12-1988

Hitch Control Simulator for Southern Illinois University E.E. 492-729

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HITCH CONTROL SIMULATOR

FOR

SOUTHERN ILLINOIS UNIVERSITY

E. E. 492-729

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BY

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FALL, 1988

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Objective:
The objective of this project was to design an end-of-line testing simulator for the new draft control circuitry on an agriculture tractor hitch control.

Evaluate Current Testing Tool:
This project began by becoming familiar with the hitch control circuitry and how it worked. This process included running an older version of the hitch control on its testing simulator according to the test procedures. This provided the background on the old control such that modifications could be made to test the new control.

The agriculture tractor has an electronic three-point hitch control which was designed, basically, to modify the position of the hitch according to the position of the electronic handle. The control will operates differently depending on whether or not there is an implement connected to the hitch. There are also other special features designed to help the operator. These are based on the velocity at which either the handle or the hitch is moving. The newest addition to the hitch control module is a feature referred to as draft control.

The draft control feature was designed to read the engine speed of the tractor and modify the position of the hitch based on this input. That is, if the engine r.p.m. drops below a preset software engine speed set point the implement is raised. This addition to the hitch control allows the machine operator to set the implement to cut deep in the ground but not stall the engine as ground conditions change. The operator may modify the software set point to meet his requirements.

The company which assembles the hitch controls is required to test every control that they make to insure that all of the hardware functions properly. This testing is accomplished by connecting the control module to a testing simulator and performing the specified test procedures on each of the hitch controls.

New Testing Circuitry:
On the new hitch control, engineers added circuitry for two new switch inputs and an engine speed input that had to be tested. One switch input turns the draft control feature on and off. A second switch changes the software set point, while the third input, a frequency input, represents the engines revolutions per minute.

To test the draft control circuitry, the tractor's engine speed had to be simulated. This was done by summing together the hitch position voltage and an external variable voltage. The variable voltage was used to simulate loads on the engine. The total voltage was then converted to a corresponding frequency signal and sent to the hitch control as shown in Figure #1.

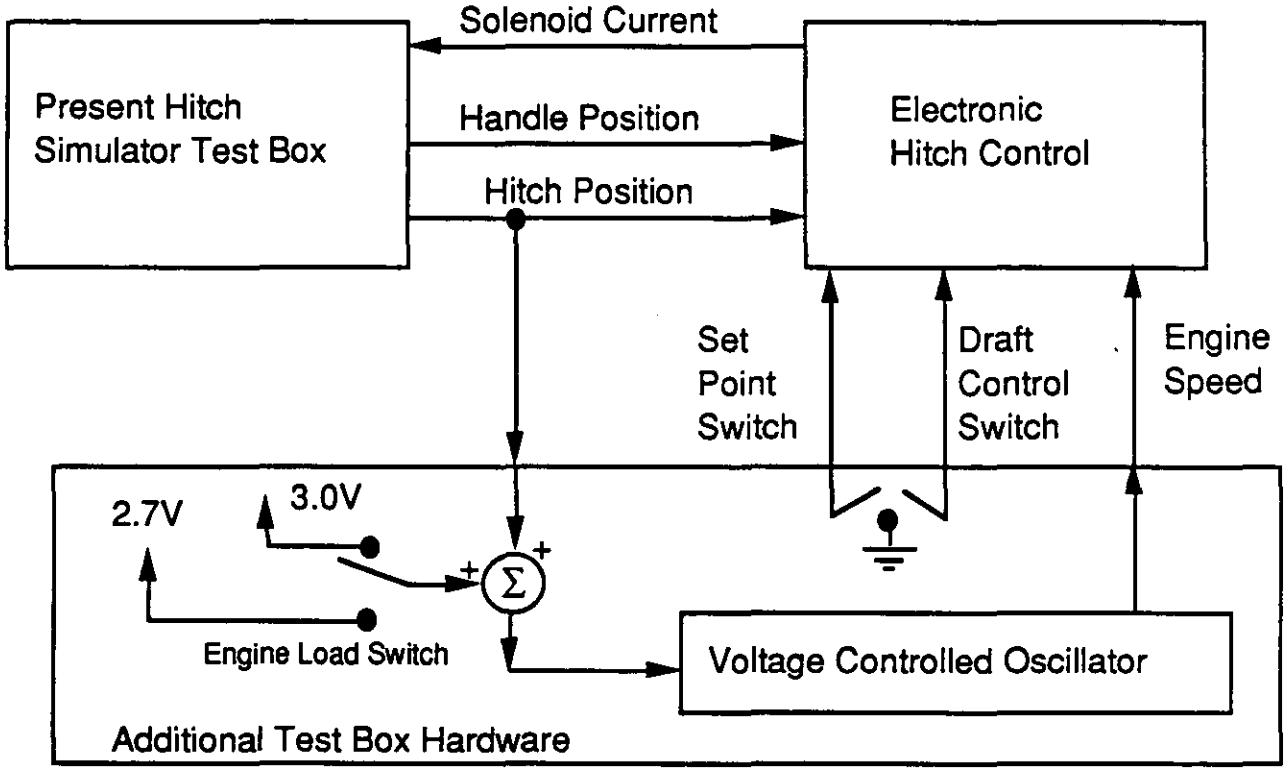


Figure #1. Block diagram of preliminary testing simulator design.

The Motorola MC14046B, an inexpensive phased locked loop which contains a voltage controlled oscillator, was selected for voltage to frequency conversion. The output frequency was scaled to meet the necessary requirements by selecting two resistors,R1 and R2, and one capacitor, C1.

That is: $f_{min} = 1/(R_2(C_1+32pF))$

$f_{max} = 1/(R_1(C_1=32pF)) + f_{min}$

With R_2 = infinity and R_1 = 30K ohms, so $f_{min} \approx$ zero Hz and $f_{max} \approx$ 5026 Hz.

On the ag tractor, the minimum engine speed of 1400 r.p.m. corresponds to 3080 hertz and the maximum speed of 2300 r.p.m. corresponds to 5060 hertz. An input between zero to eight volts into the voltage controlled oscillator produces a proportional signal from approximately 0 hertz to approximately 5026 hertz. The engine load voltage was scaled to 2.7V and 3.0V to obtain the desired frequency range. The following test procedures were developed for testing the draft control circuitry.

	ACTION	RESPONSE
1.	Rotate command position knob to the full-up position.	The hitch will raise to the full-up position.
2.	Put the engine load switch on low.	No hitch movement.
3.	Place "Draft" switch in "on" position.	No hitch movement.
4.	Rotate command position knob to the full-down position.	The hitch will lower to the 1/4 way position.
5.	Put the engine load switch on high.	The hitch will lower to the 1/4 way position.
6.	Rotate command position knob to the full-up position.	The hitch will raise to the full-up position.
7.	Hold "Set Point" switch in "on" position for 1 second.	Hitch will not move.
8.	Rotate command position knob to the full-down position.	The hitch will lower to the 1/4 way position.
9.	Put the engine load switch on low.	The hitch will raise to the 3/4 way position.

At this point in the project a preliminary circuit, shown in figure #2, for the new test box was built so the draft control hardware could be tested.

