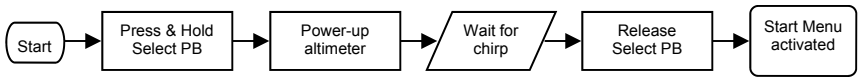
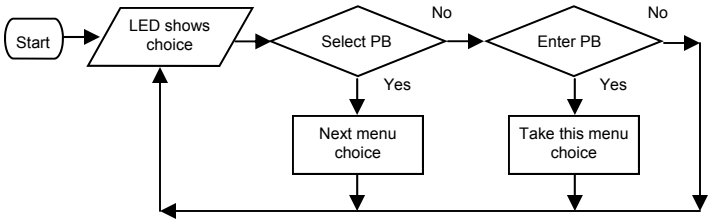
Figure 6 - Menu Navigation and Operation Flowchart

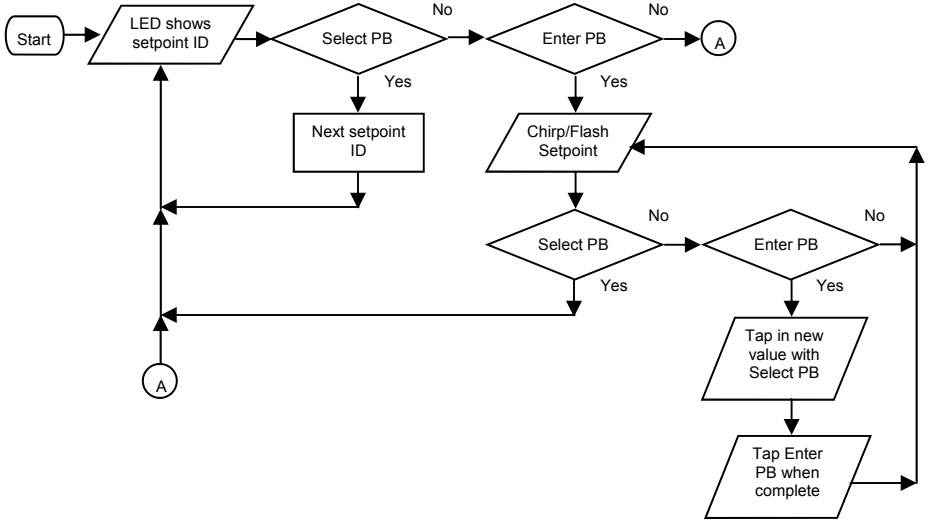
Invoking the Start Menu



Menu Navigation



Modifying a Setpoint



Product Warranty

Missile Works Corporation has exercised reasonable care in the design and manufacture of this product and warrants the original purchaser that the PET2+ is free of defects and that it will operate at a satisfactory level of performance for a period of one year from the original date of purchase. If the system fails to operate as specified, then return the unit (or units) within the warranty period for repair or replacement (at our discretion). The system must be returned by the original purchaser, and be free of modification or any other physical damage which renders the system inoperable. Upon repair of replacement of the unit, Missile Works Corporation will return the unit postage-paid to the original purchaser.

Product Disclaimer and Limit of Liability

Because the use and application of this equipment are beyond our control, the purchaser or user agrees to hold harmless Missile Works Corporation and their agents from any and all claims, demands, actions, debts, liabilities, judgments, costs, and attorney fees arising out of, claimed on account of, or in any manner predicated upon loss or damage to property of, or injuries to or the death of any and all persons arising out of the use this equipment. Due to the nature of electronic devices, and the application and environments for those devices, the possibility of failure can never be totally ruled out. It is the responsibility of the purchaser or user of this equipment to properly test and simulate the actual conditions under which the device is intended to be used to ensure the highest degree of reliability and success.

