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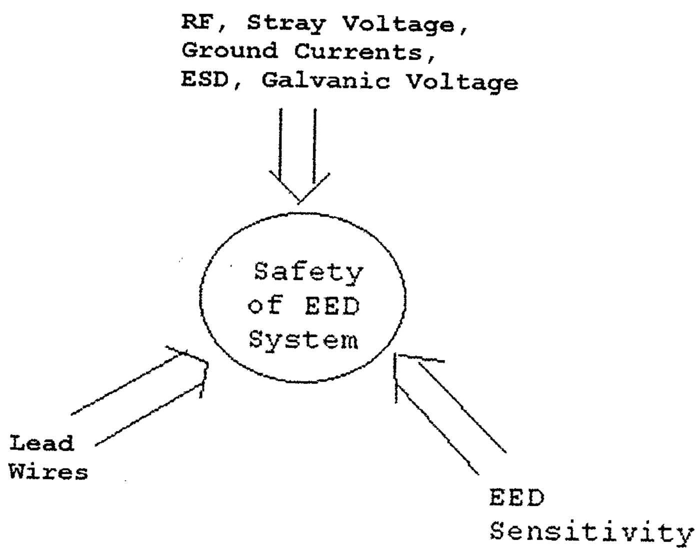
NEW APPARATUS TO TEST EED SAFETY

We recently needed to measure the level of stray voltage pickup in electric detonators in an industrial environment. An electric detonator is one form of electro explosive device, or EED. Speaking generally, there are three factors that contribute to the safety of an EED system, as we show in Figure 1. At the top of this picture are various kinds of electricity that might fire an EED. At lower left are the lead wires of the EED, where the electricity can enter the EED, so the configuration of these wires is very important. At lower right is the sensitivity of the EED – some types are more sensitive than others.

Figure 1: Factors Contributing to EED Safety



We are chiefly interested in any stray voltage that might arise due to operation of heavy equipment near the place where people will be handling electric detonators. We developed a new kind of sensor to measure the peak voltage of electromagnetic pickup in the leadwires of an EED. The cause may be inductive pickup, radio-frequency (RF) electromagnetic radiation, or other stray voltage. Such signals may come from any kind of nearby equipment, and may be very brief. Therefore our basic sensor is a peak detector.

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We show three types of sensors in Figure 2. We will connect wires, simulating the leadwires of an EED, to the terminal strip at the left of each sensor. At the right, the output goes either to an indicating meter or to a recorder. Table 1 identifies the sensor components.

