Modified Instrumentation for Torsional Impulse Projectiles

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Abstract

The demand for test projectiles instrumented for gathering in-bore torsional impulse data has been steadily increasing. A test projectile consists of a telemeter, 12 accelerometers, and the remaining necessary hardware. Cost, availability, and survivability of commercial accelerometers being used have become a major concern. In-house testing of a new source and different technology accelerometer show a cost benefit, higher availability and a much higher survivability rate.

This paper outlines the recent progress of qualifying a new source and different technology accelerometer, which leads to a modification of the current Torsional Impulse test projectile, along with potential developments to insure a more cost effective, available, and reliable test projectile to be used in future torsional impulse tests.

Introduction

Accelerometers are used to gather torsional impulse data because of their high accuracy, wide-band frequency, amplitude response, small size, light weight, long-life and ease of installation. Accelerometers currently being used today are of the piezoresistive type. Attempts are being made to qualify an accelerometer with a different technology, namely a piezoelectric accelerometer with a built-in amplifier. Currently, three sources being tested and evaluated contain internal electronics.

Piezoresistive vs. Piezoelectric

The accelerometer currently being used for gathering torsional impulse data is a piezoresistive type accelerometer. There are several papers written which define torsional impulse and the techniques of collection and verifying torsional impulse data. A list of these papers are included at he end of the paper for reference. A piezoresistive accelerometer uses solid state resistors which change electrical resistance in proportion to an applied mechanical stress. They are mechanically attached to a cantilever beam and electrically connected in a wheatstone bridge to produce a differential electrical signal proportional to vibrational motion. Piezoresistive accelerometers offer the advantage of DC response. This suits them for measurements that have long duration pulses. Piezoresistive accelerometers use an external source of electrical energy, and have an inherently low output impedance. Also for most applications the sensitivity is high enough that preamplification of the output is unnecessary.

The accelerometer currently being tested for replacement of the piezoresistive accelerometer, is a piezoelectric accelerometer with a built-in amplifier. Piezoelectric accelerometers use a spring mass system to generate a force proportional to the amplitude and frequency of vibration. The force is applied to a piezoelement which produces a charge on its terminal that is proportional to the mechanical motion. Piezoelectric accelerometers have very high resonant frequencies which suits them for measuring high amplitude shock events such as ballistic projectiles, metal to metal impacting, and blast effects.

Disadvantages of Current Instrumentation

The piezoresistive accelerometer, shown in figure 1, is currently being used to instrument Torsional Impulse test projectiles. Two problems are associated with using these accelerometers for future torsional impulse tests. Through repeated test series and quality testing it has been determined that the reliability of the piezoresistive accelerometer is about 50 percent. The qualification tests for the accelerometers consist of a series of drop ball tests. A block diagram of the drop ball test is shown in figure 2. The accelerometers are tested along the axial and transverse axis. The accelerometers are tested for survivability of up to 20,000 g’s and a rise time of up to 50 microseconds along the axial axis and the effect of the 20,000 g’s along the transverse axis. Using this qualification process the piezoresistive accelerometers have approximately a 50% survivability rate. Therefore, twice as many piezoresistive accelerometers need to be ordered to have 12 accelerometers that pass our qualification test. Second, during 1988, the manufacturer discontinued the current model series from their accelerometer product-line. However, accelerometers could be procured on special order at a premium price. The projected cost for the piezoresistive accelerometer is approximately $1200 per accelerometer. This not only increases the price approximately $400, but decreases the availability of these accelerometers. Unless large quantities are ordered at one time, there could be a shortage of accelerometers due to the long build-up period, since they are no longer a stocked item.

Another problem that exists from using the current acclerometer is the signal conditioner. The problems existing with the signal conditioner are reliability and availability. In the past, it has been determined that the reuse rate of a telemeter after field firing is about 50 percent. The availability of the signal conditioner is also an area of concern. It currently takes six to eight months to build and test a complete telemeter.

