UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AN ELECTRONIC BLASTER FOR USE IN REFRACTION SEISMOLOGY

Prepared by F.G. Fischer

July 1990

OPEN-FILE REPORT 90-429

Menlo Park, California

1990

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Introduction

This report describes a blaster designed by the USGS and used in seismic field work for detonating blasting caps at preset times. This report provides the circuit description, schematic, pictorial reference, and list of materials needed for construction. However, no warranty, expressed or implied, is made by the USGS as to the safety or suitability of this device for any particular purpose.

Design Goal

Refraction seismology experiments undertaken by the USGS require the use of timed explosions. Until 1989, all USGS explosions were detonated with a firing box, or blaster, which permitted an external time source to fire explosions after an operator had preset the firing voltage and engaged the appropriate safety switches. Our old blaster also provided an output pulse to indicate the precise time of detonation. The old blasters had worked well for decades, but technological advances have now allowed design changes which should improve reliability, ease maintenance, and permit simpler connections to additional data recording devices.

To improve reliability, mechanical high voltage generators and relays were replaced with solid state DC to DC converters and SCR's (Silicon Controlled Rectifier). All electronic components were then installed in a waterproof case. This case, lighter than the old design, includes sufficient space and power to eventually include a digital timer and event recorder as well as a small chart recorder. All safety interlocks from the original blaster were retained: two hands are still required for operation.

As of 1 January, 1990, eight new blasters were constructed. Six were field tested in Kenya: three blasters failed (caused by improper switch design and lack of short circuit protection). The current blaster design has been modified based on that experiment.

Circuit Details:

{Refer to Schematic and Pictorial}

Power for the blaster is obtained from the 12V battery through the **Enable switch, S1**, and also the Charge switch, S2. Both switches are momentary contact. The normally closed section of S1 discharges any voltage on the firing capacitor, C1, through R5. When **S1** is pressed this shunt is removed, and power is applied to all digital circuits: R11 and C4 generate a 220 mSec power-on reset to prevent either one-shot, U2A or U2B, from firing. While **S1** is pressed, the meter is illuminated. Diode D1 prevents a reversed battery from damaging the digital circuits. Diode D2 performs the same service for the DC/DC converter, U3.

While S1 is pressed, the **Charge switch, S2**, must be held down to allow the DC/DC converter, U3, to build up the firing voltage on C1. Resistor R1 limits the charging current so that an operator has time to release **S2** to set firing voltages less than 500 Volts. Diode D3 prevents the firing voltage on C1 from discharging back through U3. The meter circuit, M1, R3 & R4, draws 50μA at full scale (500V), so C1 discharges very slowly when **S2** is released.

The **Arm switch, S3,** in its normal position, shorts the output posts to reduce the firing lines tendency to act like an antenna – risking an early explosion owing to stray RF energy. When **S3** is pressed, the cap line is connected through the short-circuit limiting resistors, R7 & R8 and the current sensing transformer, T1, back to the SCR, Q1. It is important to note that without R6, pressing S3 would fire the shot by generating a rapid change in voltage across the SCR. R6 raises the allowable dV/dT to prevent false triggers.

With the Enable switch pressed, a charge on C1, the Arm switch pressed, and a blasting cap connected to the cap line output, the SCR is ready for a trigger. Triggers are initiated by a voltage greater than 3.75 volts on the **Auto Fire** input BNC. When coupled through the opto-coupler, U1, a rising edge generates a 2 mSec pulse at the output of U2B. This pulse turns on the N-channel power FET, Q2, causing 4 volts to be pulsed into the primary of T2. This generates a 2.2 V pulse on the secondary of T2 which triggers the SCR. T2 also blocks high voltage from venturing into the digital logic power. **Manual Fire** triggers, caused by pressing the Manual Fire button, **S4**, are also shaped by the U2B one-shot. This one-shot is used even for manual firing to prevent the destruction of T2 by continuous current through its primary winding.

The **Backup** fire switch, **S5**, is used only when there is a failure with the normal trigger system. This momentary toggle switch is not designed for repeated high power operations. It is a "last resort" solution. Even the Backup fire switch will not fire the shot if there is a break in the firing line. However, in such a case, holding the Backup switch closed will dump the firing voltage from C1 through R6. This will take several seconds, with the slow deflection of the meter pointer indicating that a problem exists outside the blaster.

