Pyrotechnics Device Testing
using the WaveBook

Pyrotechnics can make a lot of noise, smoke, and fire, but they're not considered explosives. An explosive wave travels through air at a velocity of about 1800 to 3000 m/s, while pyrotechnic pressure waves travel at a somewhat slower rate. Pyrotechnics are used in various military devices, fireworks, flares, kitchen matches, incendiaries, fuses, and triggers for explosives. They also power mechanical devices, propel materials such as insecticides, explode bolts, and set off safety airbags in automobiles.

Most pyrotechnic formulas, especially for military and industrial uses, are intended for a specific application and primarily produce heat or pressure to accomplish their mission. When used in fireworks displays, however, a pyrotechnic comprises a fuel, an oxidizer, a binder, plus other chemicals that generate the sparks and flames of various colors that we enjoy.

The first pyrotechnic was discovered in China during the Sung Dynasty before 1000 A.D. and used in rockets and fireworks. It was brought to Europe about 1242 and used in warfare and mining. It was made of potassium nitrate, charcoal, and sulfur, and called black powder. The mixture may be ignited by impact, sparks, flames, friction, or arcs from static electricity. Small mixtures that usually burn slowly and quietly can explode when large quantities are ignited or when they are tightly packed.

To ensure that the formulas used for mixing the ingredients consistently produce devices that are accurate, safe, and repeatable, manufacturers depend upon special data acquisition systems to acquire critical information during various tests. These data acquisition systems are extremely flexible and typically accommodate a wide variety of sensors for both impulse and steady-state test modes.

For example, one test procedure called "bomb calorimetry" determines the enthalpy of combustion. A companion test called "closed-bomb testing" measures pressures generated within a certain time period. And the test can be done in a number of different ways. For example, technicians can establish the burn times of pellets. Although the pellets have various odd shapes, including holes, the size and density of the pellets largely determine the burn time. For some applications, a quantity of pellets becomes a propellant when they are enclosed in a chamber and ignited. Technicians then record the closed bomb curves and compare them to an equation that the government supplies for evaluating burn time based on the length of the pellet. When ignited in a container, they typically burn from end to end, or from both ends to the center. The test team can determine the instant when the output pressure reaches its peak value. Here, the fuel has been completely consumed, and the descending slope of the wave represents the slowly burning remnants.

Another application for pyrotechnics is in oil-well fields where the wells have stopped producing petroleum at the normal rate because of plugged rock strata. Since the wells are expensive to drill and maintain, the investors cannot afford to wait for them to rejuvenate on their own, so they are primed with what's called perforator charges. An array of charges are deposited in the wells to a depth of about three feet and ignited. The charge perforates the rock strata in different directions and releases the trapped oil.

There are several US companies that manufacture a wide variety of pyrotechnical products. They have a number of different facilities for assembling and testing the products, from buildings that contain several diverse setups for testing relatively small devices to outdoor ranges for testing parachute flares, M2 and M16 grenade launchers, and larger military devices.