Advantage of Modification

Piezoelectric accelerometers with built-in amplifiers are being investigated as a new source for accelerometers. There are several advantages in using a piezoelectric accelerometer. One major advantage in using a piezoelectric accelerometer is design flexibility. Electronic gain can be used to reduce transducer size and increase transducer sensitivity. By electronic filters, frequency response can be designed for specific applications or to suppress the accelerometer’s mechanical response. The quality of the signal is independent of the cable motion or length, therefore solder pins can be used with smaller more flexible lower cost cables. Another advantage of using piezoelectric is the reduced cost compared to the piezoresistive accelerometer. At present prices, the piezoelectric accelerometer with built-in amplifier, would cost approximately $500. Secondly, the piezoelectric accelerometer requires a less complex signal conditioner than the one currently used for the piezoresistive accelerometer. Since the signal conditioner will be simplier, it will he easier to build, which will increase the availability of the signal conditioner. Also the signal conditioner will contain less circuitry, which will improve its reliability. Another advantage to using piezoelectric is the low current load that the accelerometer requires. The current load for the signal conditioner will decrease since the piezoelectric accelerometer requires lower current than the piezoresistive accelerometer. This will increase the telemeter’s operational time and thereby enhance field test operations.

Projected Results

Using piezoelectric accelerometers with built-in amplifiers, the total cost of a Torsional Impulse test projectile could potentially be reduced by $15,000 per round. Using a piezoelectric accelerometer, will also allow the signal conditioner to be built quicker and therefore more available. Since the signal conditioner contains less circuitry, the signal conditioner will be more reliable and have a higher survival rate. With the signal conditioner being easier to build with the piezoelectric accelerometers rather than using the piezoresistive accelerometers, the build and test time of a telemeter may also be reduced.

In summary, using piezoelectric accelerometers reduces the Cost Of a test projectile, increases the battery power to the telemeter, allows the signal conditioner to be more available and reliable, reduces the delivery time of a telemeter, reduces the build-up time of a test projectile, and causes a quicker turnaround between firings.

Current Status

Preliminary circuit boards have been designed, breadboarded and tested with excellent results.

Five airgun tests were conducted with an instrumented telemeter (Figure 3) to qualify three new sources of accelerometers (Figures 4-6). The telemeter contained two piezoelectric accelerometers with built-in amplifiers from each of the three sources. Axial acceleration and the transverse effects of the axial acceleration were monitored. Preliminary data reduction indicate that good data was collected from two of the three accelerometer sources. Other sources for self contained accelerometers are being investigated to determine their availability and applicability to this program.

Conclusion

After successful qualification of one or more sources of accelerometers, instrumentation and projectile hardware for two Torsional Impulse test projectiles (Figure 7) will be procured and fabricated to field qualify the design modifications. Given that successful data is received from live field test firings of the two Torsional Impulse rounds, then test rounds will be built and standardized using piezoelectric accelerometers.

