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A CAMAC-CONTROLLED CALIBRATION SYSTEM FOR

NUCLEAR REACTOR INSTRUMENTS

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parameter measurement system and the output multiplexer and line drivers.

The controller operates as follows:

- 1) A command consisting of 24 bits of data accompanied by a strobe pulse is received from the computer.
- 2) Upon receipt of the strobe pulse the data is decoded and appropriate signals generated to the instrument under test and the measurement system.
- 3) Output data is made available to the computer via a CAMAC input port and a LAM signal is generated.
- 4) The controller then awaits the next command.

Input Section

The input section consists of a set of line receivers designed to accept the outputs of a CAMAC output register. The output of these line receivers is connected to a set of data latches which are strobed on the trailing edge of the command strobe pulse. Upon receipt of the strobe pulse, the command is executed. The command word table contains the data format used in the system. The first 12 bits (0-11) in the command word specify the input voltage level used for the test. These bits are directly connected to a 12-bit digital-to-analog converter. The output of the converter is a unipolar current proportional to the value of the binary input. This can be expressed as follows:

$$I_o \sim \left[\frac{N}{4095} \right]$$

where N is the decimal equivalent of the 12-bit field.

This unipolar current is delivered to the summing junction of an operational amplifier where it is converted to a voltage for use throughout the system.

Bits 12, 13, and 14 are decoded by a three-line to eight-line converter and are used to select an output current-determining resistor. If all three bits are zero, no resistor is selected.

Bits 15 and 16 select the line voltage to be used to power the instrument under test.

Bit 17 and 18 are used to switch a set of calibrated resistors into the system to allow the internal current-determining resistors to be checked.

Bits 19, 20 and 21 control the input multiplexer for the DVM, the risetime mode and the readout of the trip-time timer.

Analog Signal Generator

The analog signal consists of the digital-to-analog converter and its associated amplifiers, the current-determining resistors, and the associated relays and solid-state switches. For the purposes of testing reactor instruments in which the input connects directly to the summing junction of an operational amplifier, an adequate current source consists of a voltage supply and series resistor. Therefore, in this controller the voltage source is the D-A converter and the proper resistance value is selected by the control word. A range of currents from 10^{-11} A to 10^{-4} A can be generated by suitable selection of voltage and resistance. To help insure accurate current generation into the

summing junction of the instrument under test, the operator is prompted to zero the instrument. The amplifier output is tested by the system and the calibration will not proceed until a proper zero has been achieved.

Command Decoders

The command decoders for the current-forming resistor selection, the instrument-under-test line voltage selection, and the self-calibration selection are N line to M line converters (3 to 8 or 2 to 4). The input word is directly executed upon receipt of the strobe pulse.

If a risetime measurement is selected, however, the strobe pulse causes the following sequence:

- 1) The input voltage to the current-forming network is removed and a three-second delay implemented to allow the instrument under test to stabilize.
- 2) The voltage is reapplied to the current-determining resistor.
- 3) A scaler is started when the output voltage reaches 1.0 volt and stopped when the output voltage reaches 9.0, corresponding to a 10-90% risetime measurement.
- 4) The trip timer is started at the 1.0 volt level and turned off when the output relay drops out.
- 5) After a 10-second delay to allow sufficient time for the test the scaler output is placed in the output bus by the output multiplexer and read by the computer.
- 6) If a trip-time readout were desired at this time, the software would deliver a trip-time command to place the output of the trip-time scaler onto the output bus.

The test command causes the input to the risetime comparators to be connected to the output of the D-A converter and the output from the comparators to be connected to the output bus. The software then checks the comparators for operation at 1.0V and 9.0V.

Parameter Measurement System

The parameter measurement system consists of the digital voltmeter, the risetime comparators, timers, the trip-time timer, and the RMS to DC converter.

The output from the instrument under test is connected to the following points in the controller:

- 1) The DVM input selection switch
- 2) The RMS to DC converter
- 3) The risetime comparators

As the test of a particular range on the instrument under test progresses, the digital voltmeter input is switched to the desired signal source.

A separate pair of wires is run from a spare set of contacts on a trip relay to the trip-time control.

The test of a particular range of a picoammeter would proceed as follows:

- 1) An ac line voltage of 95 volts is selected.