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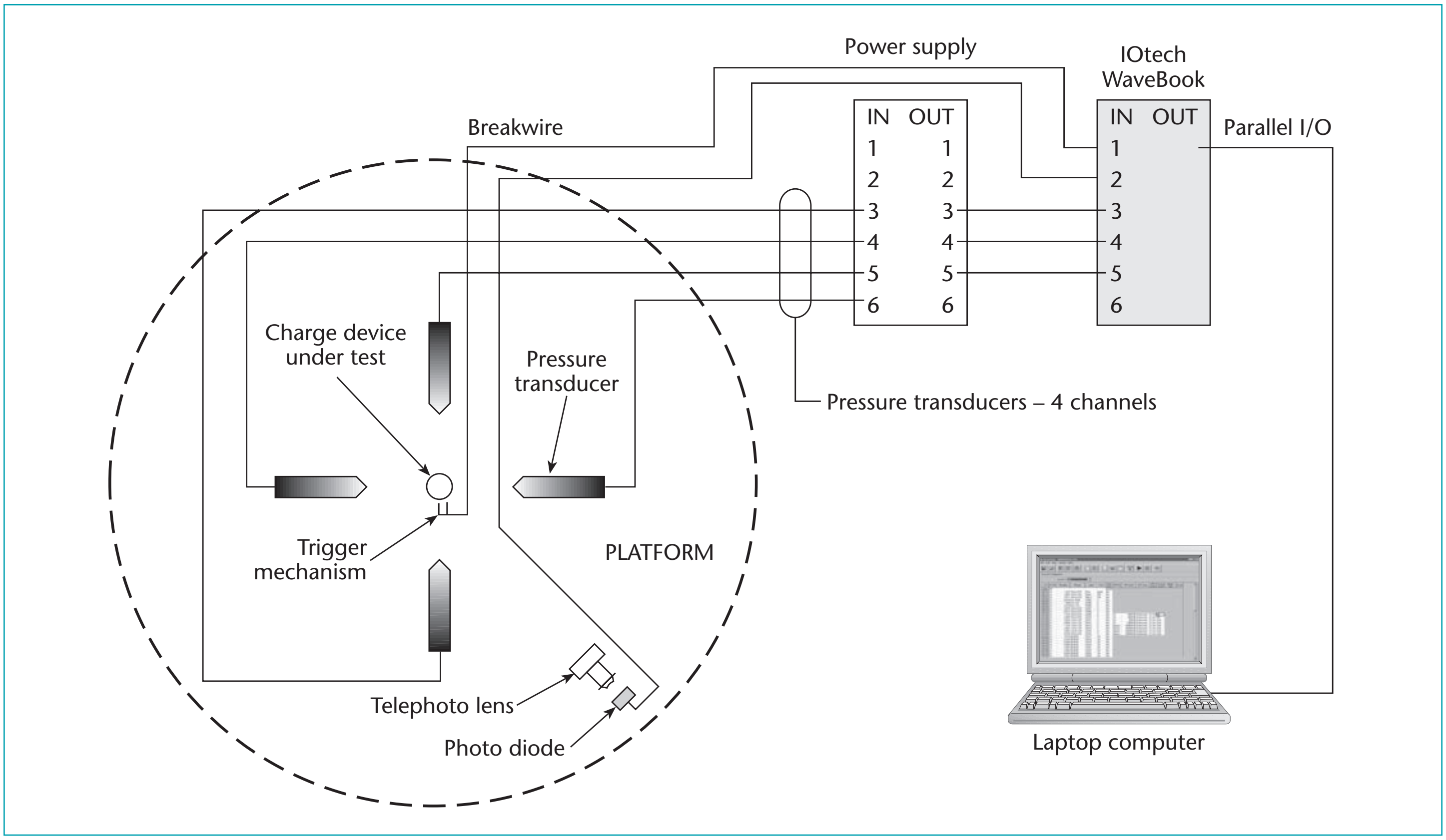

The test setup comprises an elevated platform where the test specimen resides, and four transducers spaced 90˚ around it. The transducers are located about four feet away from the test specimen, and are mounted to special brackets with pointed noses. This design lets the transducers read pressures of 3 to 5 psi without interference.

One such company makes or assembles products that an agency of the US government has designed. For example, it makes the component of a bullet that has a controlled burn rate and ensures that it meets the specs exactly. Precision is needed because out-of-spec parts have been known to self-destruct before hitting the target and causing damage where it was not wanted.

"Our company tests many different kinds of devices, including practice diversionary charges," says the technical director. "Here, we place a photodiode near the test specimen and four transducers around it, spaced 90˚, to measure the acoustic blast. When the firing pin comes around the test specimen, it hits a device that triggers our data acquisition system, an IOtech WaveBook, which begins collecting the data."

First, the primer fires, and a few milliseconds later, it kicks off the fuse. It does not become a projectile, however, it just separates into several parts about 20 feet away and emits light, which the photodiode picks up. "We monitor the four pressure transducers on individual channels," continues the director, "so we can see the output amplitude, and the time that the output peaks. We record the time from the initial trigger to the peak and measure the amplitude of the peak, which we translate into dB."

A telephoto lens is aimed at the light output from the event, which is about 30 to 40 feet away. The photodiode is located at the focal point of the lens, a surface where the plane of the film would be on an attached camera. The photodiode senses the light and feeds the signal back to the WaveBook. The speed of sound measured is based on several factors: The relationship between the flash of light at the photodiode, the pressure created at the pressure sensors from the sound wave, the distance above the concrete pad, and the distance between the device and the overpressure detector. The WaveBook measures the time from the flash of light to the primary sound wave and to the reflected wave.

"We use 4 channels for measuring the overpressure, plus one channel for the light output, which also serves as the trigger—to conserve the number of channels," says the director. The transducers are secured to low profile, steel brackets of narrow cross-section, about 2 to 2.5 feet long, located 3 to 4 feet away from the test specimen. The brackets have a pointed nose and hold a sensor about halfway back so the blast wave first sees the nose of the transducer body. The pressure transducers pick up pressures of 3 to 5 psi. This design lets the signal be monitored without interference.