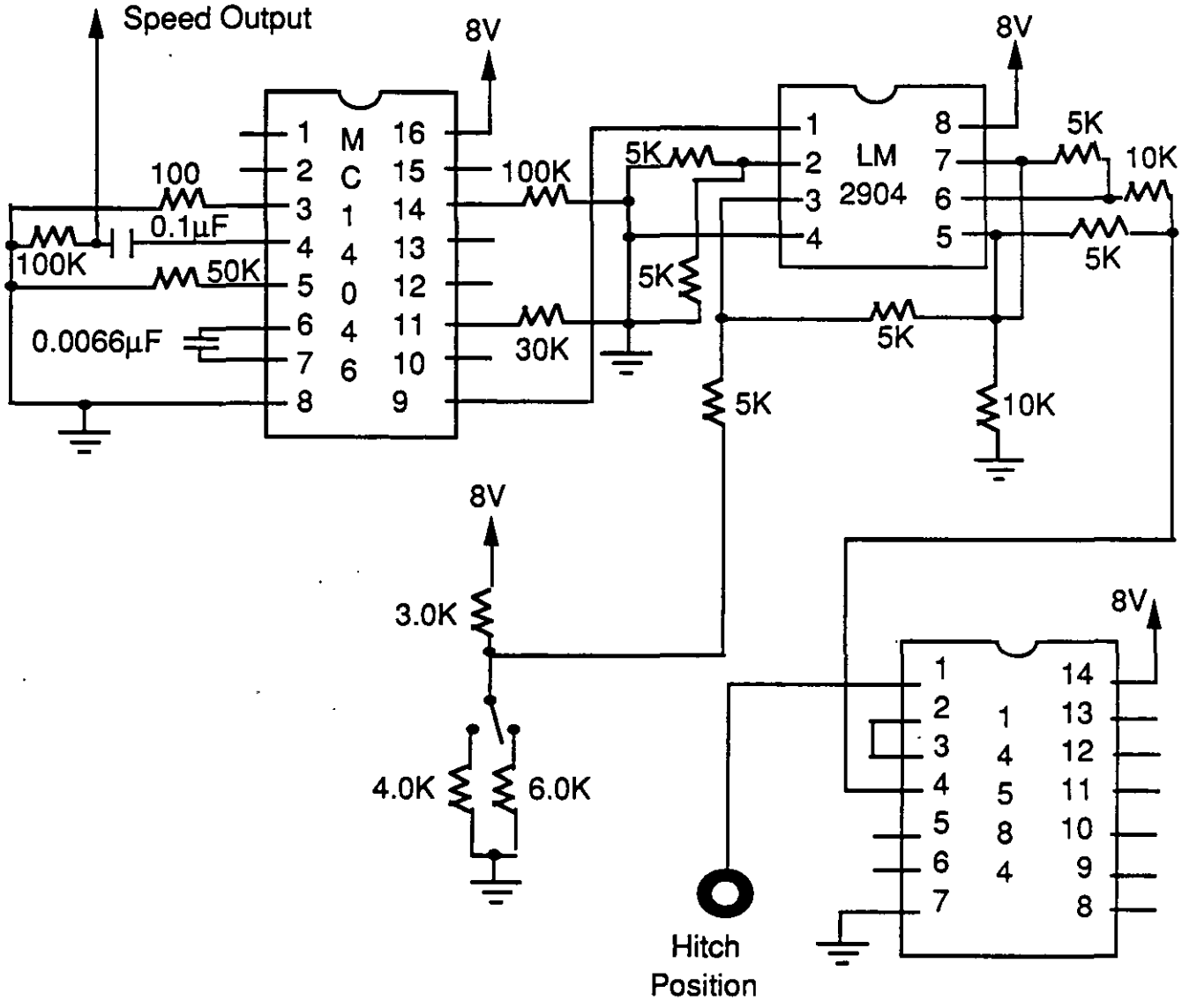


Figure #2. Schematic of preliminary design

Status Review at Assembly House:
A day was spent at the electronics firm which assembles and tests the hitch control boards. We toured their facilities and learned about their testing and manufacturing practices. We talked with them about the new hitch control and test procedures. We wanted to know if they had any ideas for improvements on the existing end of line test before we finished building the new test box. The only suggestion that they gave us about the testing procedures was that they felt some of the steps were repetitive. This made us wonder if they were actually performing all of the steps or skipping the steps they believed to be repetitive.

Repair New Hitch Control Boards:
Five newly redesigned printed circuit boards for the hitch control arrived. The boards, which were populated at the assembly house, would not function during preliminary testing. There were numerous errors in the boards. By a process of continuity checking, analyzing signals, and comparing the circuit boards against the schematic, the errors were found and the boards were corrected. The test circuit was then calibrated to work with the new hitch boards. In the process of tracking down the errors, a few minor flaws were discovered and corrected with the silk screen and on the hitch control schematic. The following corrections were made to the hitch control boards so they would function properly:

1) VR1 -- The square pad is on pin 3,
Pad 1 is pin 2,
Pad 2 is pin 3,
Pad 3 is pin 1.

2) Q14, Q16 & Q19 The square pad is on pin 3,
Pad 1 is pin 3,
Pad 3 is pin 1.

3) Q1 -- The square pad is on pin 3.

4) There should not have been a trace between C14 and R38.

5) C38 should have been connected to R38, Y1, and pin 38 of U7.

6) Three 200 ohm resistors (R16, R67, and R52) were replaced with 150 ohm resistors, which the schematic called for.

7) A 0.1μF capacitor, C48, was replaced with a 27 pF capacitor which the schematic called for.

8) There should have been a connection from C14 to pad 3 of VR1.

9) A 69.8 ohm resistor, R12, was replaced with a 69.8K ohm resistor which the schematic called for.

Status Review with Supervisor:
While reviewing the status of the new hitch controls and the testing box with my supervisor, it was determined that the use of an engine load switch was more of a software check and it was unnecessary. By checking the final hitch position with two different set points, we could sufficiently determine if the engine speed input circuitry was functioning properly.

F-to-DC Accuracy Testing:
In order to determine if this method of testing the speed input was reliable for end-of-line testing, it was necessary to evaluate the accuracy of the engine speed input circuitry. Tests were run to determine if the frequency to D.C.converters on the hitch control were accurate enough for our purposes. These tests were performed at room temperature and at 54°C. We found that, according to the test data on pages 12-17, the accuracy of these converters was better than originally expected.

Build Testing Box:
As shown in figure #3, the set point switch and the draft control switch were added to the front panel of the test box. Along with these switches, a wire wrap version of the draft control test circuitry, shown in figure #4, was built and incorporated in the original test box. The connector on the testing simulator box was changed to handle the additional signal lines.

