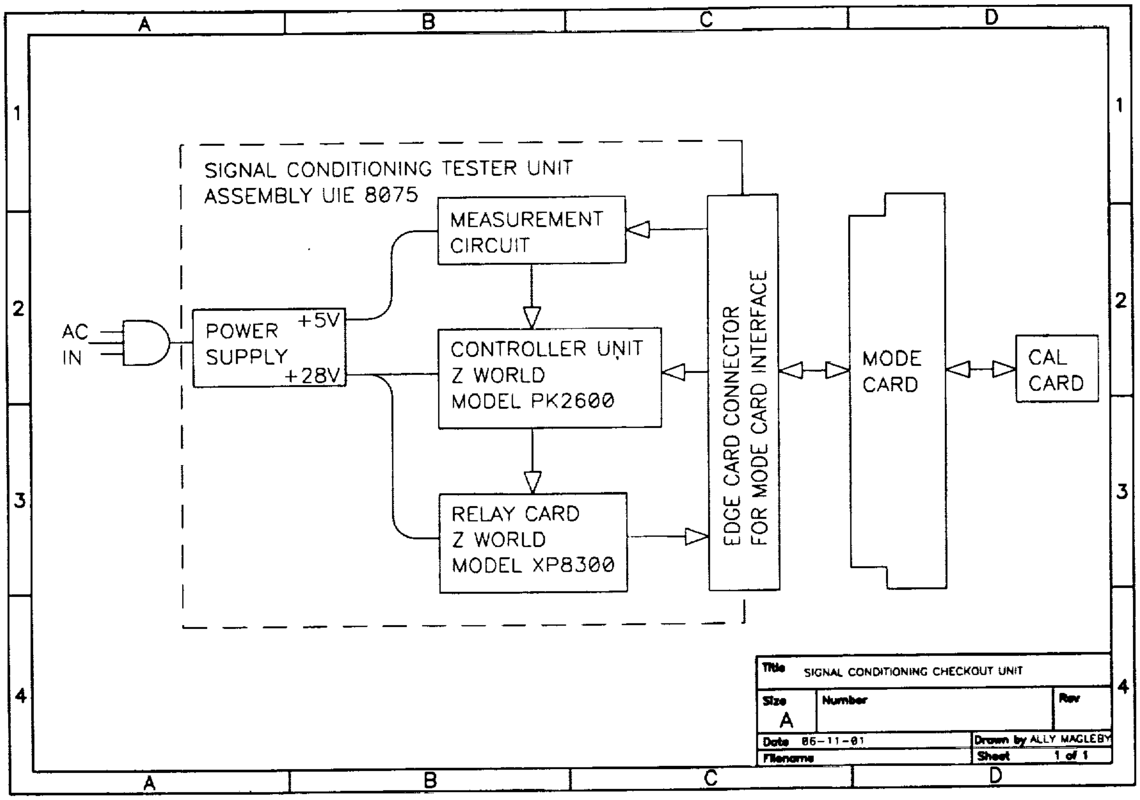


Figure 1. System Design

2.2.1 Hardware:

2.2.1.1 Power Supply

The power supply is divided into two units. A 28VDC power supply was selected as the general supply for the controller and also to match those used in the signal conditioning system to activate the relays on the mode cards. The 5VDC power supply was chosen as the signal to send across the relays. It exercises the relays at a low voltage level to account for the worst-case scenario of contact resistance across the relays. The 5VDC supply was selected for minimum ripple to allow the highest accuracy in resistance measurements.

2.2.1.2 Measurement Circuit

The measurement circuit uses a voltage divider with .01% accurate resistors to measure individual contact resistance for each mode card. It measures the voltage immediately before the switch, compares it to the 5VDC source, calculates a branch current, and then calculates the contact resistance not accounted for in resistors that make up the voltage divider. Please see Figure 2 for the schematic.

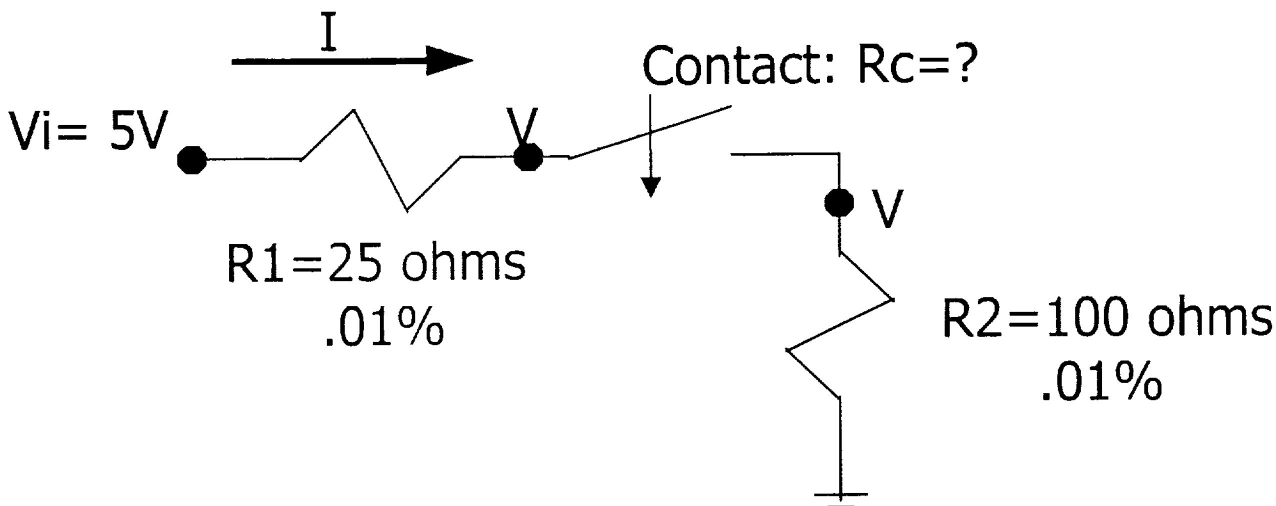


Figure 2. Measurement Circuit

2.2.1.3 PK2600 Controller

The controller for the system is a Z-world PK2600 touch-screen control unit. It was selected for it's flexibility in programming buttons on the touch-screen, it's ability to measure analog input, and it's ability to output digital signals. A more specific description of the functions of the controller will be given in the software explanation.