Figure 2: Sensors

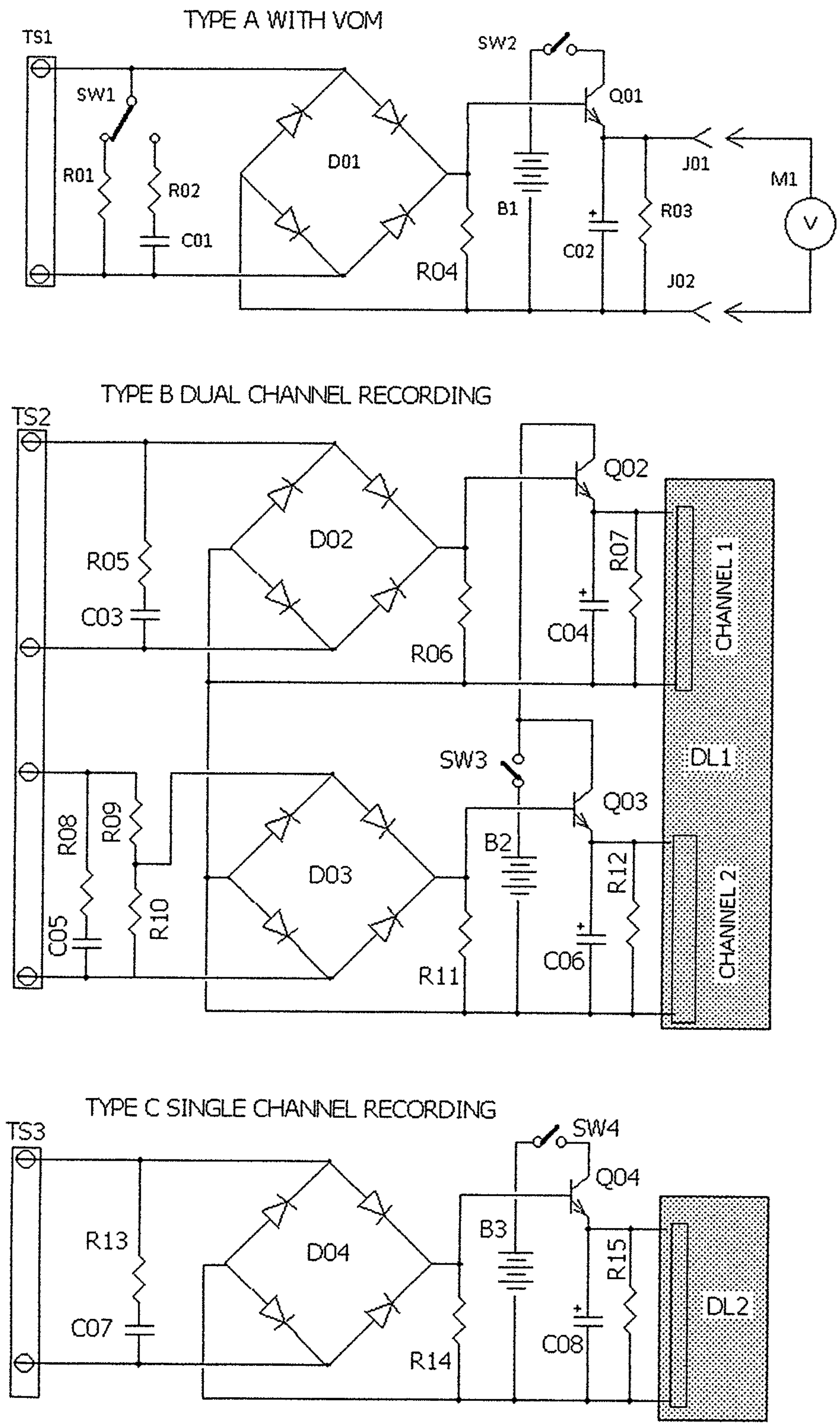


Table 1: Sensor Components

B1	Battery, 9 volts
B2	Battery, two 9V batteries in parallel
B3	Battery, 27V, three 9V batteries in series
C01	Capacitor, part of Secure load, 1.0 microfarad
C02	Capacitor, charge storage, aluminum electrolytic, 220 microfarads, 25V
C03	Capacitor, part of Secure load, 1.0 microfarad
C04	Capacitor, charge storage, aluminum electrolytic, 220 microfarads, 25V
C05	Capacitor, part of Secure load, 1.0 microfarad
C06	Capacitor, charge storage, aluminum electrolytic, 220 microfarads, 25V
C07	Capacitor, part of Secure load, 1.0 microfarad
C08	Capacitor, charge storage, aluminum electrolytic, 220 microfarads, 25V
D01	Diodes, four arranged to make a bridge rectifier, 1N4148
D02	Diode, rectifying, 4 to make a bridge rectifier, 1N4148
D03	Diode, rectifying, 4 to make a bridge rectifier, 1N4148
D04	Diode, rectifying, 4 to make a bridge rectifier, 1N4148
DL1	Data logger, AEMC model L432, 0-10 VDC, 2 channels, 5-1/2" x 2-3/4" x 1-1/8", internal batteries (2 x AA), input impedance 800k ohms
DL2	Data logger, 0-30VDC Lascar model EL-USB-3 (Easy Log USB-503).
J01	Jack, pin, red
J02	Jack, pin, black
M1	Meter, VOM, with pin probes, Simpson model 160, P.O. 73386,set on 10V scale
Q01	Transistor, NPN, current gain 100, 2N4400 or 2N3903
Q02	Transistor, NPN, emitter follower, 2N4400 or 2N3903
Q03	Transistor, NPN, emitter follower, 2N4400 or 2N3903
Q04	Transistor, NPN, emitter follower, 2N4400 or 2N3903
R01	Resistor, load, 50 ohms
R02	Resistor, part of electronic detonator load, 200 ohms
R03	Resistor, bleed, 4700 ohms; the time constant for discharging C02 is about 1 second
R04	Resistor, bias, 91k
R05	Resistor, part of electronic detonator load, 200 ohms
R06	Resistor, bias, 91k
R07	Resistor, bleed, 47k; the time constant for discharging C04 is about 10 seconds
R08	Resistor, part of electronic detonator load, 200 ohms
R09	Resistor, voltage dividing, 91k
R10	Resistor, voltage dividing, 10k
R11	Resistor, bias, 91k
R12	Resistor, bleed, 47k; the time constant for discharging C06 is about 10 seconds
R13	Resistor, part of electronic detonator load, 200 ohms
R14	Resistor, bias, 91k
R15	Resistor, bleed, 47k; the time constant for discharging C08 is about 10 seconds
SW1	Switch, SPDT, for choosing load
SW2	Switch, SPST, on/off
SW3	Switch, SPST, on/off
SW4	Resistor, bleed, 47k
TS1	Terminal strip, feed-through, 2 positions
TS2	Terminal strip, feed-through, 4 positions
TS3	Terminal strip, feed-through, 2 positions

Any kind of inductive pickup, RF, or stray voltage that may appear on the simulated lead wires will be terminated in a load that represents the EED. This load could be one or two ohms, like a common electric detonator, or it could be about 50 ohms like a resistorized detonator. The voltage that appears across this load may be of either polarity, so we put it through a bridge rectifier. The resulting signal goes through an emitter follower, to a charge-storage capacitor which holds the voltage for a predetermined time. This holding time is long enough for the indicating meter to respond, or for the recorder to preserve data.