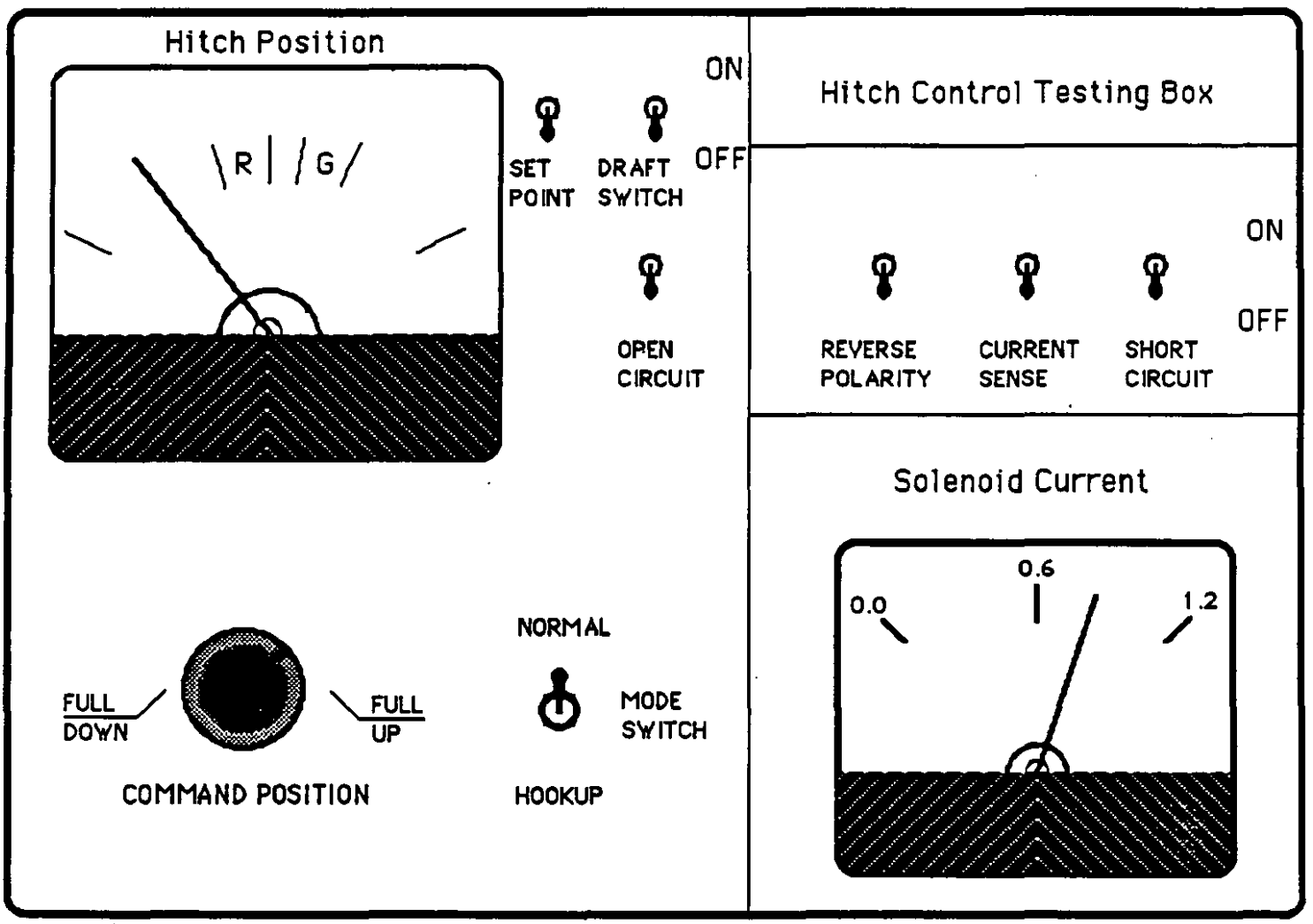


Figure #3. Front panel of simulator test box.

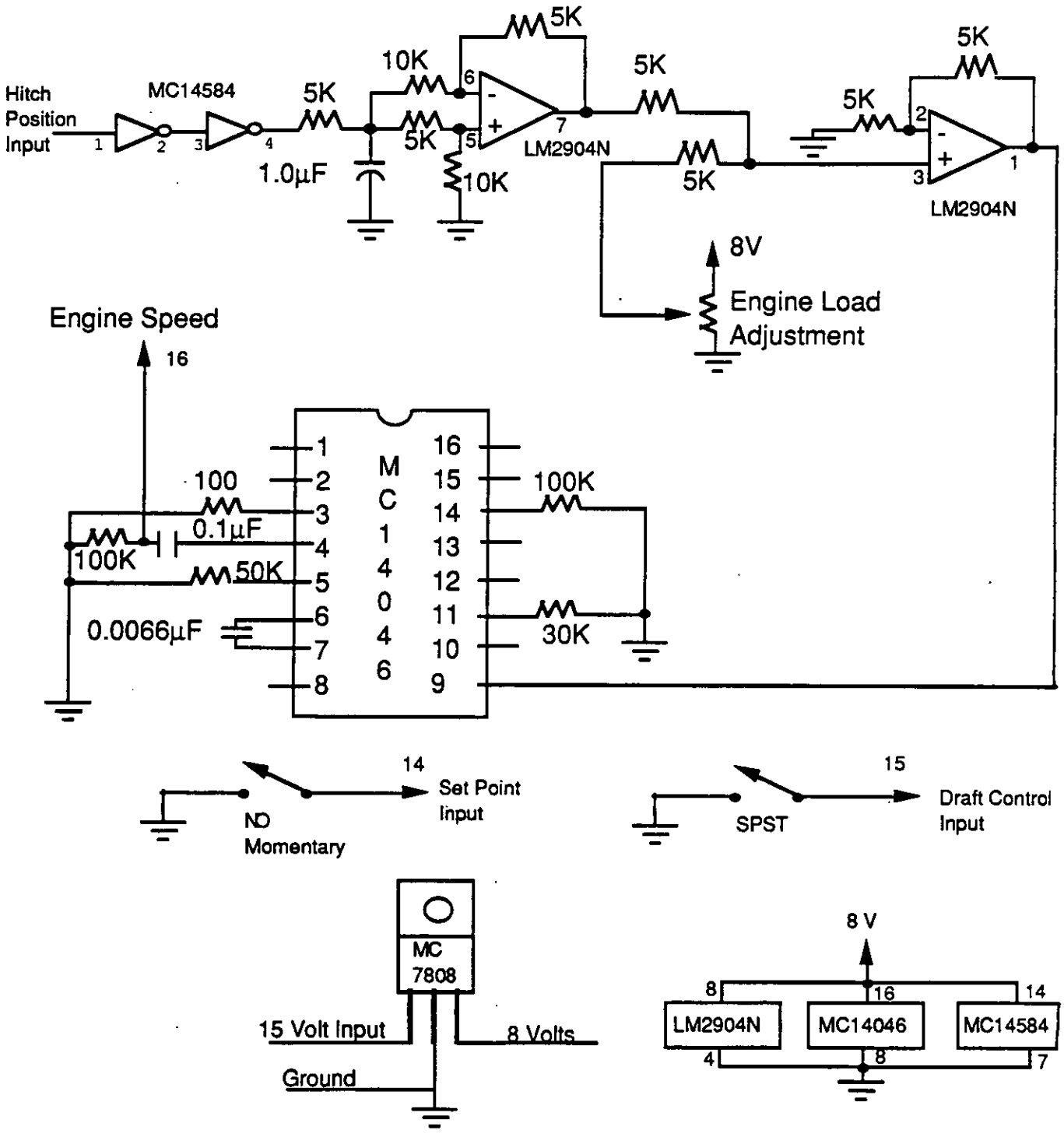


Figure #4. Draft control test circuitry.

Build New Wire Harnesses:
New lab wire harnesses, shown in figures #5-#7, were made to connect the end-of-line test box to the hitch control. Because this simulator will be used to evaluate and troubleshoot all of the different versions of hitch control hardware that have been produced in the past, the wire harnesses will be used to connect the new testing box to any version of the hitch control module.