2.2.1.4 XP8300 Relay Board

The Z-World XP8300 relay board is controlled by the PK2600. Each of the relay coils on the mode card is connected, via the edge card connector, to one of the relays on the relay board. The controller is then able to provide power to each relay on the mode card by closing the switches on the relay board and can step through energizing each relay on the mode card during testing.

2.2.1.5 User Interface

The user interface consists mainly of the PK2600 controller, but additional components were added to interface to the mode card and cal card, for power control of the unit, and for redundancy in displaying the test results. All that was needed to interface with the mode card was a 44 contact card edge connector with .1" spacing and a 10-pin connector was needed for connecting specialized cal card cable assemblies. The rest of the user interface components include: a light-up power button, a combination of LED's and circuit breakers to verify the 5VDC and 28VDC power supplies are working, a power plug for 110VAC power, LED's to signal a passed or failed card, and a buzzer speaker with volume control. These components are arranged on the front panel as shown in Figure 3.

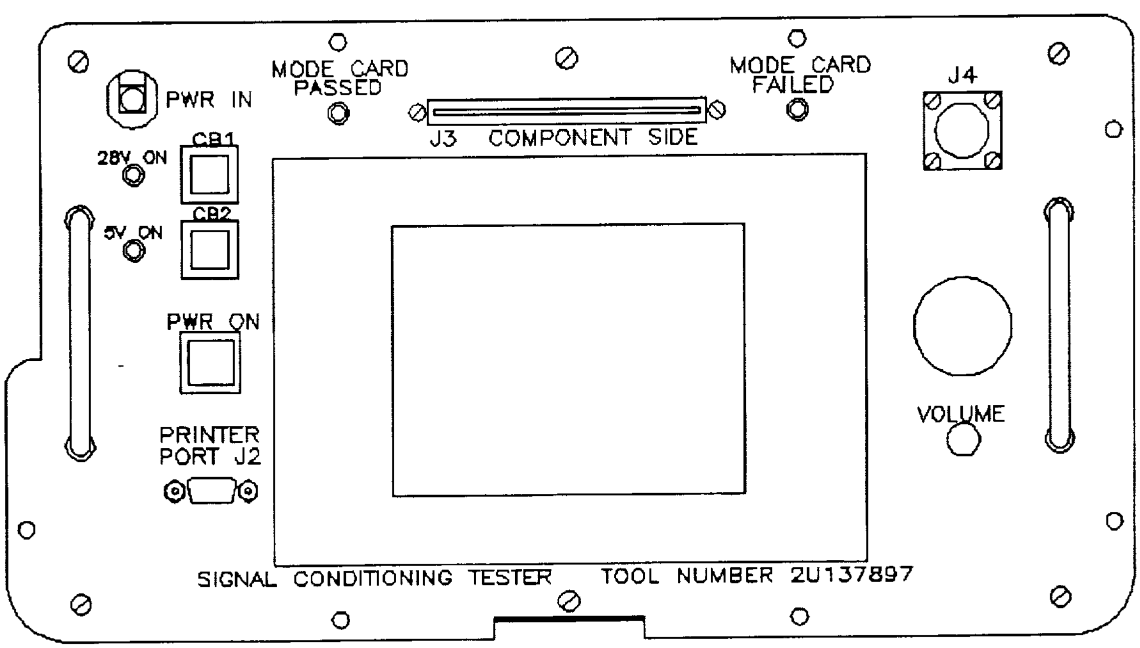


Figure 3. Front Panel User Interface

The LED's are connected to the digital output of the PK2600 controller with resistors for current limiting. The buzzer is also connected to the digital output of the controller, however it has a slightly more complicated circuit because of the volume control, and is shown in Figure 4.

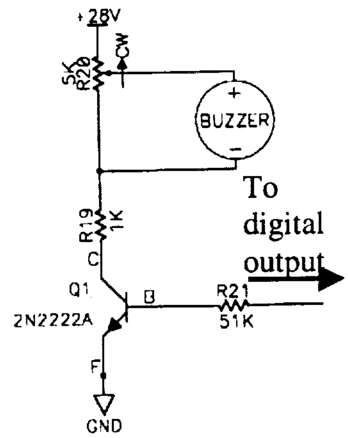


Figure 4. Buzzer circuit

2.2.1.6 Enclosure

All of the system components are split between a front panel and a lower level attached by aluminum rods. This allows for easy access to both levels for maintenance purposes. The tiered components are enclosed in a sturdy aluminum case. The case was mainly selected for optimum ease in transporting and for durability. Its measurements are 9" by 16" by 14.43". The case height and top open lid allow the technician easy access to the front panel from standing position with the case on a table. Please see Figure 5 for a schematic of the case.