When a shot fires successfully, the meter will drop immediately to zero. This process actually takes a few milliseconds. For firing currents over 0.5 Amp, T1 generates sufficient voltage to trigger the Cap Break one-shot, U2A. This produces a 20 mSec pulse, limited to 5.1 Volts by zener diode ZD2. This pulse is accessible at the **Cap Break Out** BNC, for display on an external recorder.

Blaster Characteristics

Mechanical:

Box size: 18.5" L, 14.6" W, 7.5" H
Box material: ABS Plastic with stainless steel hinge pin, w/ O-ring seal in lid & beneath panel.
Sealant: Caps and O-rings on all switches and screws, silicone seal between meter and panel.
Weight: 23 lbs. (including 12V, 9.1AH lead-acid battery)

Electrical:

DC/DC converter: 12V in, up to 500V out
Capacitor: 600V 25 μF oil filled
Output Energy: 3 Joules max. ($1/2\ CE^2$)
Short Circuit Current: 62.5 Amps (limited by internal 8 Ohm resistor)
Auto Fire Input: 4 to 35 V pulse (optically isolated, 4.7KΩ, 1/4W load)
Output: up to 500V (isolated from input, battery, and panel)
Cap Break Out: 5V pulse, 20 mSec long, 10KΩ source impedance

Assuming that 10 Amps are required to detonate a blasting cap, and that multiple caps are wired in series, this blaster will provide sufficient power to detonate a 42 Ohm circuit. Given that blasting caps have an internal resistance of less than 3 Ohms, most of the blaster energy will be used to overcome the resistance of the firing line. It is important that a blasting galvanometer be used to measure the cap and line resistance prior to each shot. For example: a 400 foot shot line with 3 caps in series might have a resistance of 25 Ohms. To determine the necessary firing voltage, add the firing box internal resistance, 8 Ohms, to the cap & line resistance, 25 Ohms, and multiply the resulting number, 33, by ten. The result, 330, represents the firing voltage necessary to produce 10 Amps in this particular circuit.

Field Operation:

Automatic Firing:

1. Connect Auto Fire cable to external timer.
2. Connect Cap Break cable to external strip chart recorder and power the recorder from the Charge/ +12V jacks if necessary.
3. Measure Cap & Line resistance with a Blasting Galvanometer.
4. Connect cap line to Cap Line posts.
5. LESS THAN 1 MINUTE BEFORE SHOT TIME, hold down the Enable button and keep it down until the shot is fired.
6. Press the Charge button until the Firing Voltage equals ten times [Cap & Line resistance plus 8 Ohms]. Allow 15 seconds to reach a charge of 500V
7. LESS THAN 5 SECONDS BEFORE SHOT TIME, turn on the chart recorder.
8. LESS THAN 2 SECONDS BEFORE SHOT TIME, hold down the Arm button and keep it down until the shot is fired.
9. If the shot does not fire on time, press the Manual Fire button. If the shot still does not fire, release only the Manual Fire button and then toggle the Backup Fire switch.
10. After the shot fires, release all buttons and turn off the recorder.
11. If the Backup Fire switch was used to fire the shot, turn in the blaster for testing.