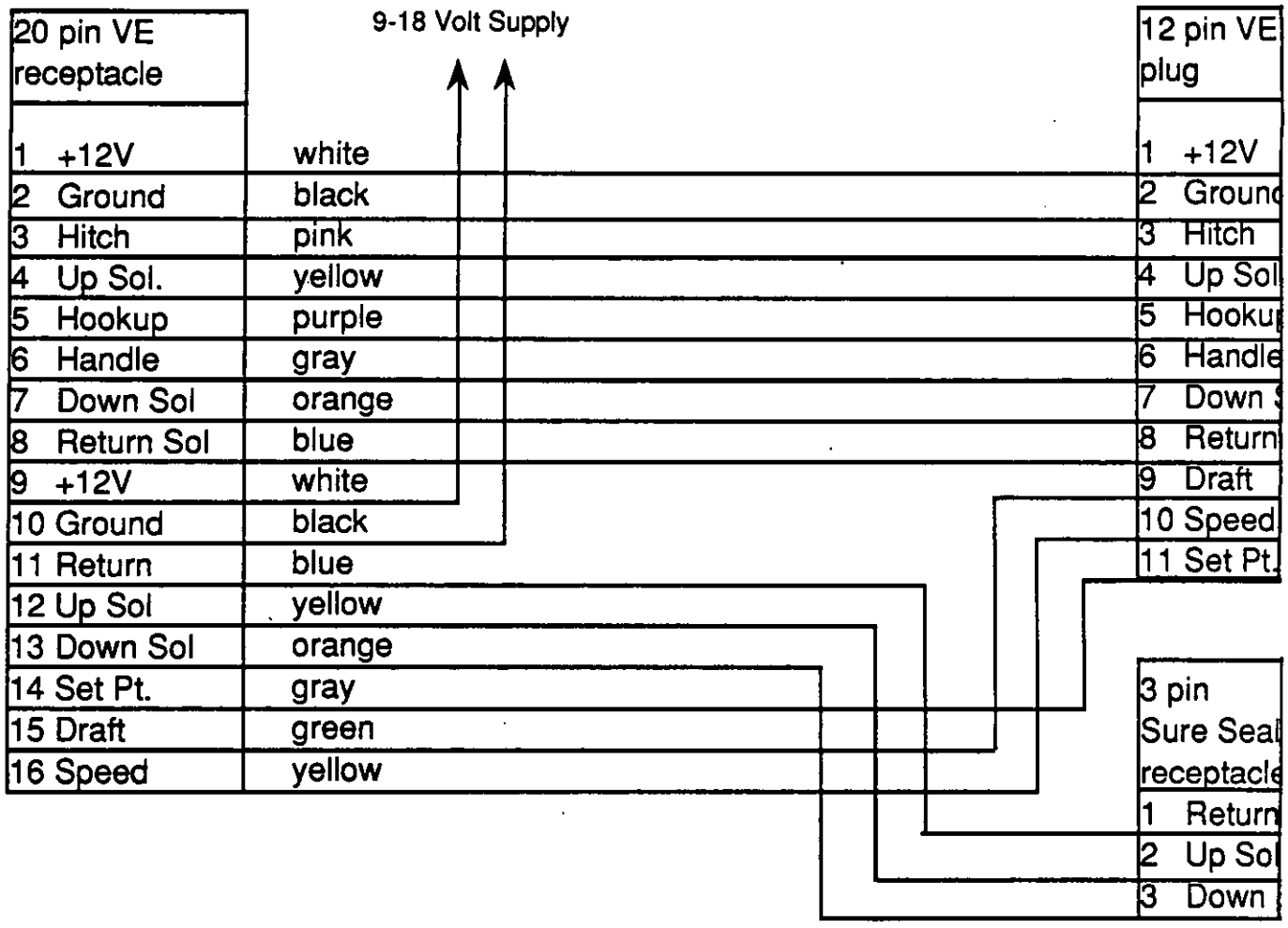


Figure #5. Wire harness from test box to breakout board.

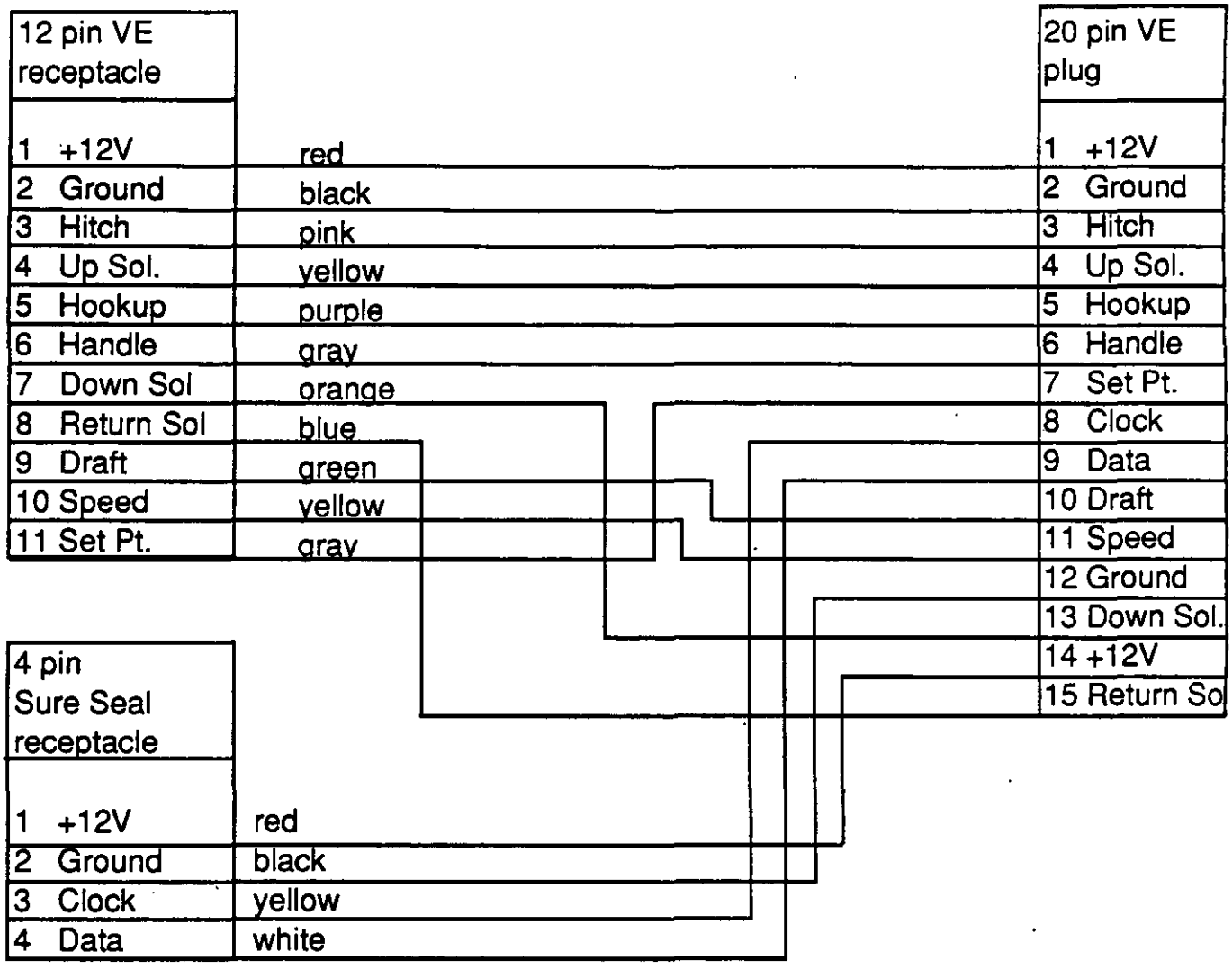


Figure #6. Wire harness from breakout board to new hitch control board.

