Before Lockheed Martin delivers a Terminal High Altitude Area Defense (THAAD) interceptor to the US Army, and before the US Navy loads a Raytheon SM-6 missile into the Aegis vertical launch system, technicians must first ensure that the resistance and stray voltage in the system’s multiple electrical circuit paths are all within allowable limits. Responding to the demands of aerospace system OEMs for a turnkey test management solution that integrates with their sequence control interface, Space Electronics has developed a new family of multichannel aerospace system circuit test equipment.

The SQB Series of igniter circuit testers measures electrical continuity, isolation, and stray voltage between any two test points using protection circuits that guarantee no inadvertent triggering of firing circuits. Already a key element of OEM quality assurance (QA) and integrated logistics support programs for a host of weapon systems that includes THAAD, Standard Missile 3, Standard Missile 6, and the Evolved SeaSparrow Missile, the SQB Series is designed for subassembly, system, and field level testing of any aerospace system with an integrated firing circuit: aircraft with fire suppression systems, ejection seats, and emergency oxygen systems; space systems with external booster and stage separation explosive bolts; and any cable harness that is connected to squibs.

**SAFETY**

The primary method of initiating a detonation sequence is by passing an electrical current through a thin wire that is bonded to a small explosive. The heat generated by the flow of electric charge provides the threshold energy needed to initiate the explosive train. Electromechanical trigger circuitry controls the timing of the current pulse. Typically, the firing of a small explosive device triggers a much larger explosive. These firing circuits are of varying complexity, ranging from the simple low-component-count mechanisms found on ‘dumb’ bombs to highly complex, very versatile circuitry seen in modern battlefield smart weapons, military aircraft, space launch systems, and spacecraft.

The safety and reliability of these devices can be verified by electrically testing the detonators, wire cabling, and control circuitry at various points in the aerospace system’s lifecycle, including QA tests during component manufacture, QA tests during final assembly (for example, explosive load, assemble, and pack), integrity testing during and after storage in warehouses or depots, and point-of-use testing prior to deployment.

It is critical to recognize that this method of testing applies electrical current to the device in a manner similar to that which initiates detonation. The only way to safely accomplish the test is to severely limit the test current to a level several hundred to a thousand times lower than the detonation threshold. The current-limiting circuitry has to have high safety redundancy with known failure modes that always fail to a safe condition. Furthermore, in many cases the accuracy of the required measurement is quite high, often approaching one one-hundredth of an ohm. Under normal circumstances, measuring resistance to this level of accuracy is difficult. The use of these low test currents only serves to exacerbate the problem in direct proportion; that is, lowering the test current by a factor of one thousandth increases the difficulty of the measurement by a factor of 1,000.

The measurement system design engineer must then contend with lower internal signal-to-noise ratios, rendering unacceptable several common but unsafe methods for controlling the injection of external noise. For this reason, the SQB Series of testers incorporates a sealed ‘failsafe’ module, which limits test current to safe levels even if every active element in the measurement circuit fails at the same time.

**DESIGN AND FEATURES**

A squib or igniter tester is a special-purpose ohmmeter capable of making extremely accurate measurements of low resistance values, while limiting test current to a value significantly lower than the minimum detonation current of the igniter being tested. With the addition of voltage and
diode testing as well as a matrix switching system, the SQB Series of testers can test several connection paths in a completed assembly with one automated sequence. Features of the SQB Series include:

- Multimeter functionality – six resistance ranges, two stray voltage ranges, and diode testing;
- Fiber-optic connection between the control computer and tester – ensuring safety isolation between computer power and the system;
- Lead resistance compensation – Kelvin four-wire cable arrangement that automatically compensates for lead resistance;
- Fast readings – stabilized in less than two seconds;
- Digital calibration – insensitive to thermomechanical drift of calibration trim potentiometers;
- Modularity and scalability – supports from eight to 1,024 test points.

The SQB Series of multichannel circuit testers also features an innovative manual measurement mode (including test cables) that allows the user to verify test circuits without the need for a separate meter. It also takes a novel approach to safety: redundant circuits and mechanisms, going beyond the single-point-failure methodology to guarantee that test current is always less than 2.5 mA, a 400:1 firing current-to-test current ratio for a 1A firing current.