References

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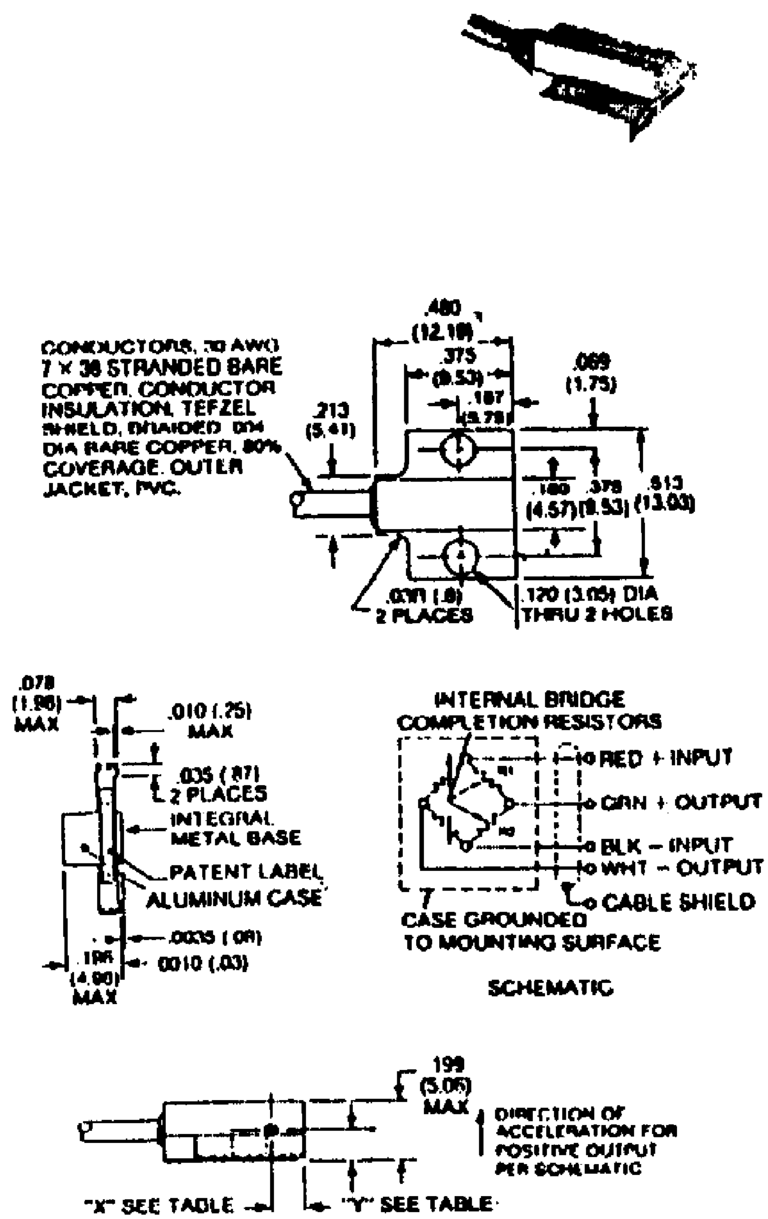

CENTER OF SEISMIC MASS		
RANGE	"X" ±.030(.76)	"Y" ±.010(.25)
2 000 g	.075 (1.90)	.100 (2.54)
5 000 g	.084 (2.13)	.100 (2.54)
10 000 g	.090 (2.29)	.100 (2.54)
20 000 g	.099 (2.52)	.100 (2.54)
50 000 g	.105 (2.67)	.081 (2.06)

Dimensions in inches and (millimetres)