The voltage drop across the bridge rectifier is about 1.2 volts, and across the transistor's base-to-emitter junction is another 0.6 volts. Thus, for a given input voltage at the terminal strip, the output will be about 1.8 volts less. This means that for any input less than about 1.8V, the output will be zero. We cannot distinguish between zero input and 1.8V input. This will not be a disadvantage if we are only dealing with insensitive detonators, for which 1.8V is no hazard.

The charge-storage capacitor is necessarily always charging or discharging. Thus the indicated or recorded voltage is not always the same as the peak voltage. We have chosen our circuit values so that the indicated or recorded voltage will be no less than about half the peak voltage.

The type-A sensor, at the top of Figure 2, has two loads, and we can choose either. One is a capacitor and resistor in series, simulating the input elements of an *electronic* detonator (as opposed to *electric* detonator). The other load is a 50-ohm resistor, simulating a common resistorized detonator. Assuming the battery is about 9.0 volts, the emitter of Q01 can go no higher than about 8.5 volts. The maximum input voltage, then, is 1.8V higher than 8.5V. Thus , the type-A sensor will have an accurate output for a range of input voltage between 1.8 and 10.3V. Table 2-A summarizes the response.

Table 2: Sensor Ranges

A

Input Voltage V_{in}	Output to Voltmeter
0 to 1.8	0
1.8 to 10.3	$V_{in} - 1.8$
Above 10.3	Not accurate

B

Sensor B Channel	Input voltage V_{in}	Recorded Voltage
1	0 to 1.8	0
	1.8 to 10.3	$V_{in} - 1.8$
	Above 10.3	Not accurate
2	0 to 18	0
	18 to 103	$(V_{in}/10) - 1.8$
	Above 103	Not accurate

C

Input voltage V_{in}	Recorded Voltage
0 to 1.8	0
1.8 to 28.3	$V_{in} - 1.8$
Above 28.3	Not accurate

The type-B sensor, in the middle of Figure 2, has two input channels. The load for both channels is the simulation for electronic detonator components. Channel 1 records its input voltage. The input voltage range is the same as for the type-A sensor described above, i.e. 1.8 to 10.3V. Channel 2 records about one-tenth of its input voltage; the voltage divider (R09 and R10) determines the fraction. Thus channel 2 can handle much higher voltage inputs than channel 1. Table 2-B summarizes the response of the type-B sensor.

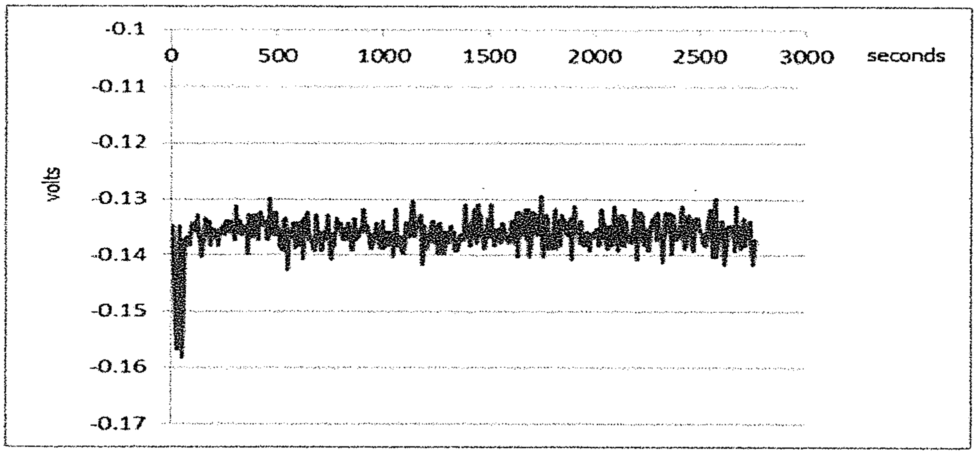
The type-C sensor, at the bottom of Figure 2, has one input channel. The load is a simulation for the electronic detonator components. This sensor records its input voltage. Assuming the battery is about 27.0 volts, the emitter of Q04 can go no higher than about 26.5V. The maximum input voltage, then, is 1.8V higher the 26.5V. Thus the type-C sensor will have an accurate output for a range of input voltage between 1.8 and 28.3V. Table 2-C summarizes the response of the type-C sensor.