The power system design ensures protection against power surges and inadvertent operator error, including attaching the tester to a source of voltage or current higher than allowed. The design also incorporates multiple ground isolation barriers to ensure that there are no potential current paths through ground paths that could exceed the rated failsafe current. To prevent damage to the circuit tester’s current-limiting circuitry, these failsafe devices are encapsulated and mounted directly at both the tester’s input power and the system’s test signal connection points. This means these barriers are after the matrix selector system, yielding an additional level of safety.

**HOW IT WORKS**

For manual operation, the supplied test leads are attached to the instrument. A measurement range is selected. The circuit resistance is then displayed on the digital readout. An internal microprocessor stores calibration and zero offset values for all ranges. Four-wire test leads automatically compensate for test lead resistance so there is no need for the subtraction of the test lead resistance. The SQB Series supports from eight to 1,024 failsafed test points, which can be selected through software in any configuration of two-wire test paths. The combination of any two test points creates a four-wire measurement path.

‘Test points’ are not the same as ‘channels.’ Earlier igniter tester designs connect to test circuits through multiple sets of four-wire channels. If three paths to test connect to a single common pin, then each of the three four-wire sets has two wires connecting to that common pin, for a total of six wires to that single pin. If more paths share this common pin, the wire count becomes unmanageable.

In a test point arrangement, only a single set of two wires connects to each pin. The matrix system allows these two wires to connect either to positive excitation and positive sense or to
negative excitation and negative sense. This brings down the cable conductor count while still maintaining the four-wire measurement system.

**THEORY OF OPERATION**

All test circuits use the same fundamental concept. The circuit is constructed of a known precision current sensing resistor in series with the unknown resistor. The processor measures the voltage V1 across the current sense resistor ($R_{\text{CURRENT.SENSE}}$) and the voltage V2 across the unknown resistor using a high-accuracy differential amplifier. The Ohm’s law calculation is then performed by the processor and the result is displayed on the LCD.

The diode measurement circuit uses the unknown resistor amplifier circuit to directly measure the voltage across the diode using a failsafe-compatible current source. A four-wire or Kelvin method of measurement avoids lead resistance errors. Any voltage drop across the main current carrying wires will not be measured by the circuit and therefore does not factor into the resistance calculation.

The manual Unit Under Test (UUT) failsafe and several automated failsafes (FS 1, FS 2, …, FS n) are the last connections between the meter and the UUT circuits. They are housed in fully sealed potted assemblies that cannot be bypassed without purposeful disassembly. The failsafes limit test current to the UUT using fusing resistors that are selected for measurement performance and failsafe protection. In the event of a worst-case failure of all active components, the measurement test circuit is reduced as shown below. The worst-case measurement circuit failure results in the maximum power supply voltage of 7V at point V1MAX feeding a series circuit of 1,197 $\Omega$ and the $R_{\text{UNKNOWN}}$ load. Assuming the load to be less than 1 $\Omega$, the failsafe current is 5.8mA.

**US DOD CERTIFICATION**

Lockheed Martin Space Systems, Raytheon Missle Systems, and Textron Systems are some of the companies which currently rely on the Space Electronics SQB Series of aerospace system circuit testers for systems deployed worldwide with the US Army, Navy, and Air Force. That reliance is based in large part on the legacy of Space Electronics’ 101-5HJ single-channel US Navy Igniter Circuit Testers – with more than 5,000 instruments placed in service in the past 40 years without incident.

The SQB Series’ revolutionary approach to safety – redundant circuits and mechanisms – coupled with its multiple ground isolation barriers and encapsulated failsafe devices has contributed to the US Department of Defense’s approval of this family of fully automated circuit testers that dramatically reduces the risk of accidental detonation without compromising performance.
Measure mass properties with extreme accuracy...
...test igniter circuit integrity in total safety

Mass Properties Measurement
- Over 100 standard models of mass properties instruments
- Test components or complete systems from 500 gm to 12,000 kg
- Precision gas bearings for friction-free rotation; MOI to 0.1% of measured value

Weight & Center of Gravity | Moment of Inertia | Full Mass Properties | Dynamic Balancing | Gimbal Balancing | Moment Weight Scales | Fixturing & Accessories

Igniter Circuit Testers
- US Navy type-classified 5HJ Series single and multi-channel ohmmeters
- SQB Series of fully automated multi-channel circuit testers
- Measures resistance and stray voltage in system’s multi-path circuits

Rocket Igniters | Fuses | Explosive Bolts | Squibs | Blasting Caps | BIT Lines | Electro Component Lines | Relays | Actuators | Diodes | Semiconductor Devices