FIGURE 1
PIEZORESISTIVE ACCELEROMETER

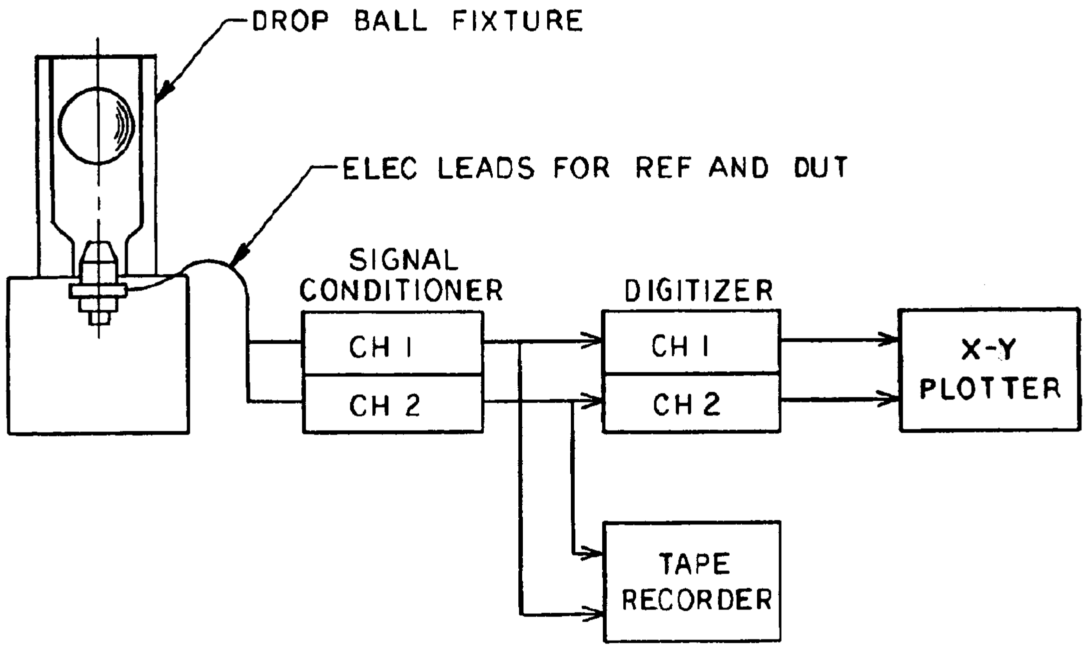

FIGURE 2
DROP BALL QUALIFICATION BLOCK DIAGRAM

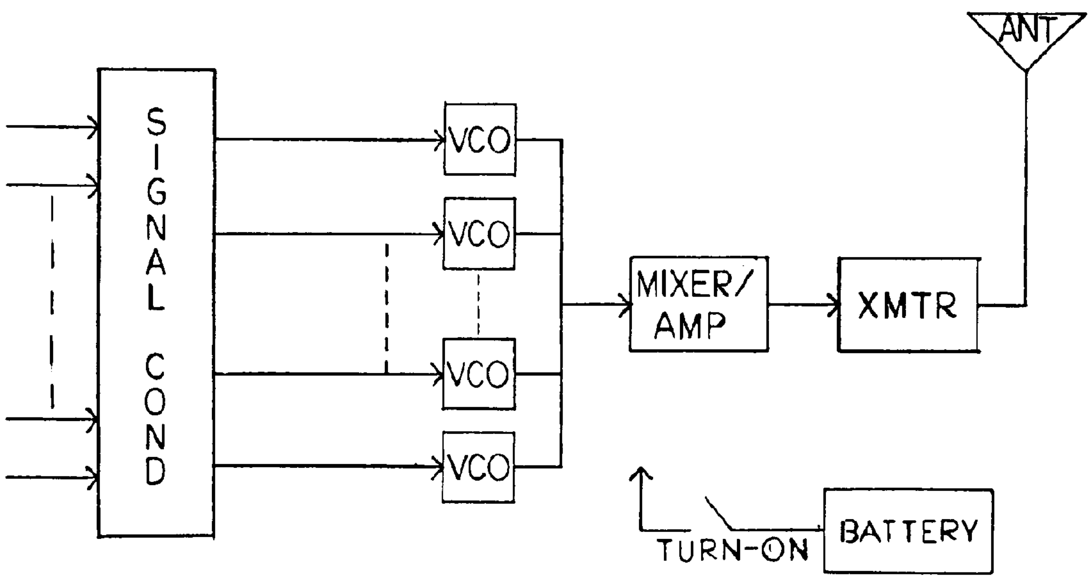

FIGURE 3
TELEMETER BLOCK DIAGRAM

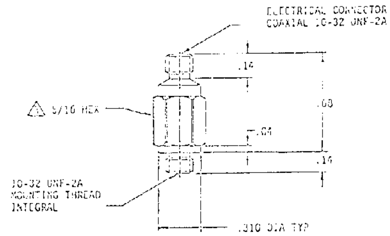

FIGURE 4
SOURCE 1