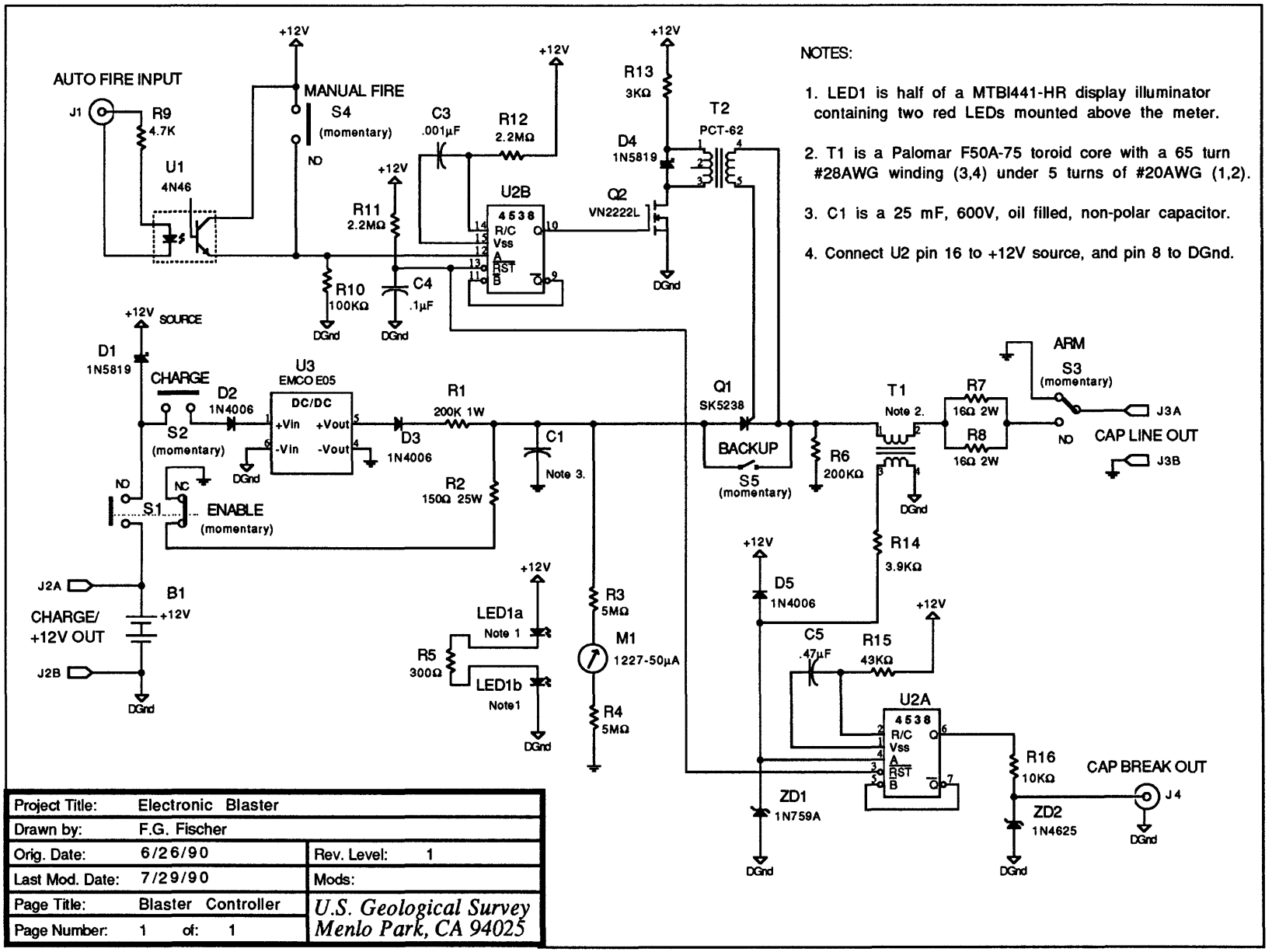
Manual Firing:

Repeat previous steps 2 through 8, then press the Manual Fire button (while still holding down the Enable and Arm buttons). Repeat step 10 (and step 11 if necessary).

Acknowledgments:

Numerous USGS employees contributed to the present state of this blaster. The following people provided exceptional help:

Initial design and drafting: Gray Jensen
Parts selection: Ron Kaderabek and Don Farrell
Machining: Bill Linne and Ron Blackwell
Wiring and other assembly: Don Farrell (with early assist from Jim Ellis)
Field testing: Water submersion by Walter Mooney and other tortures by Ed Criley.



