A MISSILE INSTRUMENTATION SYSTEM DESIGN APPROACH

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ABSTRACT

Requirements and design constraints of a missile instrumentation system are identified. These considerations were applied and a programmable master/slave PCM encoder with integral signal conditioning was selected for a major classified missile program. The engineering philosophy and hardware selected for this application are presented in this paper.

INTRODUCTION

The missile instrumentation engineer is faced with unique challenges which guide his selection of airborne hardware. Major requirements imposed on the engineer are used to determine the desired capabilities and performance of the instrumentation equipment. The engineer selects an architecture which satisfies the program needs and offers additional felxibility for changes and growth.

The best hardware solution for the application is chosen. Innovative technology may be required to achieve significant advantages in size, power and cost. Performance is ensured by the proper integration of the selected components and testing.

SYSTEM REQUIREMENTS, CONSTRAINTS AND CONSIDERATIONS

One of the more challenging tasks in the design and development of an instrumentation system is the identification of the requirements and constraints. Requirements can be found in documents such as a Prime Item Development (PID) Specification, IRIG 106, Program Measurement List, etc. It is guaranteed that some of these requirements will change during the life of the program. The measurement list is a prime example of this. Historically, the measurement list is in a constant state of flux right up until launch.

A system concept is established early in the program which provides the basis for cost and schedule. In many cases it may be just the opposite. A schedule may be mandated which in turn can significantly influence the hardware configuration. In either case, it is very important to carefully consider the various requirements and limitations imposed on the program to enable a detailed definition of the hardware. If this is not accomplished there is a considerable risk that one of those limitations will force a hardware change which may cause an increase in cost and create a slip in the schedule.

In some cases, vehicles are designed with little consideration for test instrumentation. This is justifiable since size and weight significantly affect vehicle performance. Electrical power is at a premium since the power required can be associated with added vehicle size and weight. With this in mind, it can be stated that most applications require instrumentation that is small, lightweight, and consumes little power. In this application there was not enough room for the instrumentation wiring to allow a single PCM Encoder therefore it was necessary to use a master/slave arrangement.

Flexibility is an important consideration. The equipment should be capable of accommodating a frequently changing measurement list. One way to satisfy the flexibility requirement is to provide a signal conditioner which is designed and manufactured within the company. This allows changes to be made easily throughout the program. Another approach, that has only recently become available, is to buy a programmable PCM Encoder with integral signal conditioning. Signal conditioners of this type are available for resistive temperature devices (RTDs), strain gages, and thermocouples. Attenuators, pulse counters, filters, AC/DC converters, serial and parallel digital interfaces are also available. The use of in-house hardware probably provides greater flexibility and control; however, the cost of a signal conditioner produced by a large aerospace company is considerable. To achieve the required flexibility the signal conditioner is most likely to be constructed with discrete components at a penalty of size and weight. In the Convair application, space was critical. Additionally, since a master/slave PCM encoder configuration was chosen, it would be necessary to build two separate signal conditioner units, one located at the master and one at the slave. This would mean additional space and cost. As a result, the selected design approach incorporates the signal conditioning in the PCM encoder.

A HARDWARE SOLUTION

An Aydin Vector MMP-900 Master/Slave PCM System with integral signal conditioning was chosen for this application. The MMP-900 and its predecessor the MMP-600 have an impressive flight qualification history with over 1000 units used on aircraft, missiles, RPVs and other vehicles. This hardware provides a modular approach to signal conditioning and encoding which offers significant size advantages over other units. The Master MMP-900 contains a UV EPROM with all of the programming information for gain, offset, single ended/differential mode selection, and formatting. The Master and Slave units each contain a programmable gain amplifier and integral signal conditioning for high voltage signals, RTDs, and frequency inputs in addition to the unconditioned analog and differential bi-level inputs. Low pass filtering and an RMS/DC converter are provided. The capacity of each unit as configured for this application is listed in Table I. Expansion can be achieved by adding modules for either multiplexing or signal conditioning. Custom modules can be created to satisfy unique requirements.