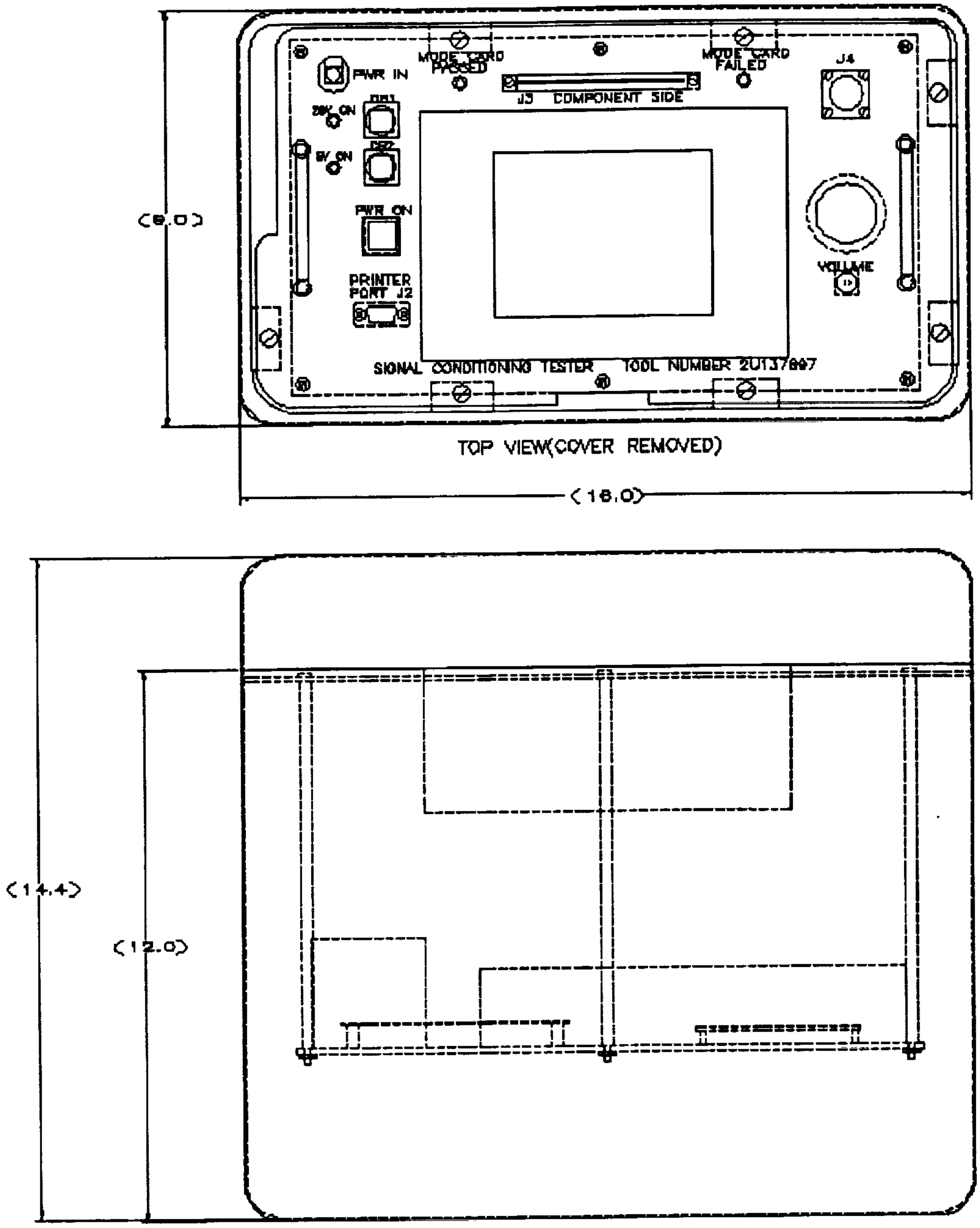


Figure 5. Case Enclosure

2.2.2 Software:

The software for the system design consists of one program for the controller and one for the display of the PK2600. The programs have to be loaded separately on different ports, and then work together to run the tests.

2.2.2.1 Display

The software for the display programs the various screens for the display. The initial screen on the touch-screen module displays the software name and version for a few seconds, and then changes to the main screen. The main screen has buttons for each of the three tests, display boxes to show which relays need to be replaced, a button to switch to the measurement data display screen, and a button to clear the test before starting a new test. Please see Figure 6 for a graphic of the main screen.

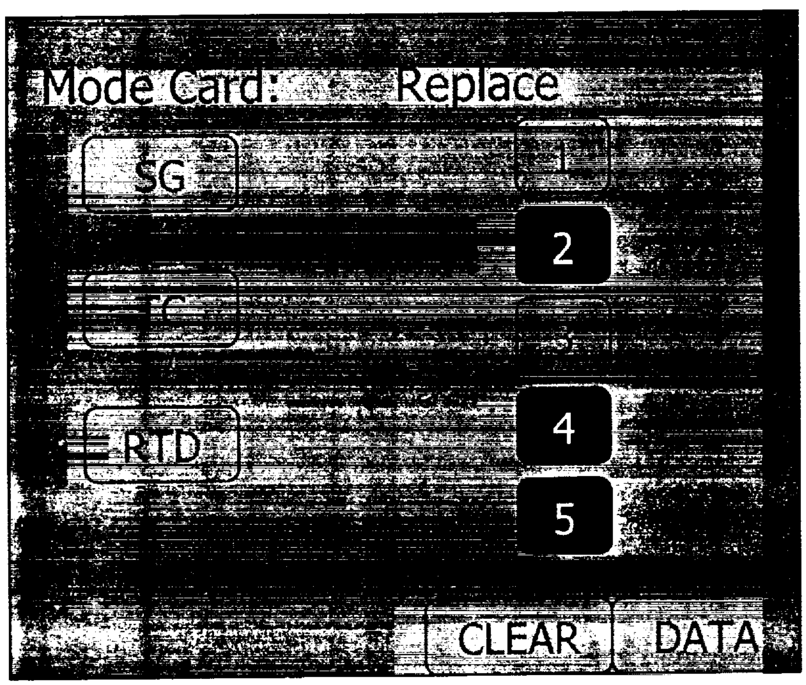


Figure 6. Main Display Screen: showing relays 2, 4, and 5 as failed

The measurement data display screen lists the resistance measurements taken, with a column for each test, and lists the average of the tests. This enables the technician to evaluate a mode card for a different resistance tolerance than the software is set for and to have more control over the test. The data display screen also has two buttons, one to return to the main screen, and one for printing the data. The print function is a feature left for future upgrade, if needed. During the display of each of the screens, the display software scans for buttons pressed when a test is not running, or for information sent from the controller when a test is running. The display software communicates with the controller software to initiate the mode card tests and ask for the measurement information.

2.2.2.2 Controller

The controller software controls the taking and recording of measurements and the output to the user interface components on the front panel, including the pass/fail LEDs and the fail buzzer. The controller software waits for a signal from the display screen that a test has been selected before running one of three types of card tests: strain gauge (SG), thermo-couple (TC), and resistive thermo device (RTD). It then steps through energizing relays, taking and recording measurements, and comparing the measurements to a set tolerance for the specific relays to be tested on each type of mode card. If a card is functioning properly, or all its relays are within tolerance, the controller lights the pass LED. If a card is defective, or any of its relays are out of tolerance, the controller lights the fail LED and sounds the buzzer. For accuracy, the controller software tests for resistance within 1% error tolerance of the minimum data acquisition system load, and for the repeatability of that resistance measurement.