12 pin VE receptacle		10 pin Sure Seal receptacle
1 +12V	red	1 +12V
2 Ground	black	2 Ground
3 Hitch	white	3 Hitch
4 Up Sol.	yellow	4 Up Sol.
5 Hookup	green	5 Hookup
6 Handle	gray	6 Handle
7 Down Sol	brown	7 Down Sol
8 Return Sol	blue	8 Return Sol
9 Draft		
10 Speed		
11 Set Pt.		

Figure #7. Wire harness from breakout board to old hitch control board.

Modify Documents:
Reviewed and modified the testing procedures for the end of line test. The modified procedures need to fully test all of the hitch control circuitry. The order of the original testing steps was rearranged to eliminate the appearance of repetitive steps. The following steps were added to the testing procedures:

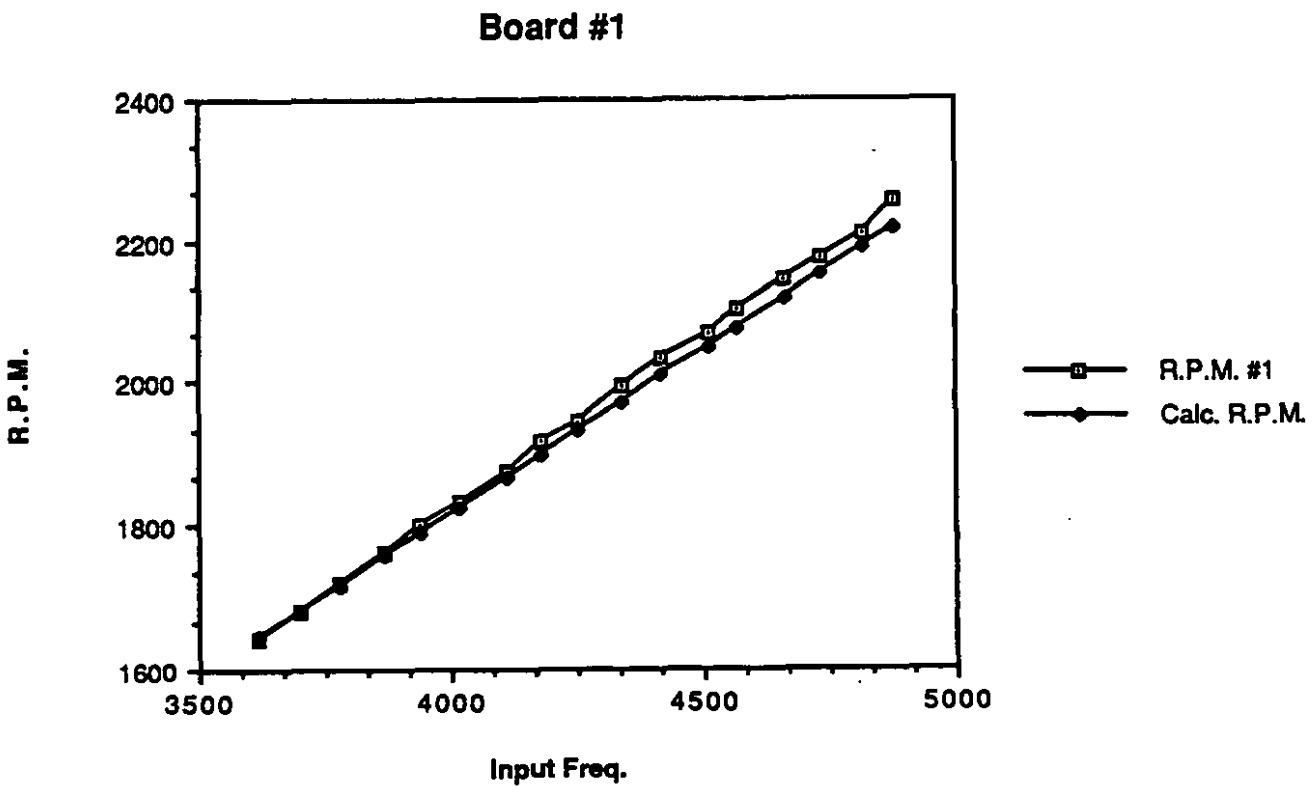
	ACTION	RESPONSE
1.	Rotate command position knob to the full-up position.	The hitch will raise to the full-up position.
2.	Place "Draft" switch in "on" position.	No hitch movement.
3.	Rotate command position knob to the full-down position.	The hitch will come to a stop in the red zone.
4.	Rotate command position knob to the full-up position.	The hitch will raise to the full-up position.
5.	Hold "Set Point" switch in "on" position for 1 second.	Hitch will not move.
6.	Rotate command position knob to the full-down position.	The hitch will come to a stop in the green zone.

The test box schematic was marked up with the changes made to the test box. This schematic and the modified test procedures were given to the packaging section. The packaging people were responsible for entering this information into the corporate print system.

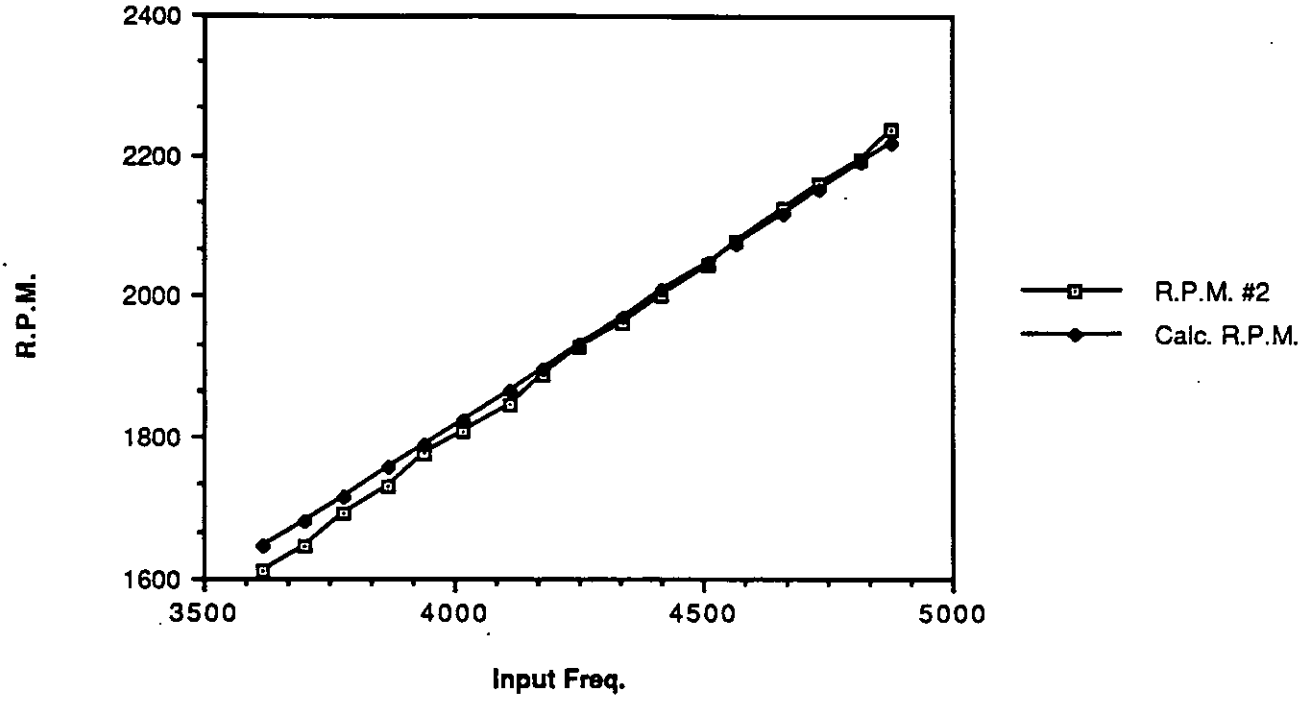
Grounding Problem:
With the procedures updated and the test box modified, the hitch control boards were tested. During these tests, intermittent board failures occurred. The tests uncovered a grounding problem and a couple capacitors of the wrong value were discovered. The capacitors were changed to the proper size. A storage oscilloscope and a scope camera were used to document the grounding problem. The grounding problem occurred because the A-to-D converter was placed next to the high current diodes and transistors. The layout of the board was changed to solve the grounding problem and new printed circuit boards were ordered.