TABLE I

MASTER	SLAVE
32 Attenuated Analog Inputs	32 Attenuated Analog Inputs
64 Analog Single Ended Inputs	32 Analog Single Ended Inputs
32 RTD Inputs	48 RTD Inputs
6 Words of Bi-Level Input	3 Words of Bi-Level Input
4 Counter Inputs	2 Counter Inputs
1 6-Pole Butterworth Filter	
1 RMS/DC Converter	
1 Computer Interface	

INPUT MULTIPLEXING AND SIGNAL CONDITIONING MODULES

High voltage analog inputs are signal conditioned by the AM-951 Attenuation Analog Multiplexer. This module incorporates precision resistive attenuators for scaling voltage up to ±50 volts (single ended or differential). Sixteen (16) single ended inputs (8 differential) are attenuated and multiplexed per module.

Analog inputs to ±10 volts (single ended or differential) are accepted through the MP-901 Analog Multiplexer. Thirty-two (32) single ended inputs or 16 differential inputs are accommodated per module; a mixture of single ended or differential channels can be used through the same module.

RTDs are signal conditioned with the BR-963 module which uses a half-bridge configuration with constant current multiplexed excitation. This technique excites the device only during the PCM sampling period. Significant savings in power are achieved and RTD self-heating is eliminated since a low duty cycle is used for excitation. This multiplexer is available in two versions (see Figure 1). A single active arm configuration can be used with a completion resistor inside the module to minimize the number of wires per measurement. A half-bridge configuration can be used with a second element at the sensing location. This element can be a passive resistor to cancel lead resistances or an active element to provide a very accurate measurement of differential temperature. Shunt calibration is included to verify proper operation of each transducer channel. Sixteen (16) resistance temperature devices are signal conditioned per module.

Differential bi-level inputs are accepted through the DB-968 Differential Bi-Level Multiplexer. Three (3) bi-level words are accommodated per module. All bits of each word are sampled simultaneously.

The CM-967 Counter Module accepts two frequency inputs. Amplification and Schmitt triggering is provided to ensure the proper count with low amplitude, poor quality signals typical of turbine flowmeters. Counter resolution to 20 bits/channel can be achieved with reset on sample, overflow, or external command.

OTHER MODULES

The interface between the master and slave units is accomplished through the use of the IR-961 module in the master unit and the IR-962 module in the remote unit (see Figure 2). Four pairs of wires are required. Line driver/line receiver pairs are used on all interfaces to ensure operation with long lines in a noisy environment. The interface is as follows:

- Serial Digital Address from Master
- Serial Digital Data to Master
- 4 x Bit Clock
- Word Clock

In addition to the above modules the following overhead modules are provided in each unit.

LA-926 Programmable Gain Amplifier provides 8 gains and 8 offsets.

AD-906 Sample/Hold; A/D Converter contains a fast sample and hold device followed by a 10 bit successive approximation Analog to Digital Converter.

PX-928 Synchronous Power Supply is a crystal controlled DC/DC converter providing isolated synchronous voltages for the signal conditioning and encoding circuitry from raw 28V missile power.

FM-918 Formatter interleaves the digitized analog data and conditioned digital data from the counter and bi-level modules into a single NRZ-L data stream. The formatter in the master unit also interleaves the computer data, remote unit data and synchronization words into the primary NRZ-L data stream.

The master unit contains additional modules not found in the remote unit. These moudles are described below.

PR-914 Programmer - controls all system activity through an 8-bit parallel address bus. This bus is structured with two 8 bit bytes for each PCM word.

TM-915 Timer - accepts the serial digital output of the formatter and provides parity, code conversion, output buffering, and a six-pole Bessel filter. This module also creates all of the timing signals required. Buffered diagnostics are also provided.

CI-942 Computer Interface - accepts a serial digital input with the appropriate handshakes.

PHYSICAL CONSIDERATIONS

The Aydin Vector MMP-900 offers significant savings in size, weight, and power over less innovative approaches. Physical parameters of the selected units are listed below (excluding mounting plate):

	MASTER	SLAVE
Length:	6.127 in	4.877 in
Width:	1.524 in	1.524 in
Height:	1.774 in	1.774 in
Volume:	16.56 cu in	13.18 cu in
Weight:	0.77 lbs	0.60 lbs
Power:	15 w	14 w

CONCLUSIONS

Programmable PCM encoders with integral signal conditioning are now available in either stand alone units or in master/slave configurations which proivde characteristics such as small size, light weight, low power and a high degree of flexibility. Utilization of this technology can trim a substanital amount from the instrumentation budget by eliminating the high cost of designing and manufacturing signal conditioninbg by a large aerospace company.