2.3 VERIFICATION:

Many tests were run under various conditions for verification of each of the following design requirements:

2.3.1 Speed

The speed of each test was timed and measured well under the limit of one minute. The SG test takes 25 seconds, the TC and RTD tests take approximately 15 seconds each, in addition to the minimal time it takes to plug in the card and connect the specialized cal card attachments.

2.3.2 Portability

The total unit weight is 17.2 pounds, which is easily portable by a single Test Area technician. Please see Table 1 for a listing of the major component weights.

Table 1. Major Component Weights

Component	Weight (lbs)
Controller	2.68
Relay Card	0.3
5V power supply	3.125
28V power supply	1.1875
Case	7.2
Panel	1
Total	15.4925

The upright case is not too bulky to carry comfortably and the power supplies and other components were placed in the case for even balance.

2.3.3 Consistency

The tests are consistent to within an ohm, which was verified from testing various mode cards consecutively and comparing the resulting measurements.

2.3.4 Simplicity

The simplicity of the interface was tested by the technicians on a two-week trial run of the unit, without previous training. All were pleased with the unit's functionality.

2.4 USE:

The unit will be used to verify proper function for each of the Signal Conditioning Mode Cards in the data acquisition channels every time a shuttle motor is fired for testing.

To test a card, the technician would complete the following simple steps:

1. Turn on the test unit and verify that the power supplies are functional.
2. Connect a cal card or cal card assembly to a mode card to be tested.
3. Plug the mode card into the card edge connector, and connect the cal card assembly as needed.
4. Select the test that corresponds to the mode card to be tested.
5. Verify that the card passes verification test and that the test continues.
6. Wait for the test to finish stepping through the relays and measuring.
7. Record, if any, which relays need to be replaced and continue to the next card.

2.5 SUMMARY:

To allow for multiple location use, two B&F Signal Conditioner Test Units were built, and they are functioning well. This pre-testing of cards before they are installed for data collection procedures has already helped resolve some of the calibration accuracy problems and extend the life of the equipment, as well as save troubleshooting time for the technicians. These units have proved to be so useful that another unit is going to be built to assist in setting up systems for other small motor firings. Please see figure 7a) and 7b) for photographs of the finished product.

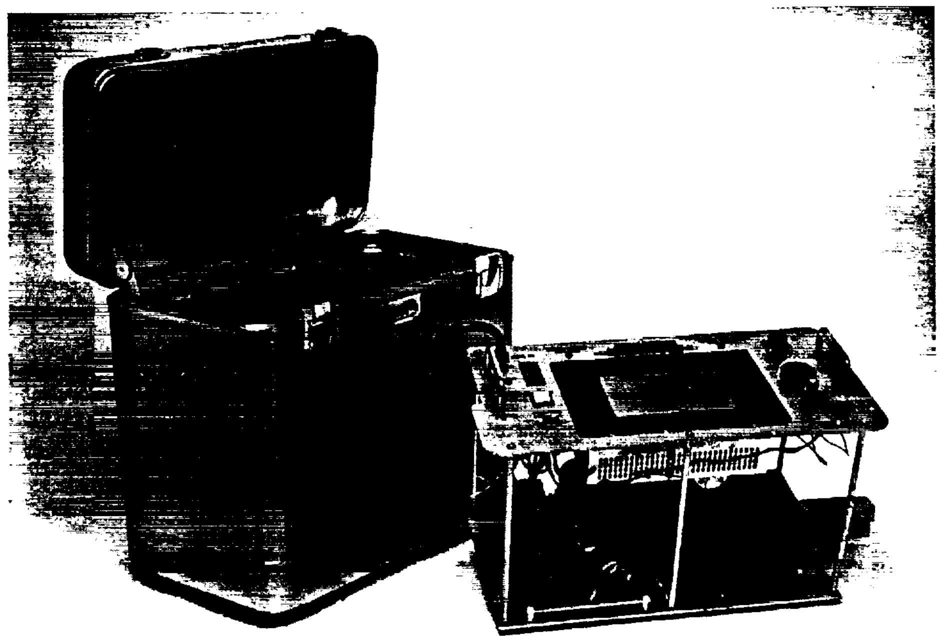


Figure 7a) Finished product with components removed from case

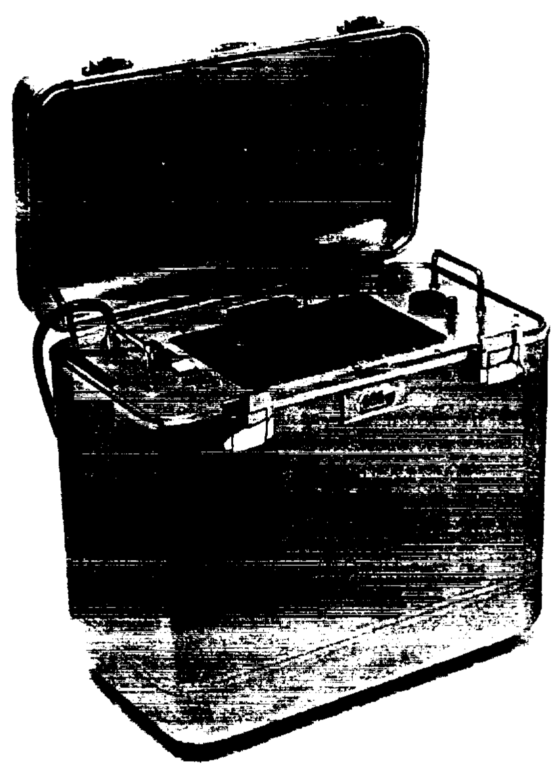


Figure 7b) Finished product

B&F Signal Conditioner Checkout Unit

Final Review

Agenda:

- Objective
- Problem Statement
- Problem Analysis
- Solution
- Design Requirements
- System Design
- Requirement Verification
- Budget
- Finished Product
- Summary

Project Objective:

Extend the life of the B&F conditioner mode cards until smart sensors can be implemented.