- 2) Various values of input current are generated, and the output voltage and the RMS noise voltage are recorded for each value.
- 3) A risetime measurement is performed.
- 4) The above steps are repeated for 117 Vac and 135 Vac.
- 5) The above sequence is repeated for the next range to be tested.

In implementing this system, we have elected to use an external DVM to measure the required parameters because of the ease of providing NBS traceability for such a DVM. The other parameters in the system that must be calibrated are the oscillator for the risetime timer and the current-determining resistors.

The internal oscillator's calibration is checked with a traceable counter timer. The current-forming resistors can be measured without removing them from the chassis by means of a connector arrangement.

Output Multiplexers and Line Drivers

The digital output of the DVM is converted to a binary value and latched in a tri-state buffer. The outputs of the risetime and trip-time scalars are also tri-state devices and are connected to a common output bus along with the DVM buffer outputs. Normally the DVM latches are enabled and the DVM data is delivered to the computer when a conversion-finished signal is generated.

When either the risetime or trip-time mode is selected, the appropriate output is enabled and the remaining two outputs are in the high-impedance mode. Line drivers interface the system with the CAMAC input register located 200 feet from the test instrument.

System Software

As previously mentioned, the software package for the system consists of a set of Fortran application sub-routines which interface to the hardware controller via the CAMAC crate by means of an assembly language handler.

The assembly language handler allows the Fortran programmer to use all the features of the instrument checkout system. The programmer need only provide the call statement: CALL INSTF (VOLT,IRANGE,LINE,ICALR, IDVM,IVMO,IER). VOLT determines the output and voltage of the D-A converter, IRANGE selects the current-determining resistor, LINE selects the ac line voltage applied to the instrument under test. ICALR selects the internal calibration system and IDVM selects the DVM mode. The arguments thus are used to form the output command word. Subroutine INSTF provides the full capabilities of the instrument checkout system together with all required CAMAC operations and range checking of INSTF arguments. The allowable argument ranges are:

$$0 \leq \text{VOLT} \leq 10.0, \text{IRANGE} = \{0, 4, 5, 6, 7, 8, 9, 10\},$$

$$\text{LINE} = \{0, 1, 2, 3\}, \text{ICALR} = \{0, 1, 2, 3\},$$

$$\text{IDVM} = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}.$$

The arguments IVMO and IER are returned by the subroutine such that:

$$\text{IDVM} = 0, 2, 4, 6, 8 \Rightarrow I(x) = 1 \cdot 10^4 \cdot (\text{VOLTAGE})$$

$$\text{IDVM} = 3, 5 \Rightarrow I(x) = 10 \cdot \text{MILLI-SECONDS}$$

$$\text{IVMO} = I(x) : \begin{cases} 0: \text{NO COMP. TRIP} \\ 2: 10\% \text{ " " "} \\ 3: 90\% \text{ " " "} \end{cases}$$

$$\text{IDVM} = 9 \Rightarrow I(x) = \text{COMMAND WORD}$$

$$\text{IER} = x : \begin{cases} x=0 \Rightarrow \text{INSTF arguments within acceptable range} \\ x=1 \Rightarrow \text{INSTF arguments not within acceptable range} \end{cases}$$

The CAMAC operations include transmission of the command word via a Jorway, Model No. 40, Dual 24-Bit Output Register, and reception of the read word via a Jorway, Model No. 60, Dual Parallel Input Register. When operating, the Fortran program leads the operator, via a Hazeltine CRT operating in form-fillout mode, through all of the steps required to check out any one of the 11 ZPR picoammeters.

System Operation

The calibration system is located in the reactor control panel to allow convenient use. When a calibration is desired, the current input and the ac line cord are removed from the instrument under test and attached to the appropriate outputs on the hardware controller. A cable is then attached between the instrument and the controller to allow the output response to be measured. The checkout begins by requiring operator input, such as date, name of operator, model number, serial number, date of last calibration, and ZPR facility number. System checks are provided to assure all of these entries are appropriate, and, if so, based on these entries the system then leads the operator through a checkout appropriate for the particular instrument under test. If required, the checkout will begin with an automatic calibration of the system's internal range resistors and comparator trip levels. The system then proceeds to generate appropriate picoammeter input signals for measuring amplifier output voltage, RMS noise level, risetime, trip time and bucking-current characteristics over an input current range from 10^{-11} to 10^{-4} amperes for a variety of instrument ac line voltages. The operator needs simply to enter meter readings, reset the trip circuit and change range switch settings under prompting by the CRT. The system provides ongoing measurement results, via the CRT, where any parameters not within acceptable tolerance are flagged. When an out-of-tolerance value is detected, the operator has the option to continue the calibration, to restart the calibration or to terminate the calibration and enter a maintenance routine. The maintenance routine is provided to allow the operator to make any given measurement for diagnostic purposes.