REFERENCES

1) Price, Edward J., and Ricker, William G., “New Approaches to Transducer Excitation and Conditioning”; Proceedings of International Telemetry Conference 1980.

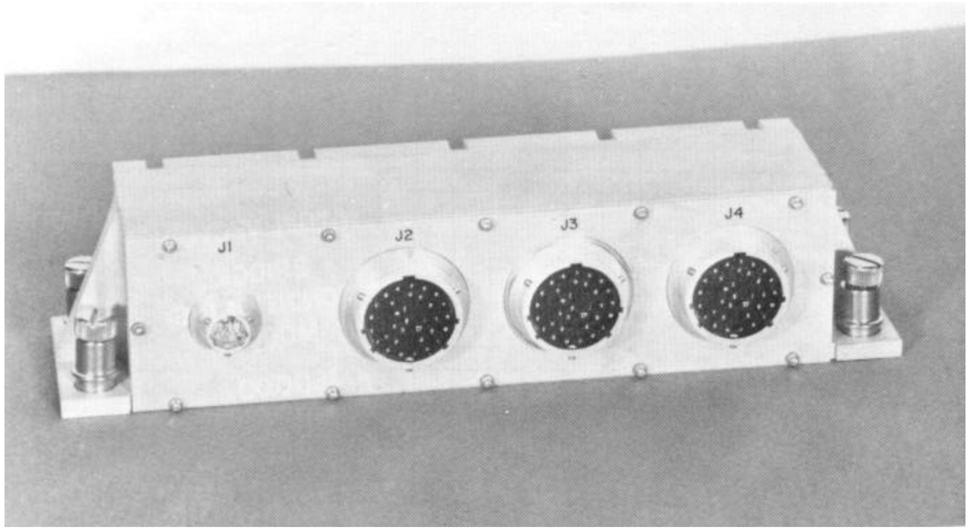

FIGURE 1