Project Title:	Electronic Blaster		
Drawn by:	F.G. Fischer		
Orig. Date:	6/26/90	Rev. Level:	1
Last Mod. Date:	7/29/90	Mods:	
Page Title:	Blaster Controller	*U.S. Geological Survey*	
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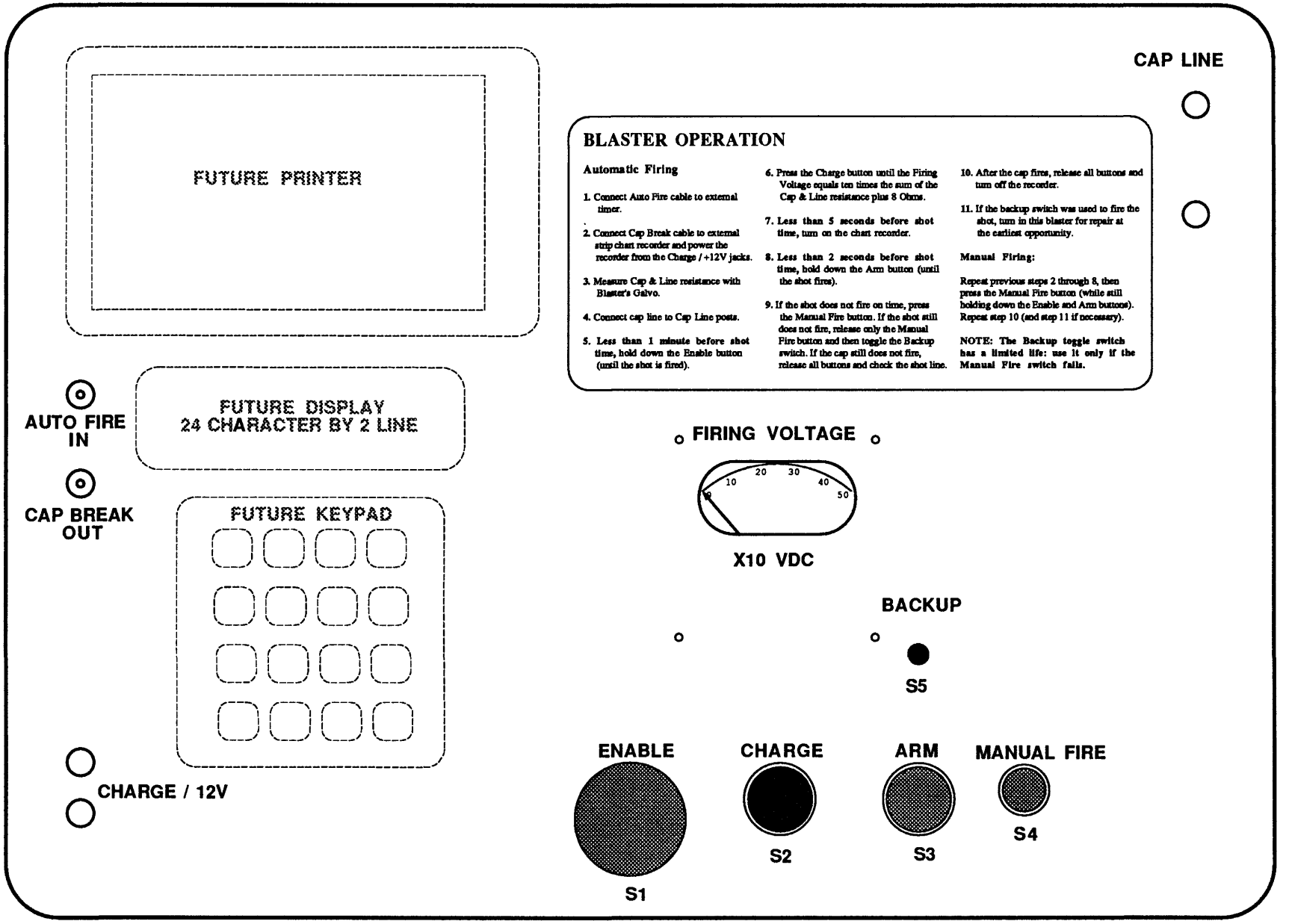
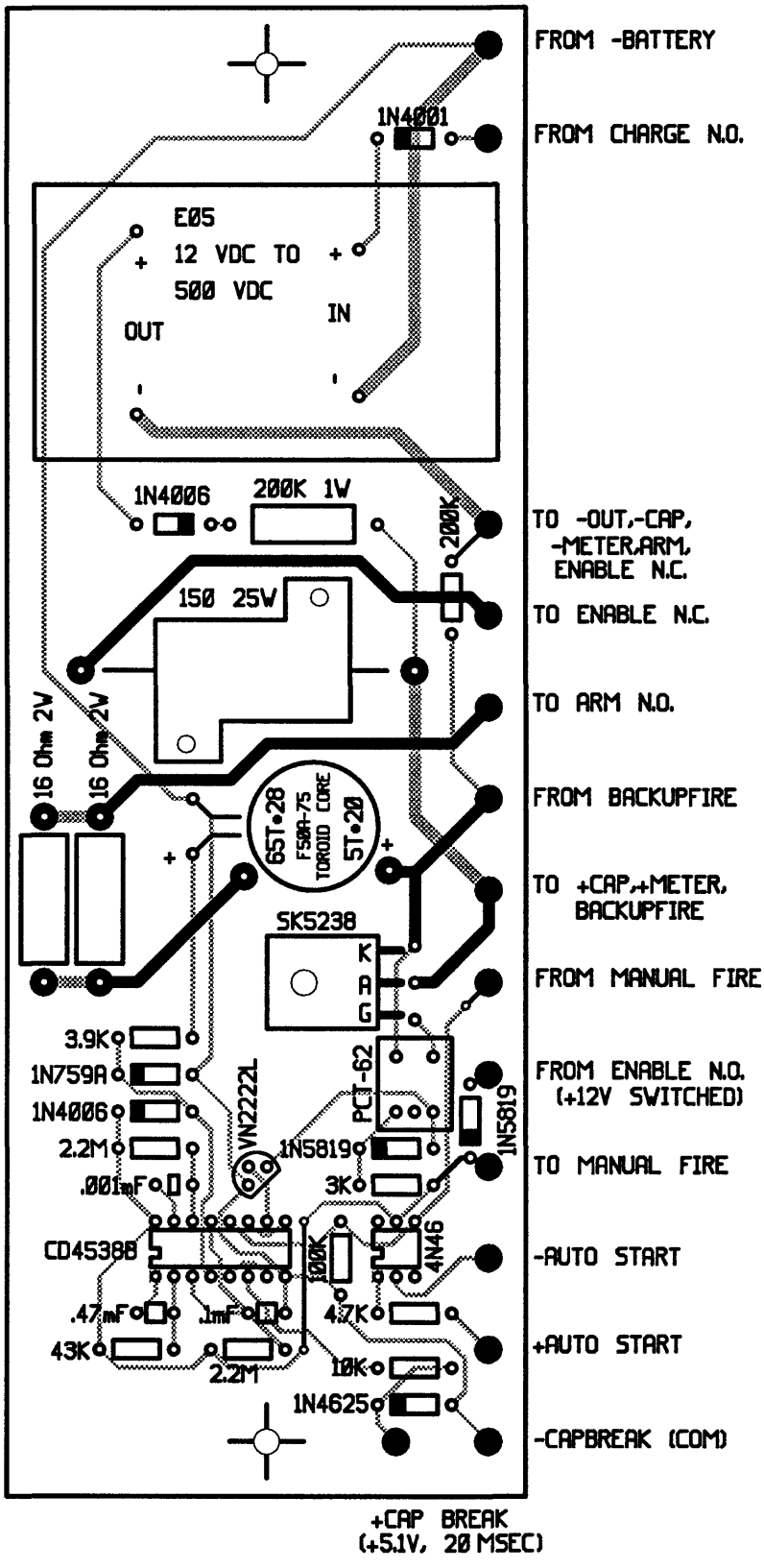