After the measurements are made, the system then enters a print cycle whereupon an appropriately formatted report is printed on the system line printer (see appendix). This report includes all operator input parameters as well as the flagging and delineation of all parameters which are outside of specified tolerances. Due to its completeness, the report is appropriate for interrogation by technical as well as auditing personnel.

* To be used in period generator code.

Conclusion

This computer-controlled calibration system has resulted in a significant savings in the time required to calibrate instruments. By providing printed records with any out-of-range values flagged, the system has improved the task of maintaining long-term instrument calibration logs. Future development of the system will include calibrating pulse mode instruments and recording the system data on magnetic tape to provide a rapid means of observing long-term parameter drift.

Command Word Table

Bit				
0				
1				
2				
3				
4				
5	D/A Command Voltage Select			
6				
7				
8				
9				
10				
11				
12	Range Resistor	000-NOP	011-10 ⁶	110-10 ⁹
13		001-10 ⁴	100-10 ⁷	111-10 ¹¹
14		010-10 ⁵		
15	Line Voltage	00 115	10-135	
16		01 95	11-NOP	
17	Self-Calibrate	00 Normal	10-10 ³	
18		01 Reserved	11-10 ⁷	
19	DVM & Risetime	000 Source	011 RMS	110 TRIPTIME
20		001 CAL-R	100 NOP	111 TEST
21		010 IUT	101 RISE T.	
22	Reserved for Period Meter Tests			
23

Fig. 2. Hardware Controller

Fig. 1. System Block Diagram

APPENDIX

DATE 10 / 3 / 77
 FROM MITCHELL LADEWSKI
 TO ZPR INSTRUMENT CHECKOUT LOG
 SUBJECT CALIBRATION OF INSTRUMENT CHECKOUT SYSTEM

OPERATOR INPUT PARAMETERS

STANDARDIZED CALIBRATION RESISTOR VALUES, 1X10(3) = 998.500
 1X10(7) = 9924000.000

LINE VOLTAGES, 115VAC = 115.00
 135VAC = 135.00
 95VAC = 95.00

VOLTMETER CALIBRATION DATE, 7/17/77
 ELECTRONICS CALIBRATION DATE, 7/17/76 *** NOT WITHIN CS4 TIME STANDARDS ***

RESULTS OF RANGE RESISTOR CALIBRATION

1X10(4) = .101E 05
 1X10(5) = .101E 06
 1X10(6) = .995E 06
 1X10(7) = .989E 07
 1X10(8) = .950E 08
 1X10(9) = .100E 10
 1X10(10) = .100E 11

RESULTS OF COMPARATOR CALIBRATION

10% TRIP LEVEL = .960
 90% TRIP LEVEL = 8.902

DATE 10 / 3 / 77
 FROM MITCHELL LADEWSKI
 TO ZPR INSTRUMENT CHECKOUT LOG
 SUBJECT CALIBRATION OF LINEAR INSTRUMENT
 MODEL NUMBER CD271-24
 ANL NUMBER 12465
 DRAWING NUMBER A0069-0259-DC-00
 REACTOR FACILITY ZPR-9
 CHANNEL NUMBER 5

LINE VOLTAGE = 95.00

RANGE	INPUT CURRENT (AMPS)	METER READING	AMPLIFIER OUTPUT (VOLTS)	NOISE (MV)		RISETIME (MS)		TRIP TEST(MS)	
				ACCEPTABLE TOLERANCE	RMS NOISE	ACCEPTABLE TOLERANCE	10-90P TIME	ACCEPTABLE TOLERANCE	TRIP TIME
ZERO		.00	.00						
1E- 4	.97E-04	.96	-9.55	<100.	14.6	< 1.	.3	<60.	42.9
1E- 5	.97E-05	.98	-9.71	<100.	13.8	< 10.	2.5		
1E- 6	.97E-06	.96	-9.49	<100.	8.4	< 100.	25.8		
1E- 7	.97E-07	.94	-9.34	<200.	9.5	< 100.	30.4		
1E- 8	.97E-08	.93	-9.25	<300.	26.4	< 200.	50.5		
1E- 9	.97E-09	.95	-9.40	<400.	75.9	< 500.	113.9		
1E-10	.97E-10	.98	-9.68	<500.	207.0	<2000.	232.7		