BCA916 SELF BALANCING
BRIDGE CONDITIONING AMPLIFIER ASSEMBLY

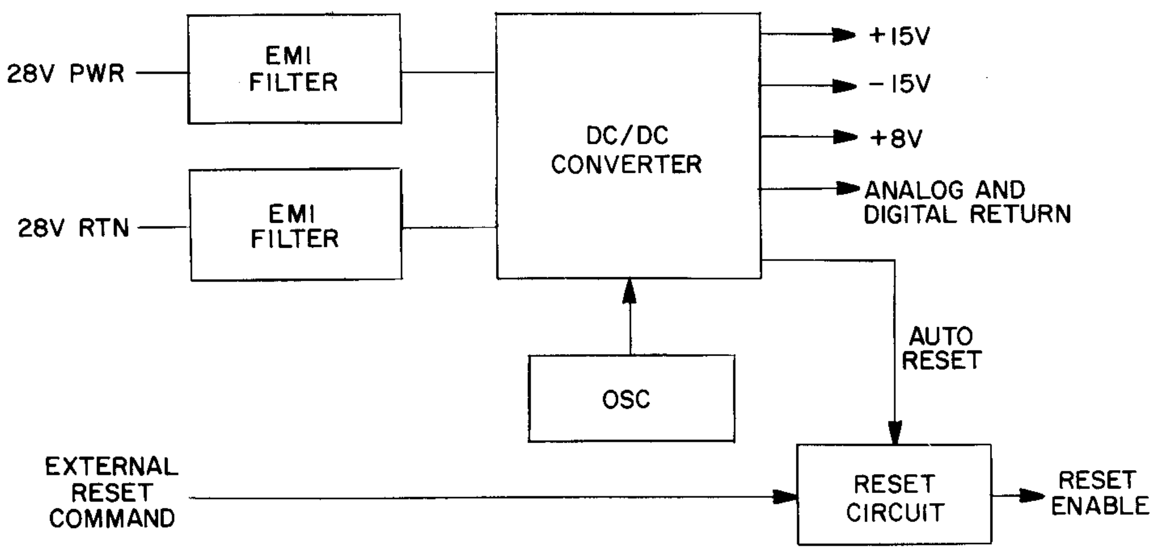

FIGURE 5
BCA916 POWER SUPPLY
SIMPLIFIED BLOCK DIAGRAM

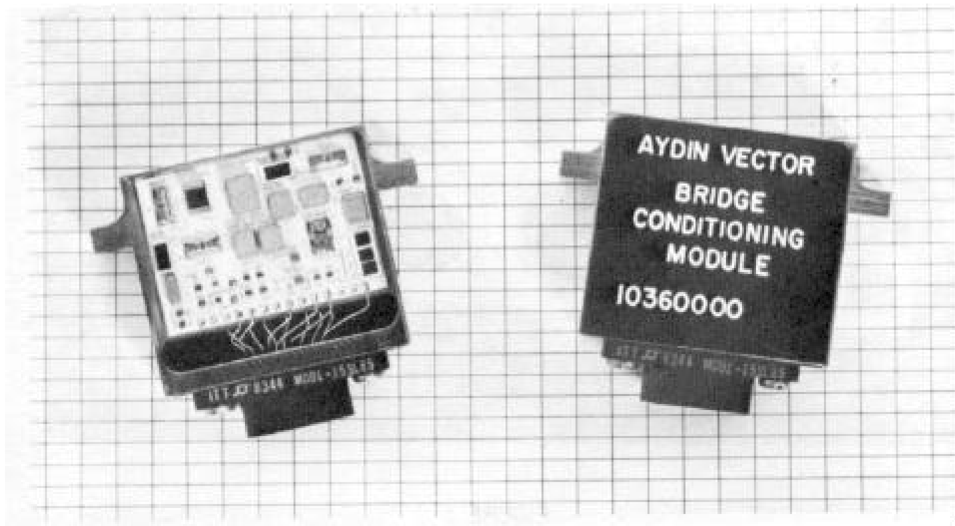

FIGURE 2