Problem:

- B&F signal conditioning units are becoming old and worn, resulting in:
  - ⇨ Inaccurate calibration data
  - ⇨ Inconsistent calibration data
  - ⇨ Excessive relay contact resistance

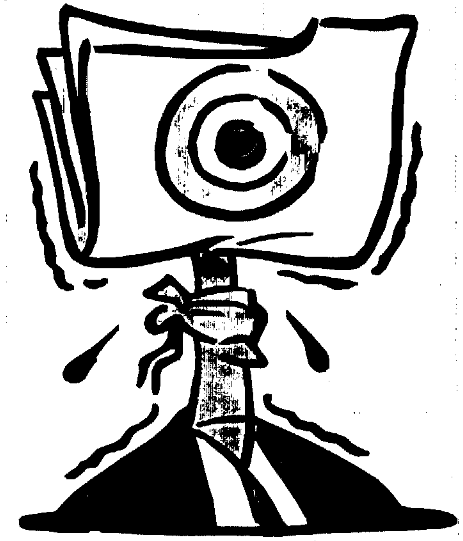
Problem Analysis:

- Errors due to slow timing on relays
  - Timing was measured and it was found that the relays were closed for ample time to get the signal through.
- Errors due to dirty relay contacts
  - Contacts were cleaned and tested but no improvement was found.
- Errors due to corroded relays that need replacing
  - Best results were found when bad relays were replaced with new ones.

Solution:

Build a unit to test individual relay contact resistance and alert the technician when the relays need to be replaced.

Design Requirements:

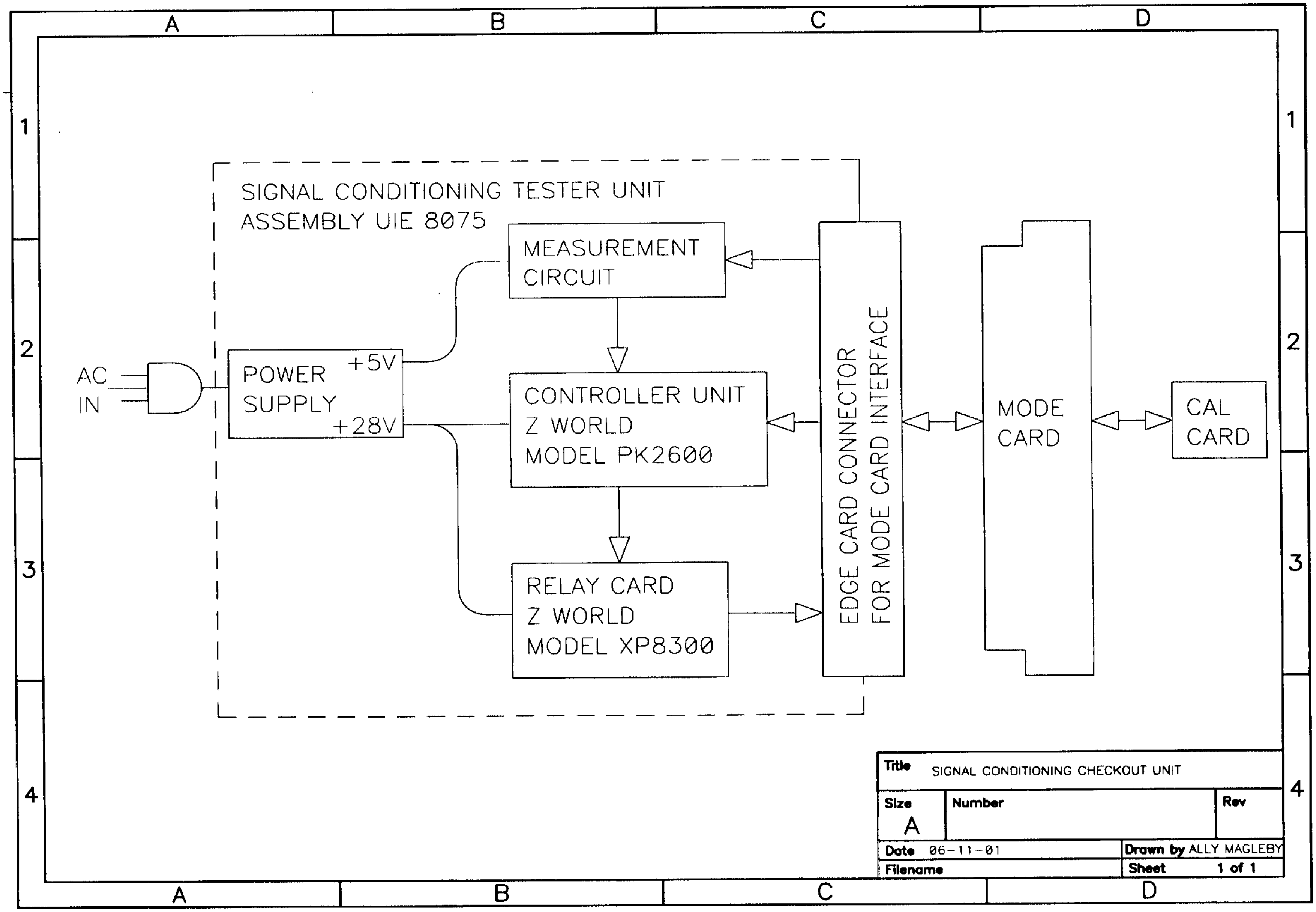


- Conduct test quickly
- Be easily portable and weigh less than 30 lbs
- Test for consistent contact resistance within determined tolerance
- Return information to the technicians to clearly tell them which relays to replace

System Design

- Hardware
  - Components of System Block Diagram
- Software
  - Display program
  - Controller program

Hardware System:

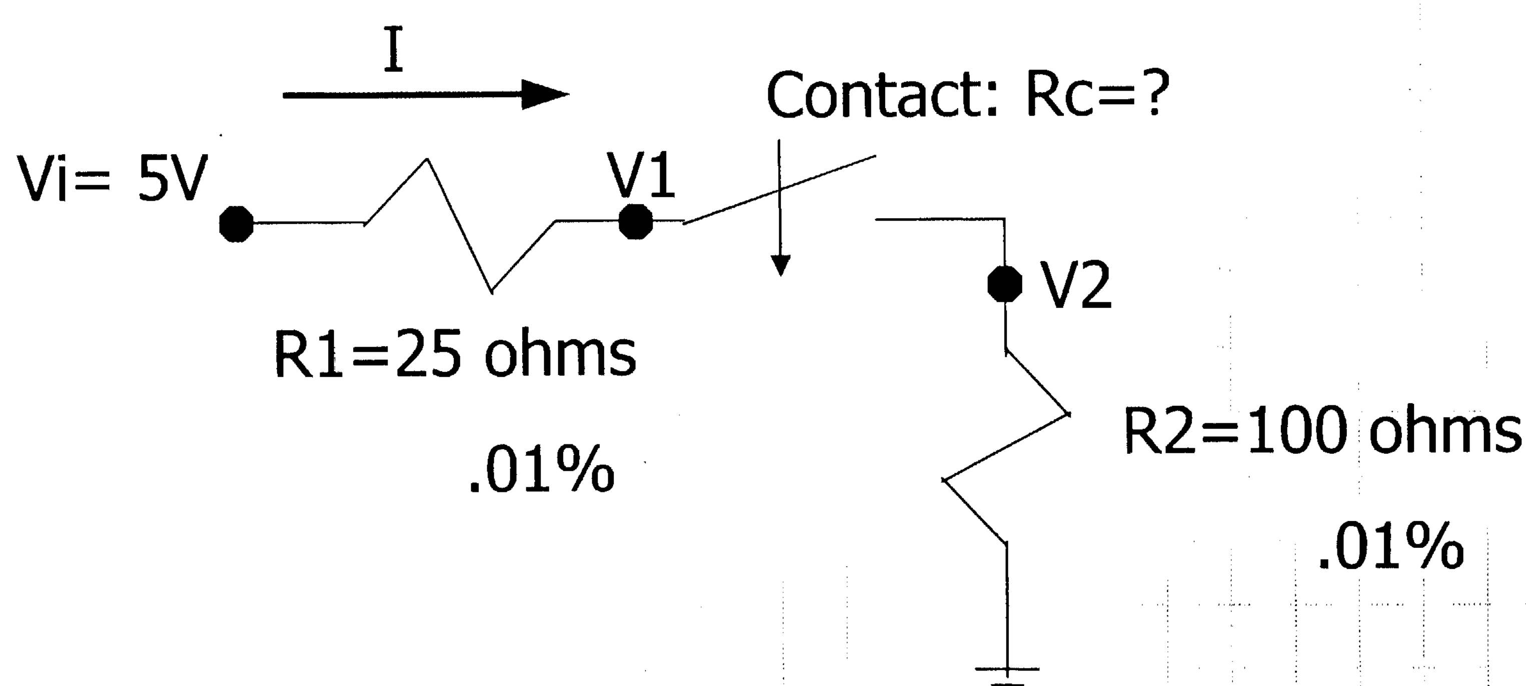


Power Supplies

- +28V supply
  - Supplies controller power
  - Match system supply to activate relays
- +5V supply
  - Minimum ripple for high accuracy in resistance measurements
- Both are light weight

Method of Measurement

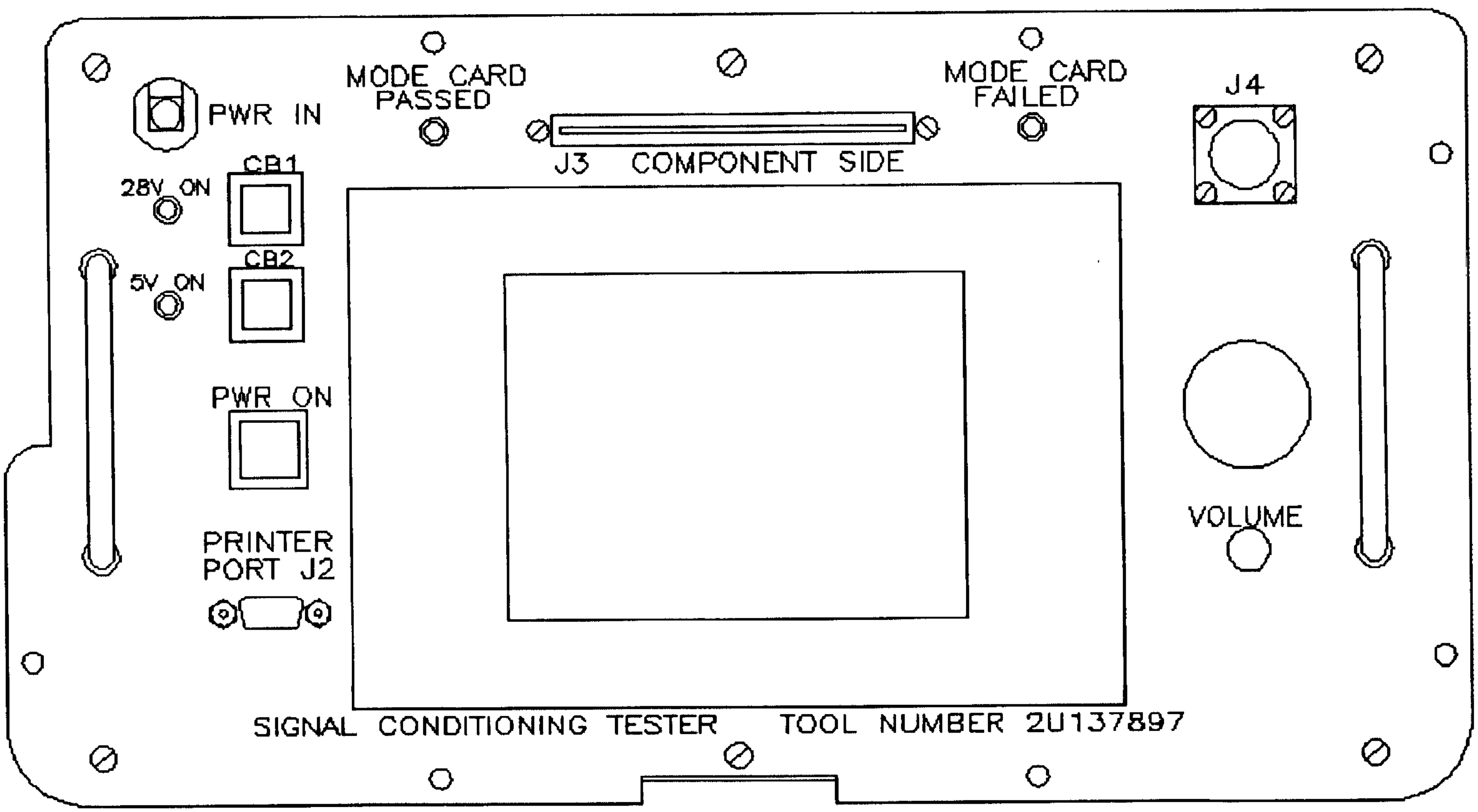
- Voltage divider
- Program calculations