PIEZOELECTRIC ACCELEROMETER

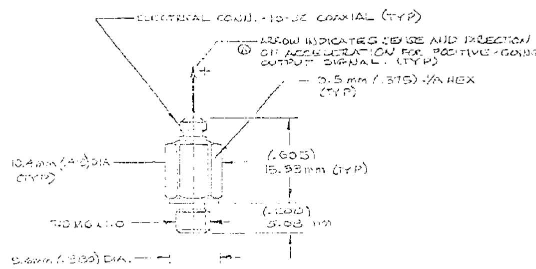

FIGURE 5
SOURCE 2
PIEZOELECTRIC ACCELEROMETER

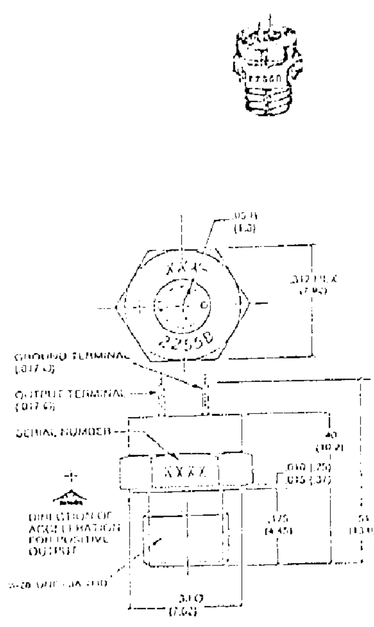

FIGURE 6
SOURCE 3
PIEZOELECTRIC ACCELEROMETER

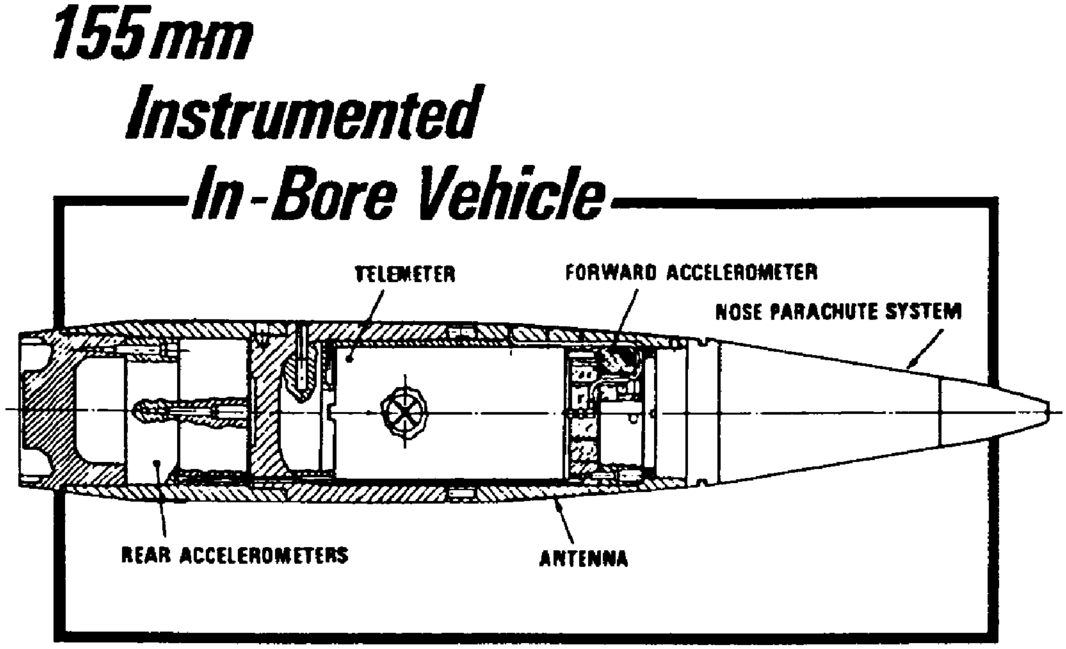

FIGURE 7
TORSIONAL IMPULSE
TEST PROJECTILE