BRIDGE CONDITIONING MODULE

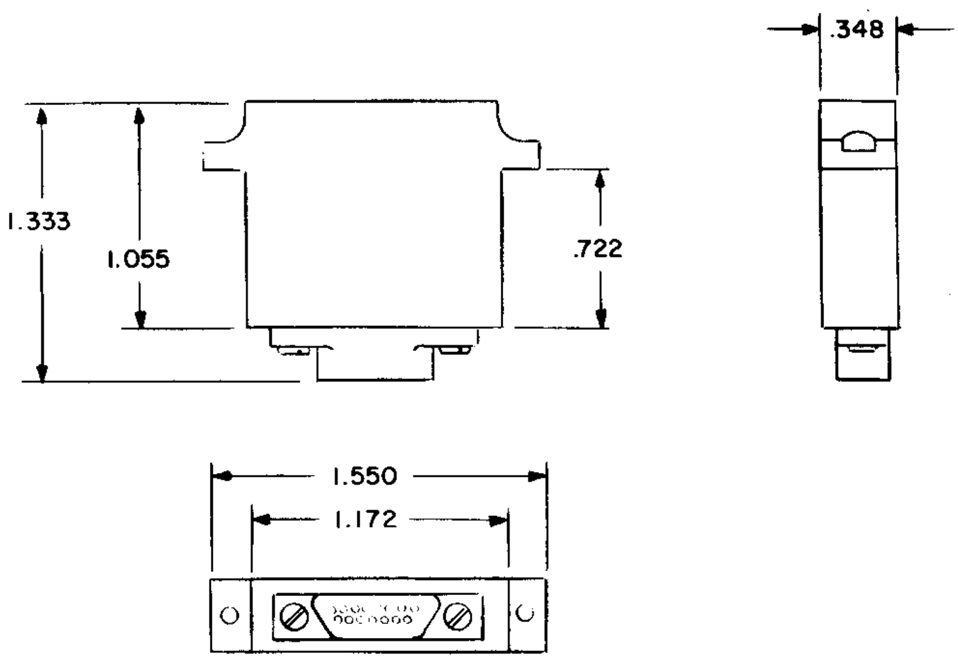

FIGURE 3
BRIDGE CONDITIONING MODULE
OUTLINE DRAWING

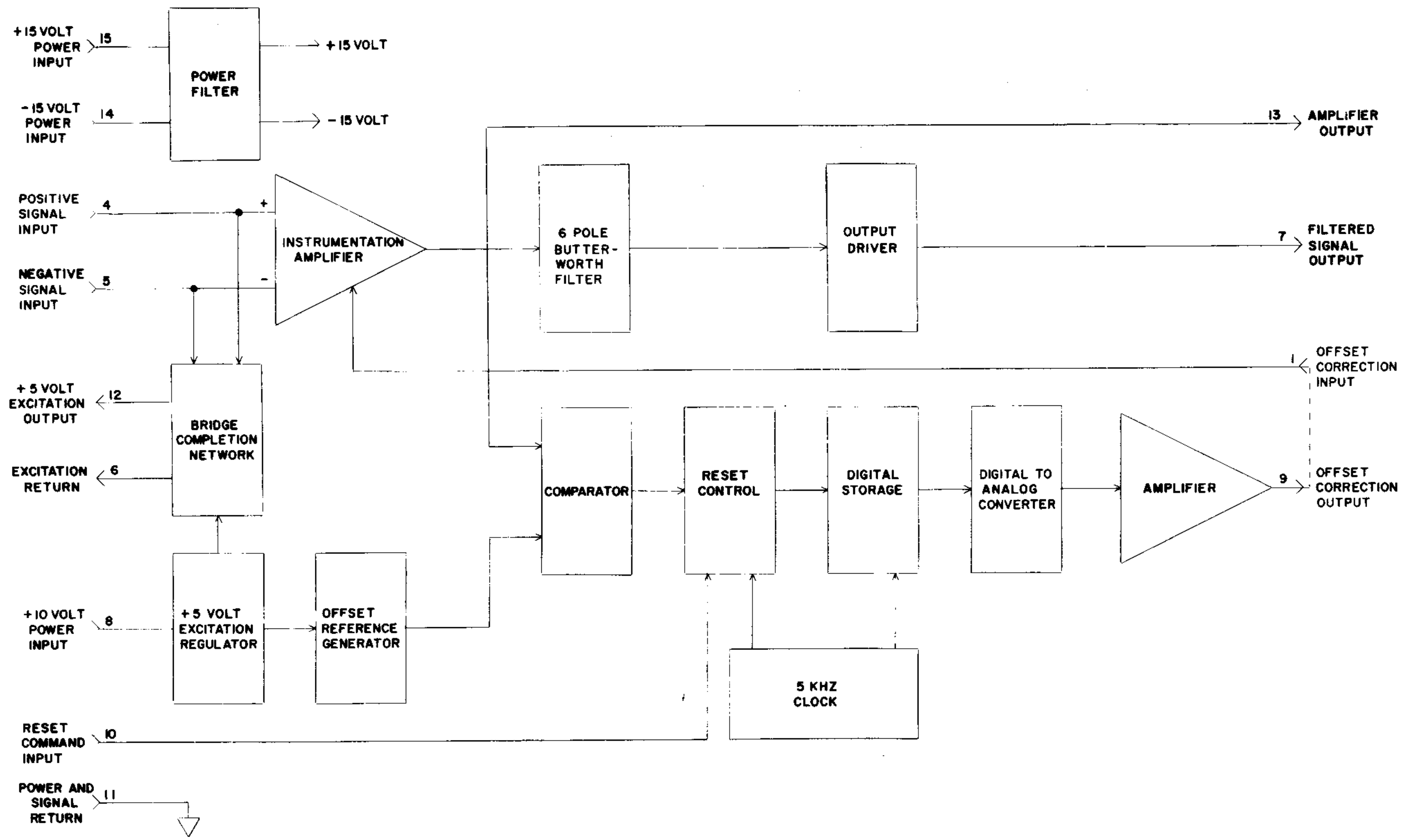

FIGURE 4 FUNCTIONAL BLOCK DIAGRAM SELF ADJUSTING STRAIN GAGE AMPLIFIER