Pictorial View of Blaster Face Plate



Blaster Control
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Component Xray Scale1:1

Blaster Parts List

Part	Qty	Description
R1	1	200KΩ, 1 W, 5% Resistor
R2	1	150Ω, 25 W, Wire Wound Resistor
R3, R4	2	5MΩ, 1/4 W, 5% Resistor
R5	1	300Ω, 1/4 W, 5% Resistor
R6	1	200KΩ, 1/4 W, 5% Resistor
R7, R8	2	16Ω, 2 W, Carbon Comp. Resistor
R9	1	4.7KΩ, 1/4 W, 5% Resistor
R10	1	100KΩ, 1/4 W, 5% Resistor
R11, R12	2	2.2MΩ, 1/4 W, 5% Resistor
R13	1	3KΩ, 1/4 W, 5% Resistor
R14	1	3.9KΩ, 1/4 W, 5% Resistor
R15	1	43KΩ, 1/4 W, 5% Resistor
R16	1	10KΩ, 1/4 W, 5% Resistor
C1	1	25 µF, 600 VDC, Oil Filled Cap (CDE #SCRN 229)
C3	1	.001µF, Monolithic Ceramic Cap
C4	1	.1µF, Monolithic Ceramic Cap
C5	1	.47µF, Monolithic Ceramic Cap
U1	1	4N46, Opto-Coupler
U2	1	CD4538BE, Dual One-Shot
U3	1	E05, 12V to 500V DC/DC Converter
Q1	1	SK5238, 600V, 10A RMS, 120A Peak, SCR
Q2	1	VN2222L, N-Channel Power FET
D1, D4	2	1N5819, 1 A, 40 V, Schottky Diode
D2, D3, D5	3	1N4006, 1 A, 800V, Diode
ZD1	1	1N759A, 12V, 500 mW, Zener Diode
ZD2	1	1N4625, 5,1V, 250 mW, Zener Diode
LED1	0.5	Display Illuminator, (MTBL441-HR)
T1	1	Toroid Core, (Palomar F50A-75) with custom wound 5T #20 pri, 65T #28 sec.
T2	1	Transformer, 1500Ω pri, 600Ω sec. (Stancor PCT-62)
S1	1	Red Mushroom Switch Head, 1 9/16" Dia. (Telemecanique ZA2-BC4), with
	1	N.O.&N.C. Contact Block and Mtg. Collar (Telemecanique ZA2-BZ105)
S2	1	Black Booted Switch Head, (Telemecanique ZA2-BP2), with
	1	N.O. Contact Block and Mtg. Collar (Telemecanique ZA2-BZ101)
S3	1	Red Booted Switch Head, (Telemecanique ZA2-BP4), with
	1	Collar, (Telemecanique ZA2-BZ009), and
	1	Switch, 20A, 480 VAC (Microswitch BA-2RQ1-A2), with
	1	Switch Adapter, Lexan, .85" L, 15/32-32 to .805-26 tpi, USGS Custom

Blaster Parts List (continued)

Part	Qty	Description
S4	1	Switch, Momentary Pushbutton (MPE-106F), with
	1	Button Guard, Black, with
	1	Cap, Red, .59" Dia.
S5	1	Switch , Momentary Toggle, 10 A at 115VAC (Eaton 8811K17), with
	1	Toggle Cover, Black Plastic
	18	4-40 Threaded Mtg. Post (LTA #1282 [-4-11.2] Blue)
M1	1	Meter, 50 μA Full Scale (Simpson # 1227)
	2	BNC Panel Mt., Female, (Amphenol 31-221)
	2	Binding Posts, Red, 5 Way
	1	Banana Jack, Panel Mount, Red
	1	Banana Jack, Panel Mount, Black
	2	Circuit Board Mtg. Posts, AL., 0.5" Dia., 2.75" L, Ends Tapped 4-40, USGS Custom
	1	Capacitor Mtg. Rail, AL., 0.5" W, 8" L, 0.25" Thick, USGS custom
	1	Meter Mtg. Plate, AL, 1/16" x 3" Sq., with Lexan Cover, 1/8" Thick, USGS Custom
	4	Nylon Spacers, #4, 1/2" Long
	6	Screws, 4-40, 1", Stainless Steel, Flathead
	4	Screws, 4-40, 1/4", Stainless Steel, Flat Head
	20	Screws, 4-40, 1/4", Stainless Steel, Pan Head
	6	Hex Nuts, 4-40, Stainless Steel
	20	Lockwashers, #4, Stainless Steel
	2	Hose Clamps, #40, 3"", Stainless Steel
B1	2	Battery, 6V, 9.1 AH, Lead Acid (Panasonic LCR-856P)
	3	Battery Braces, Lexan, 0.25" Thick, Custom Formed by USGS
	1	Vector Board, 2.8" x 7", USGS Custom Wired (see page 6)
	1	Case, ABS, with Latch Locks & Instrument Panel (Underwater Kinetics Model 718)
		Assorted Lengths of Teflon Covered Hookup Wire