Graph Data Thu, Oct 20, 1988 2:16 PM

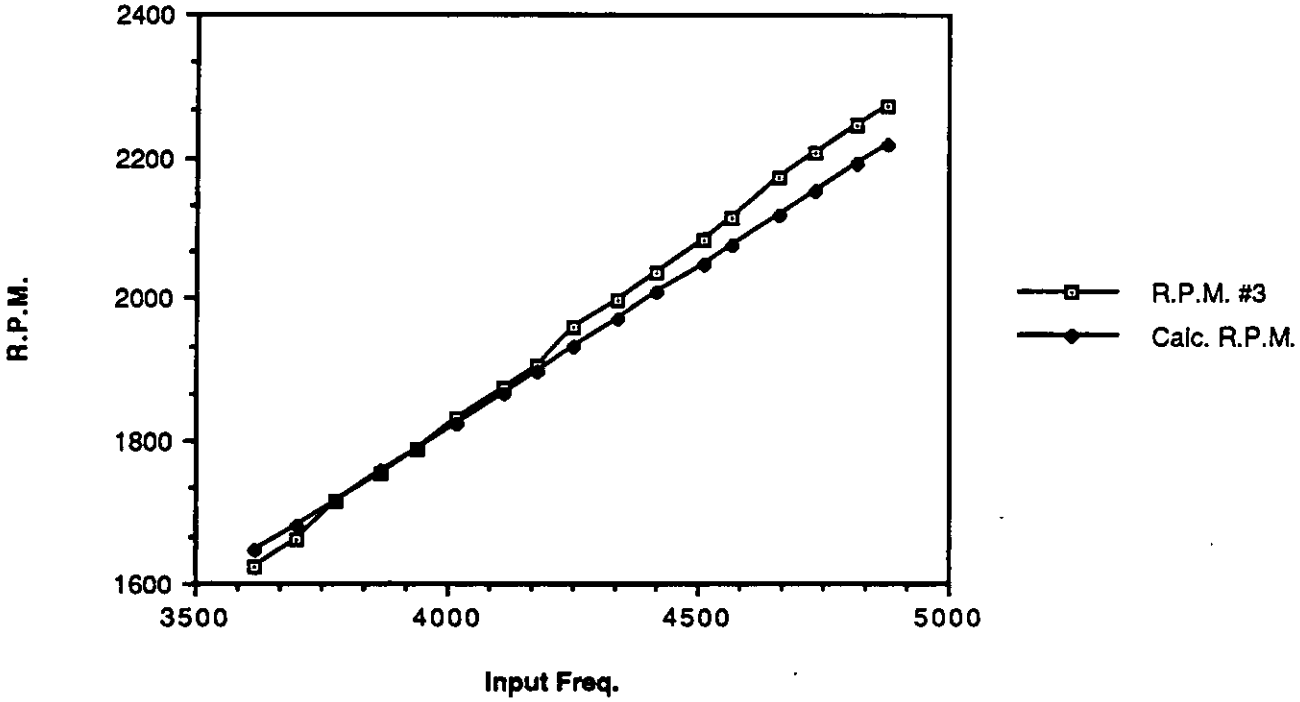
	Input Freq.	R.P.M. #1	R.P.M. #2	R.P.M. #3	R.P.M. #4	R.P.M. #5	Calc. R.P.M.
1	3618	1643.529	1611.765	1622.353	1611.765	1632.941	1644.545
2	3698	1682.353	1647.059	1661.176	1654.118	1678.824	1680.909
3	3776	1721.176	1692.941	1714.118	1696.471	1717.647	1716.364
4	3866	1763.529	1731.765	1752.941	1735.294	1763.529	1757.273
5	3940	1802.353	1777.647	1788.235	1770.588	1795.294	1790.909
6	4016	1830.588	1809.412	1830.588	1805.882	1837.647	1825.455
7	4110	1872.941	1848.235	1872.941	1848.235	1876.471	1868.182
8	4178	1915.294	1890.588	1904.706	1887.059	1918.824	1899.091
9	4248	1943.529	1929.412	1957.647	1929.412	1961.176	1930.909
10	4338	1992.941	1964.706	1996.471	1971.765	2000.000	1971.818
11	4418	2031.765	2003.529	2035.294	2003.529	2045.882	2008.182
12	4510	2067.059	2045.882	2081.176	2052.941	2084.706	2050.000
13	4564	2102.353	2077.647	2112.941	2077.647	2123.529	2074.545
14	4662	2144.706	2127.059	2172.941	2116.471	2162.353	2119.091
15	4734	2176.471	2158.824	2208.235	2155.294	2201.176	2151.818
16	4817	2211.765	2194.118	2247.059	2197.647	2232.941	2189.545
17	4880	2257.647	2236.471	2271.765	2240.000	2278.824	2218.182