When we want to take measurements with these sensors, we attach two wires to the sensor, to simulate leadwires of an EED. As a worst case, we spread the wires 180° apart to make a dipole, the most efficient kind of receiving antenna for RF and stray voltage. We could also use a loop antenna; in fact, we have used both a dipole and a loop antenna on the two inputs of the type-B sensor. Then we visit everywhere people use EEDs. In each location, we move our sensor and wires to every orientation.

We are chiefly interested in any stray voltage that might arise due to operation of heavy equipment near the place where people will be handling electric detonators. If some equipment does not operate on a daily basis, we can leave a recording sensor in the area, where it will record peak voltage every ten seconds for as long as two weeks.

We retrieve the sensor data as an Excel file from which we can create charts such as Figure 3, which is for a Type C sensor. In this example we see that the recorded voltage remained in the range from -0.129 to -0.158 volts. This is essentially an output of zero volts; it was just referenced to a slightly different ground. From Table 2-C we see that this indicates the input voltage was less than 1.8V. Such voltages present no hazard to the insensitive EEDs we are considering, so we conclude it is safe to handle EEDs in this environment.

Figure 3: Sensor Data



SMOKING RULES

Many of us have seen a metal can or box outside an area where people handle propellants or explosives. The metal can or box carries a sign like what we show in Figure 4. The idea is that any person entering the area should first remove from his or her pockets any item that can make an open flame, or any item that is meant to burn. We want to discuss whether this is really necessary.

Figure 4: Warning Sign

From a simple safety point of view, we do not think that cigarettes in a person's pocket are hazardous. There is no chance that a cigarette will jump out of a pocket, light itself, and cause a fire.

As for matches and lighters, however, it is conceivable (though very unlikely) that these items could fall out of a pocket onto the floor and be stepped on, or run over, and start a flame.

Further, from a psychological point of view, we can think of a few reasons why we should obey the warning sign:

In the first place, people sometimes forget "no smoking" rules. If we allow a person who smokes at home to keep cigarettes and a lighter in his pocket at work, he might unthinkingly start smoking at work one day. Near propellants and explosives, the result might be a dangerous fire. Of course, if we had made that person leave all smoking materials outside, there would be no such fire hazard.

The second psychological reason is that putting away all smoking materials is a good reminder. When we enter a place where we work with propellants and explosives, our mind should focus on safety. Putting away smoking materials is a ritual, a habit that forces us to think about safety. This habit reinforces our feeling that we are entering a special place, where special rules apply. We are all human, we all make mistakes, and we all forget things, but rituals and habits can force our mind into a certain channel – we can call this the safety channel.

From an historical point of view, the prohibition on matches and lighters near explosives and propellants has been in effect since the days of black powder. Most modern materials are not so dangerous, but black powder has always been a terrible fire hazard. Even when there is nothing to be seen, traces of black powder dust may be present in tiny cracks, on a wooden table top for instance, or in a wooden wall. Long ago, when black powder was the propellant for cannons on board wooden ships, naval authorities were aware of this hazard. In those days, smoking tobacco was allowed only in a certain place, far away from any black powder; and only at certain times, when the "smoking lamp" was lit. Sailors were not allowed to have their own matches, but could light their pipes from the smoking lamp.

When working around or with propellants and explosives, we should be careful always to obey safety rules, and to demand that others obey them, too. The rules are designed to prevent accidents – accidents which could have disastrous effects.

MEETINGS, COURSES, AND OTHER ACTIVITIES

Activity	Venue	Date(s)	E&P Issue
17th International Seminar (NTREM 2014) "New Trends in Research of Energetic Materials"	Pardubice,Czech Republic	9-11 Apr. 2014	Sep. 2013
10th CAD/PAD Technical Exchange Workshop	Joint Base Andrews, Maryland USA	20-22 May 2014	Mar. 2014
Tenth International Symposium on Special Topics in Chemical Propulsion	Poitiers, France	2-6 June 2014	Sep. 2013
11th Workshop on Pyrotechnic Combustion Mechanisms	Colorado Springs, CO	12 July 2014	Sep. 2013
40th International Pyrotechnics Seminar	Colorado Springs, Colorado, USA	13-18 July 2014	May 2013
Courses:			
Underwater Blasting		8-10 April 2014	Jan. 2014
Electroexplosives: Functioning, Reliability, and Hazards	Oaks, Pennsylvania USA	28 Jul-1 Aug 2014	Jan. 2014