The present test setup evolved after some trial and error work. "Initially, we set the test specimen about one foot above a concrete pad," says the director. "We measured extremely high pressures and couldn't figure out why. Someone proposed the theory that the wave reflected off the concrete pad and reinforced the main wave. Eventually, we proved that to be the case. We then elevated the test specimen 3.5 to 4 feet. The primary wave still travels downward, hits the ground, and reflects, but it's delayed long enough that we can isolate the reflected wave. We see the initial peak when the blast wave reaches the transducers, then we see the

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blast wave go up and back down, and several milliseconds later, we see another smaller wave, the reflected wave."

Before the company purchased the IOtech WaveBook, it used one of the first 4-channel digital oscilloscopes available. But the 'scope had limited storage capabilities, and no computer interface; it saved everything on a 5.25 inch floppy diskette. "We tried a standard analog 'scope," says the director, "but it could not accomplish what we needed. We even tried to trigger multiple 'scopes simultaneously, but to no avail. By comparison, the WaveBook is basically an 8-channel scope and can be expanded to many more channels than we could possibly use."

The director developed an automated spreadsheet to present the data. He simply pulls up the ASCII file on the WaveBook and loads it into the spreadsheet. It displays a graph on the screen that shows the wave, reduces some of the data automatically, and lets him do a better job of giving the customer the information it requested.

Moreover, the WaveBook does the conversion from mV to psi. There is no need to calibrate the peak of the photodiode; it is strictly a time hack. "We use either pressure transducers to measure other pressures defined in psi/mV, or we let the WaveBook do it," says the director. "We put the conversion into the WaveBook and use that extensively. But anything else that has to be calculated is accomplished with the spreadsheet."

The director didn't have nearly as tight a time per point available using the analog scope, but the bigger problem with it was that it didn't have the number of points capability that the WaveBook has. And he is sampling every 10 ms over 4 to 5 channels, which records a lot of data. "When I was running the earlier system," he says, "we never would have considered that such capability existed. I bought one of the first WaveBooks, and it had been in service until a lightning strike took it out. Then I replaced it with the newer WaveBook/516E. This is a big cost advantage; we are competitive and we stretch every dollar. We don't do a lot of research, but one objective for engineering is to make the most of its resources. I take that to heart."

WaveBook Series

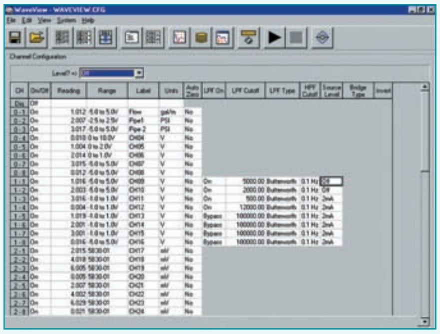
The WaveBook/516E digitizer offers multi-channel waveform acquisition and analysis for portable or laboratory applications. The WaveBook includes 8 built-in channels expandable up to 72 channels of voltage, accelerometer, microphone, strain gage, thermocouple, position encoder, frequency, high voltage, and other signal types. For applications beyond 72 channels, up to four WaveBooks can be combined within one measurement system, for a total capacity of 288 channels. You can also add up to 854 thermocouples, without consuming measurement bandwidth of the WaveBooks, using the WBK40 Series, and DBK90 signal conditioning options. The 12-bit WaveBook/512A and 16-bit WaveBook/516A attach to the WaveBook/516E via their built-in parallel port interface. Other than the interface, the WaveBook/512A and WaveBook/516A are identical to the WaveBook/516E.

Features

- 16-bit/1-MHz A/D
- 1 µs/channel scanning of any combination of channels
- Single and multichannel analog triggering with programmable level and slope
- Digital TTL-level and pattern triggering
- Pulse trigger and external clock
- Programmable pre- and post-trigger sampling rates
- Sixteen digital inputs can be scanned synchronously with analog signals
- Operable from AC line, a 10 to 30 VDC source, such as a car battery, or optional compact rechargeable battery module
- Expandable up to 288 high-speed channels
- SYNC connection allows multiple units to sample synchronously
- Add up to 854 lower-speed thermocouple channels
- DSP-based design provides real-time digital calibration on all channels

Signal Conditioning Options

- IEPE dynamic signal inputs
- Strain gages
- Programmable filtering
- Simultaneous sampling
- Quadrature encoder inputs
- Pulse/frequency measurements
- Thermocouples
- High-voltage measurements
- Vehicle bus network



WaveView graphical data acquisition and display software is included with all WaveBooks

Software

- Includes WaveView for *Out-of-the-Box* setup, acquisition, and real-time display*:*
  - Scope mode for real-time waveform display
  - Logger mode for continuous streaming to disk
- Optional eZ-Analyst and eZ-TOMAS for real-time vibration analysis
- Comprehensive drivers for DASYLab®, LabVIEW®, MATLAB®, Visual C++®, Visual C#®, Visual Basic®, and Visual Basic® .NET
- WaveCal software application for easy user calibration

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