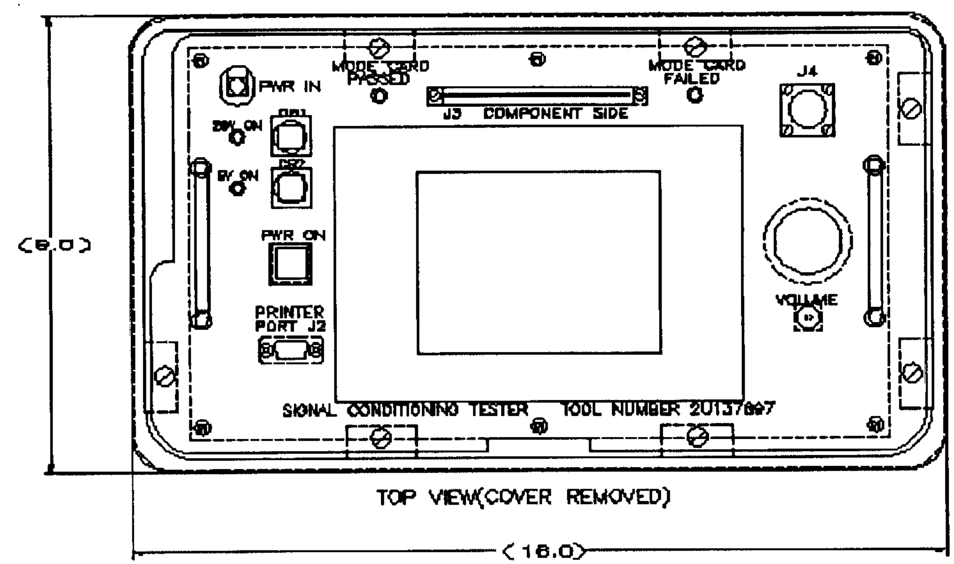
Controller and Relay Board

- Z-World PK2600 Controller
  - Heart of the system
    - Touch-screen display
    - Controls relay board
    - Controls measurements
- Z-World XP8300 Relay Board
  - Used as power switch to activate relays on mode cards

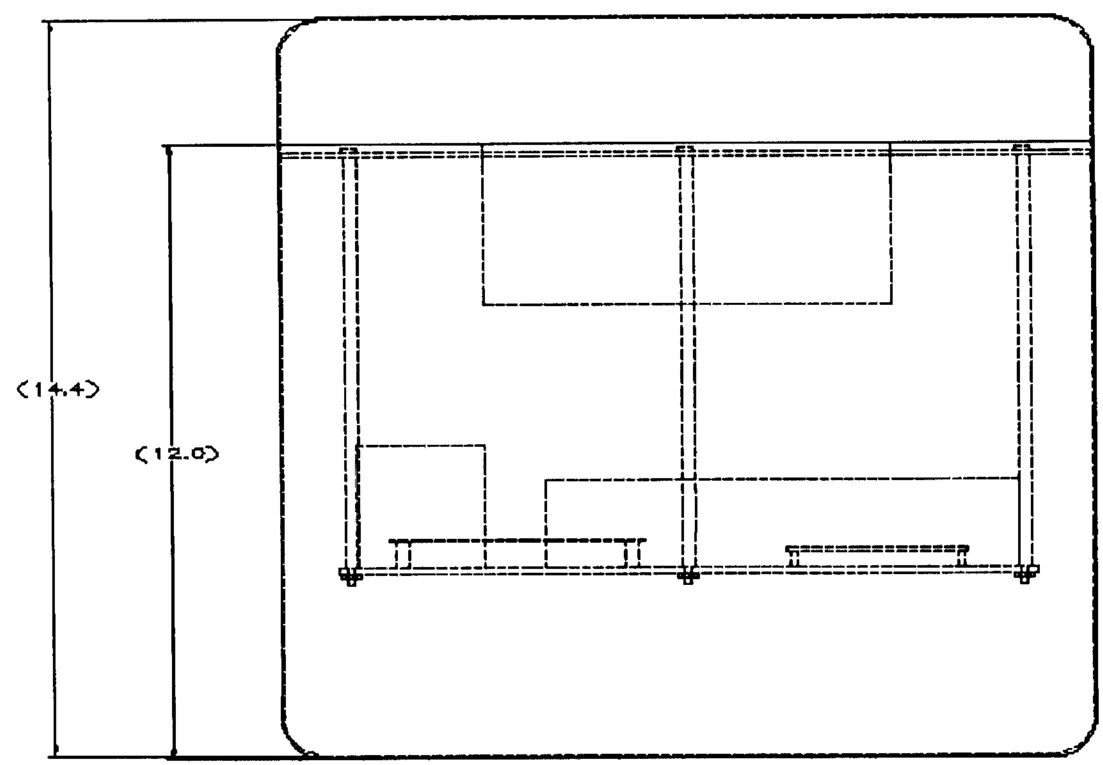
User Interface



Enclosure



TOP VIEW(COVER REMOVED)

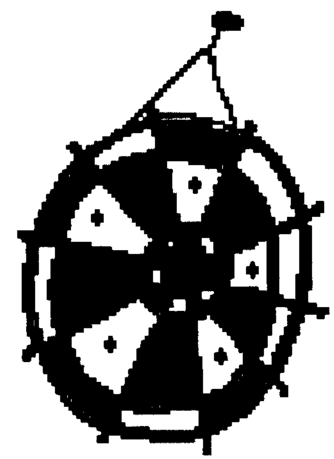


Software System:

- Display software
  - Programs display screens
  - Communicates with controller software
- Controller software
  - Controls measurements and user interface components (pass/fail LEDs and buzzer)
  - Communicates with display software

Requirement Verification:

- Speed
- Ease of Transport
- Test Consistency
- Display Simplicity



Speed

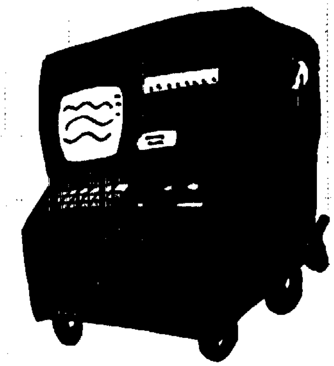
- Speed of test was determined by the ability of the relays to open and close quickly, and their settling time.
- Software was written to minimize time taken to test a card.
- Results:
  - 25 s for SG
  - 15 s for TC
  - 15 s for RTD

Ease of Transport

- Weight of all major components is well under the requirement of 30 lbs. Also, the components are placed for the best balance of weight for ease in carrying.

Component	**Weight**
Controller	2.68
Relay Card	0.3
5V power supply	3.125
28V power supply	1.1875
Case	7.2
Panel	1
Total	15.493

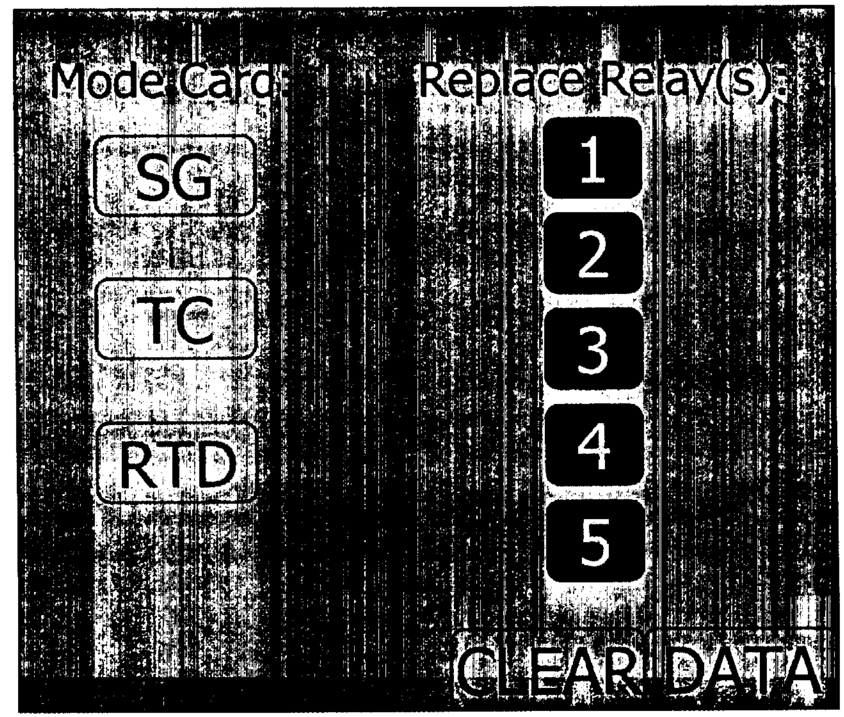
Test Consistency



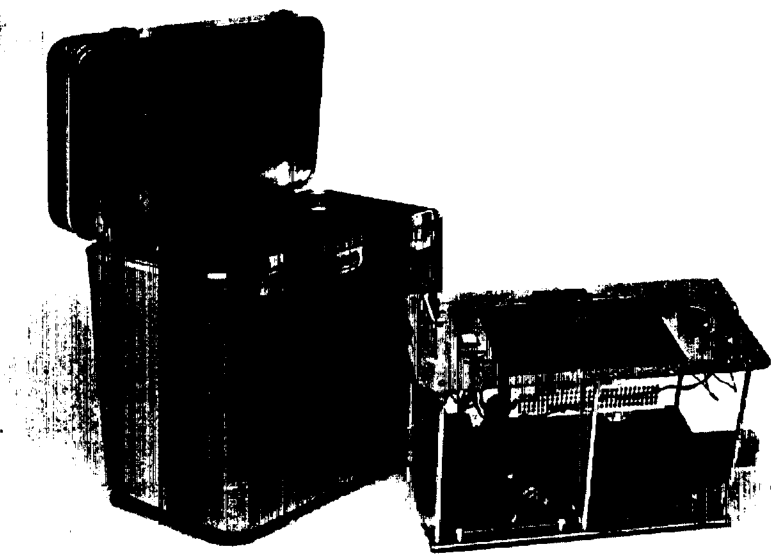
- Tested several cards a few times consecutively and recorded measurements.
- Compared measurements and found the standard deviation around .5 ohm.

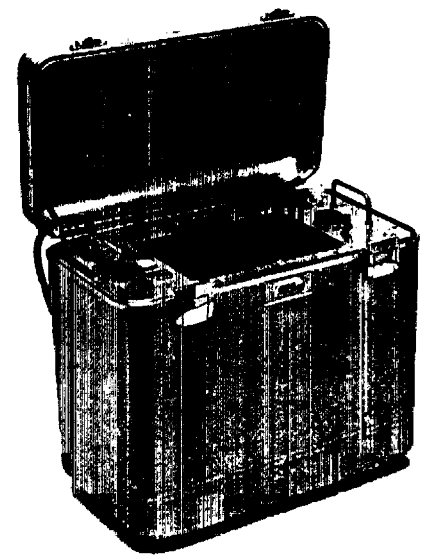
Display Simplicity

- Used LEDs and an LCD screen to display card go/no-go information and relay replacement.
- Data screen displays actual measured resistance values for more detailed information.



A Finished Product





Summary:

- This solution has:
  - Resolved calibration inaccuracy
  - Extended equipment life
  - Saved troubleshooting time