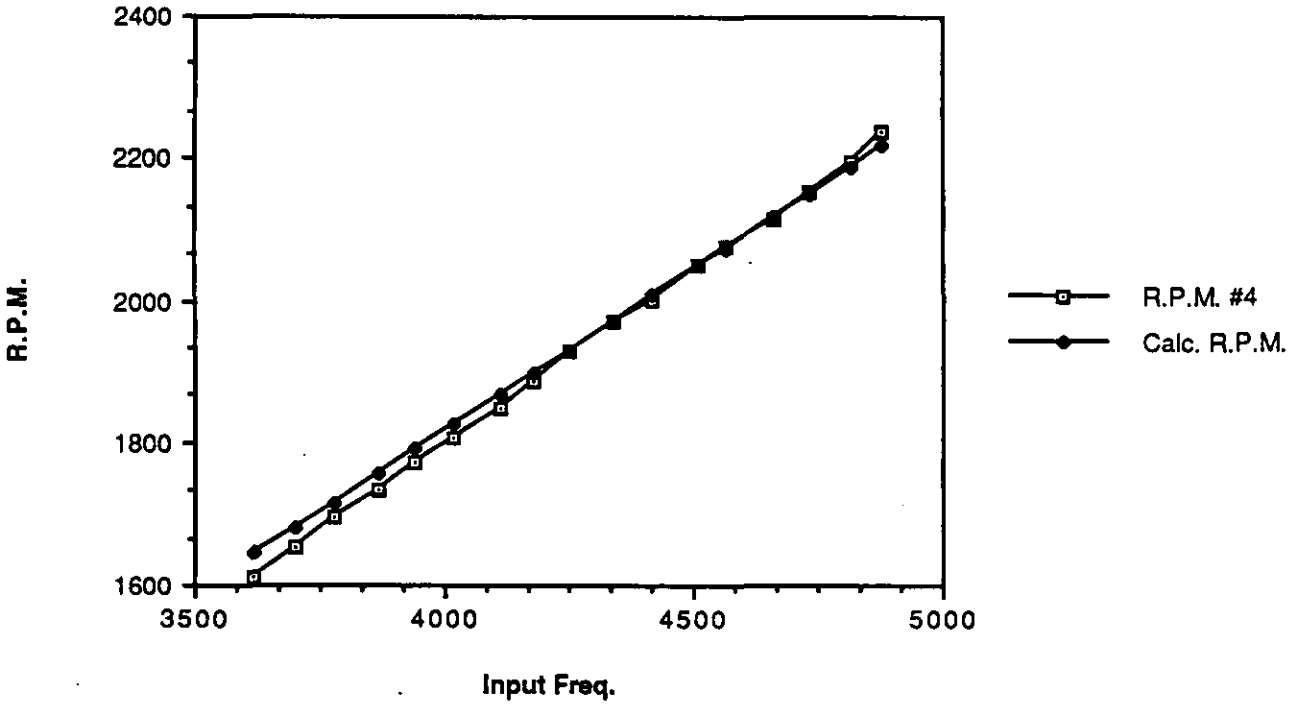
Board #2



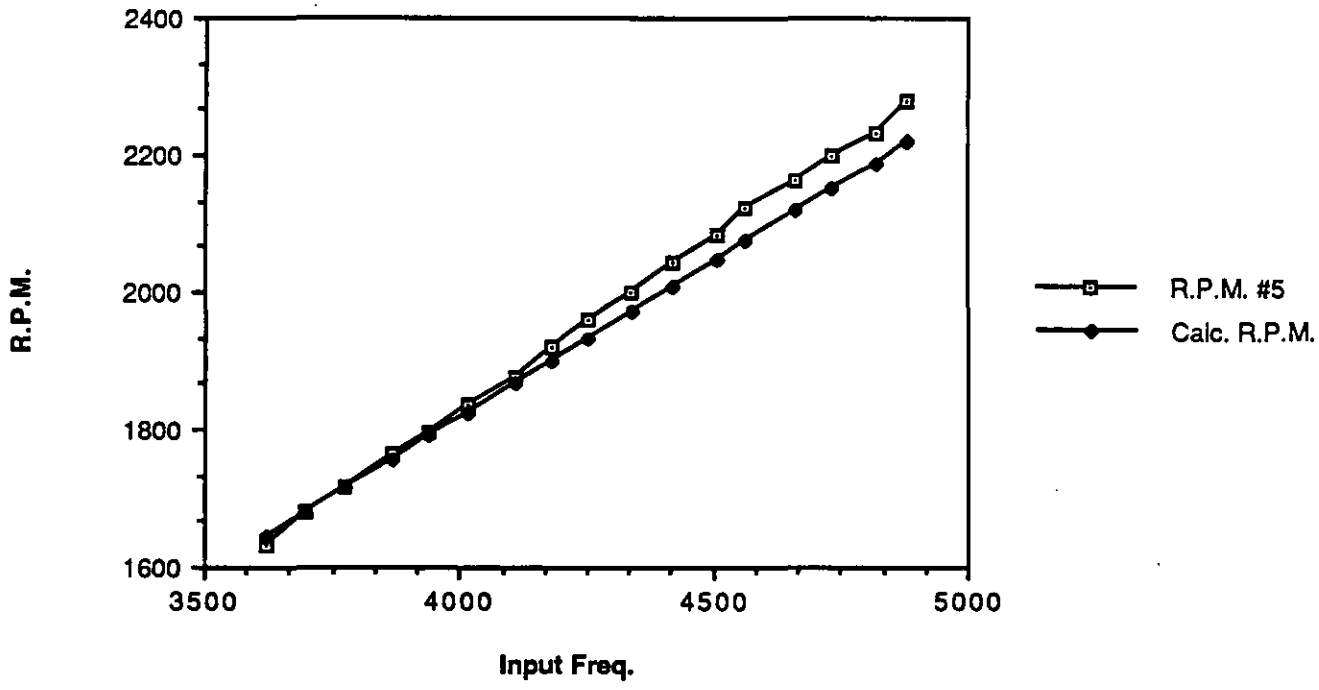
Board #3



Board #4

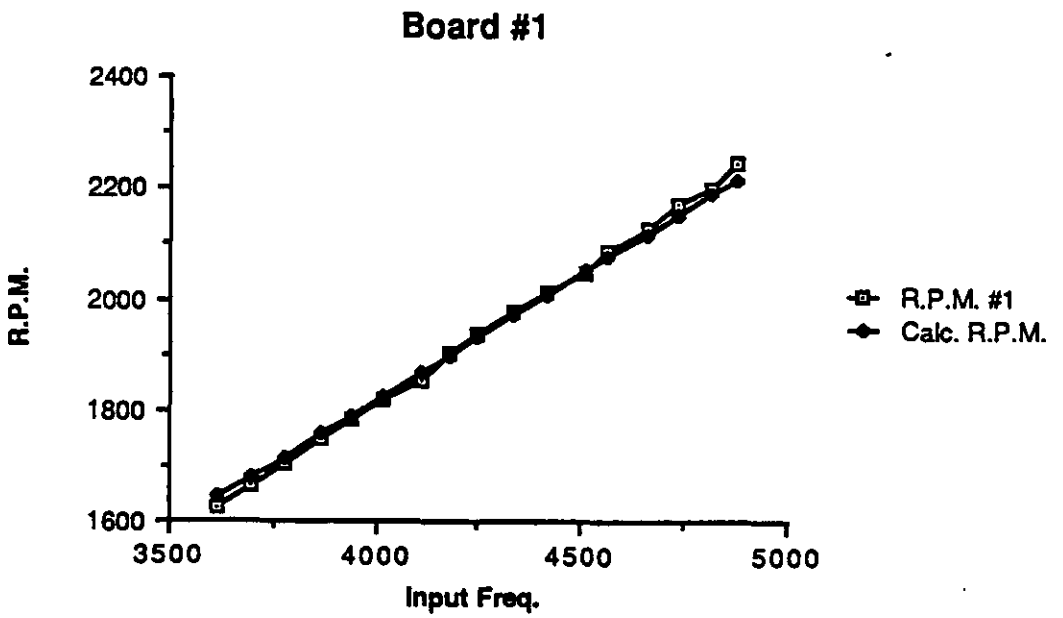


Board #5

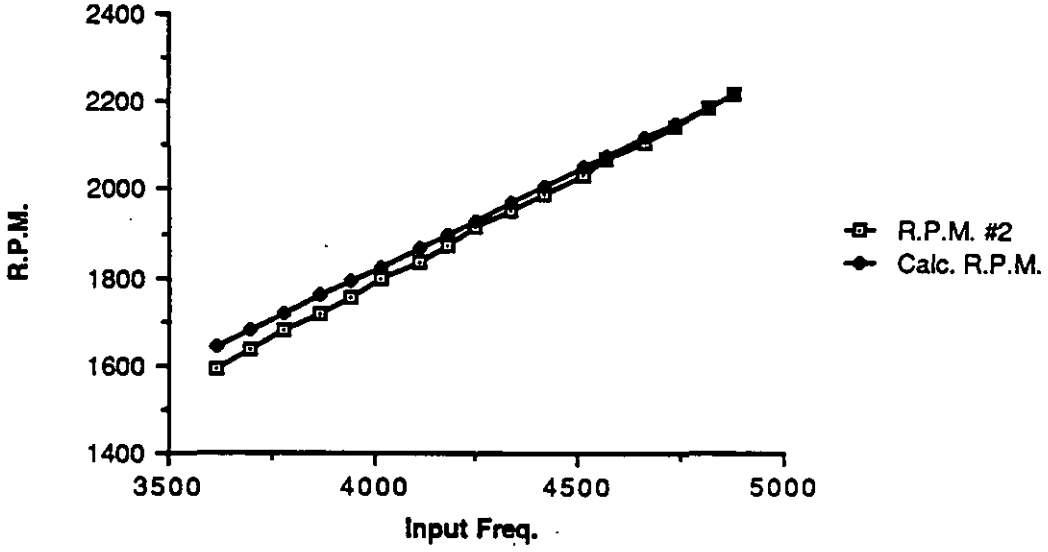


Graph Data @ 54 Deg. C Mon, Oct 24, 1988 1:29 PM

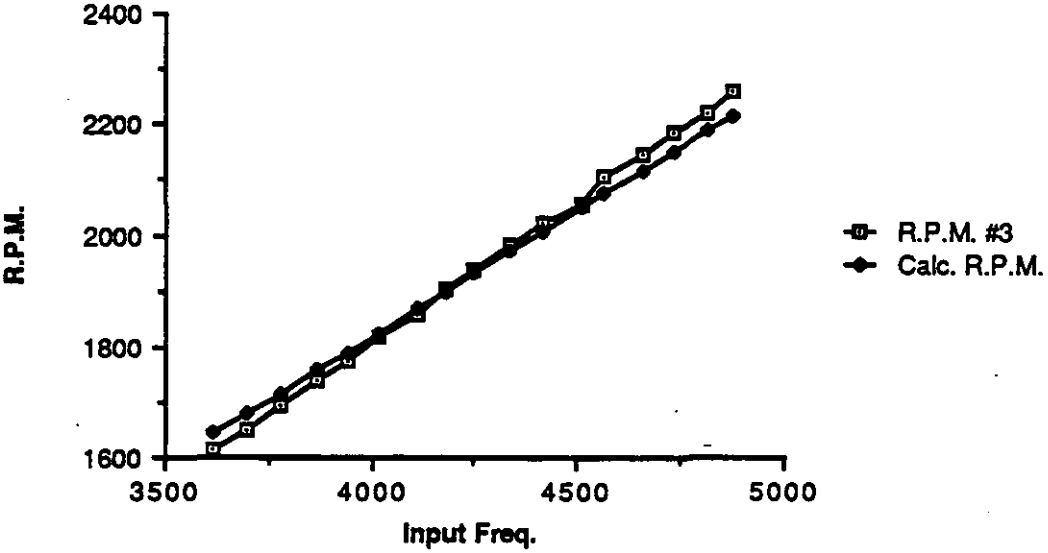
	Input Freq.	R.P.M. #1	R.P.M. #2	R.P.M. #3	R.P.M. #4	R.P.M. #5	Calc. R.P.M.
1	3618	1625.882	1594.118	1615.294	1587.059	1615.294	1644.545
2	3698	1664.706	1636.471	1650.588	1632.941	1661.176	1680.909
3	3776	1703.529	1682.353	1692.941	1671.765	1703.529	1716.364
4	3866	1749.412	1714.118	1738.824	1721.176	1745.882	1757.273
5	3940	1784.706	1756.471	1774.118	1752.941	1784.706	1790.909
6	4016	1820.000	1798.824	1816.471	1791.765	1823.529	1825.455