DATE 10 / 3 / 77
 FROM MITCHELL LADEWSKI
 TO ZPR INSTRUMENT CHECKOUT LOG
 SUBJECT CALIBRATION OF LINEAR INSTRUMENT
 MODEL NUMBER CD271-24
 ANL NUMBER 12465
 DRAWING NUMBER A0069-0259-DC-00
 REACTOR FACILITY ZPR-9
 CHANNEL NUMBER 5

LINE VOLTAGE=115.00

RANGE	INPUT		AMPLIFIER OUTPUT (VOLTS)	NOISE (MV)		RISETIME (MS)		TRIP TEST(MS)	
	CURRENT (AMPS)	METER READING		ACCEPTABLE TOLERANCE	RMS NOISE	ACCEPTABLE TOLERANCE	10-90P TIME	ACCEPTABLE TOLERANCE	TRIP TIME
ZERO		.00	.00						
1E-4	.97E-04	.97	-9.60	<100.	14.7	< 1.	.4	<60.	44.7
1E-5	.97E-05	.98	-9.76	<100.	14.4	< 10.	2.5		
1E-6	.97E-06	.96	-9.54	<100.	9.1	< 100.	25.0		
1E-7	.97E-07	.94	-9.39	<200.	10.2	< 100.	29.4		
1E-8	.97E-08	.94	-9.30	<300.	29.0	< 200.	46.5		
1E-9	.97E-09	.95	-9.45	<400.	80.0	< 500.	107.6		
1E-10	.97E-10	.98	-9.75	<500.	232.3	<2000.	221.0		

LINE VOLTAGE=135.00

RANGE	INPUT		AMPLIFIER OUTPUT (VOLTS)	NOISE (MV)		RISETIME (MS)		TRIP TEST(MS)	
	CURRENT (AMPS)	METER READING		ACCEPTABLE TOLERANCE	RMS NOISE	ACCEPTABLE TOLERANCE	10-90P TIME	ACCEPTABLE TOLERANCE	TRIP TIME
ZERO		.00	.00						
1E-4	.97E-04	.97	-9.63	<100.	15.1	< 1.	.4	<60.	45.3
1E-5	.97E-05	.98	-9.79	<100.	14.1	< 10.	2.5		
1E-6	.97E-06	.97	-9.57	<100.	8.6	< 100.	24.6		
1E-7	.97E-07	.95	-9.42	<200.	10.1	< 100.	28.9		
1E-8	.97E-08	.94	-9.33	<300.	30.0	< 200.	48.0		
1E-9	.97E-09	.95	-9.48	<400.	84.1	< 500.	112.1		
1E-10	.97E-10	.930.	-9.82	<500.	298.3	<2000.	213.9		

DATE 10 / 3 / 77

FROM MITCHELL LADEWSKI

TO ZPR INSTRUMENT CHECKOUT LOG

SUBJECT CALIBRATION OF LINEAR INSTRUMENT

MODEL NUMBER CD271-24

ANL NUMBER 12465

DRAWING NUMBER A0069-0259-DC-00

REACTOR FACILITY ZPR-9

CHANNEL NUMBER 5

TOTAL NUMBER OF ERRORS DETECTED IN CHECK OF ABOVE INSTRUMENT IS 2 ERRORS.

CHECK OF 1E-10 RANGE ERRORS INDICATES 2 ERRORS.

- 1) AT LINE VOLTAGE OF 135.00 VAC, AMPLIFIER INPUT CURRENT, (.97E-10 AMP.), IS NOT WITHIN FIVE PERCENT OF METER READING, (.930).
- 2) AT LINE VOLTAGE OF 135.00 VAC, AMPLIFIER OUTPUT VOLTAGE, (-9.82 VOLTS), IS NOT WITHIN FIVE PERCENT OF METER READING, (.930).