7	4110	1855.294	1837.647	1858.824	1834.118	1865.882	1868.182
8	4178	1901.176	1872.941	1901.176	1869.412	1901.176	1899.091
9	4248	1940.000	1915.294	1940.000	1908.235	1947.059	1930.909
10	4338	1975.294	1954.118	1982.353	1950.588	1982.353	1971.818
11	4418	2014.118	1992.941	2021.176	1989.412	2024.706	2008.182
12	4510	2049.412	2035.294	2056.471	2031.765	2070.588	2050.000
13	4564	2088.235	2070.588	2105.882	2067.059	2105.882	2074.545
14	4662	2127.059	2109.412	2148.235	2109.412	2141.176	2119.091
15	4734	2169.412	2148.235	2187.059	2144.706	2180.000	2151.818
16	4817	2201.176	2187.059	2218.824	2183.529	2225.882	2189.545
17	4880	2243.529	2222.353	2261.176	2222.353	2261.176	2218.182



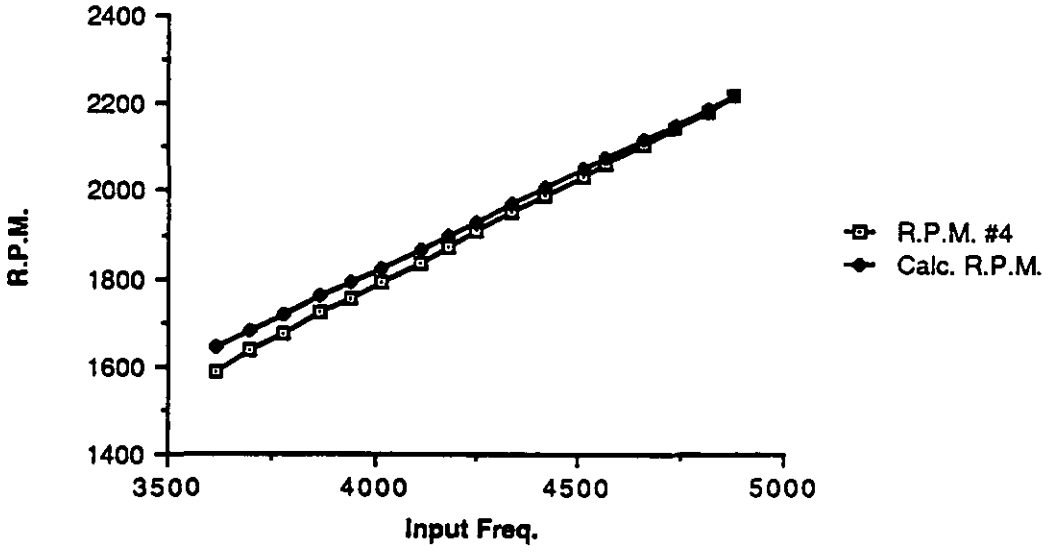
Board #2



Board #3



Board #4



Board #5