Missile Works Corporation
PO Box 1725
Lyons, CO 80540

Tel: 303.823.9222 Fax: 303.823.9777
On the World Wide Web @ www.missileworks.com

User Manual and Instructions
Model PET2+ - Programmable Event Timer
Revision 1.12

System Overview

The PET2+ provides a highly advanced and versatile dual-event timing control system targeted for high power rocketry. The design of the PET2+ utilizes a RISC microcontroller with a precise internal factory-calibrated 4MHz system clock for accurate and reliable event timing control. In addition the PET2+ uses a 3-axis "micromachined" accelerometer to detect specific inertial events during flight. This 3-axis capability allows mission specific timer orientation in the rocket. Each timer is fully independent, providing extremely flexible solutions for any rocketry timing application.

Just some of the applications that can be achieved with the PET2+ timer include:

- Precise booster separation and sustainer ignition of multi-stage composite powered rockets
- Ignition of secondary composite motors after primary motor ignition for airstarted boosts
- Fail safe backup and redundancy of primary rocket recovery control systems
- Triggering a camera shutter, audible/visual tracking device, or other electrical device at various stages of flight

General Specifications

Arming Mode	Inertial/Breakwire	Dimensions	1" W x 3.15" L
Inertial G trigger range	2-5 G's	Output current (sinking)	5A @ 0.5 sec
Battery/Power range	6-14 VDC	Continuity current	9µa @ 9V
Nominal Battery load	6-14ma	Weight	17 grams

Handling Precautions

Always handle in a properly grounded environment. ESD damage is not covered under your warranty.

Never touch/handle the unit when it is armed and connected to live pyrotechnic charges.

Always allow the unit to adjust to ambient temperature prior to arming/flying, and avoid extreme temps.

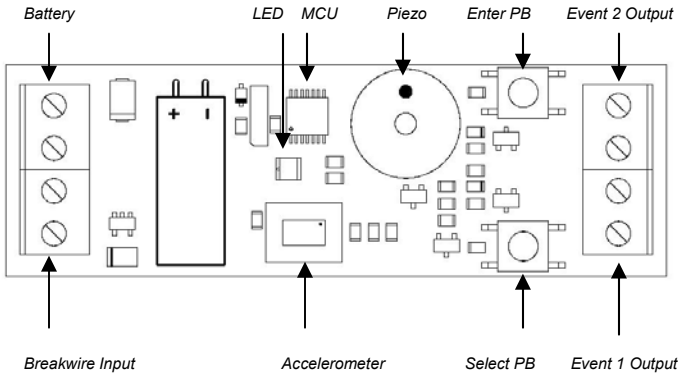
Never arm the timer and then load your rocket onto the launch rail. Arm the timer once on the rail.

Always prepare your rocket and timer system components with the unit powered off.

Physical Overview

Figure 1 depicts the general component layout of the PET2+ Programmable Event Timer.

Figure 1 - General component layout of the PET2+



All user input and output connections are made to the compression terminals as shown. These terminals include: *Battery* (logic and/or pyro power), *Breakwire* (for a N/C wire loop or switch), and *Event1/Event2* (for external pyro events or controls). All terminals are marked on the board silkscreen for reference.

Note: Before using the PET2+, familiarize yourself with the location and designation of all the user connection terminals, pushbutton controls, and with the audible feedback and LED functions. These functions, operations, and connections are covered in subsequent sections of this manual.

Pre-Flight / In-Flight / Post-Flight Modes of Operation

The PET2+ has several distinct modes throughout the course of its operation during flight. These modes of operation are easily identified by the function of the piezo and the LED.

Power-up mode

When power is first applied to the unit, it will provide a continuous 2-second chirp to indicate it has been switched on. During this 2-second chirp the LED will be solid **RED.**

Accelerometer initialization mode

After the Power-up mode, the unit goes through a 10-second accelerometer initialization start-up delay. The LED will flash slowly in **YELLOW** while in this mode. This delay period allows stabilization of the device and establishes the initial orientation and inertial references.

POST (Power Up Self Test) Verification / Error Chirp Mode

The PET2+ performs several sanity checks after initialization mode based on its current configuration to ensure that the rocket and timer are oriented properly and within allowable launch angle and calibration limits. If using the Breakwire trigger, this input is also checked for a proper "closed loop" condition. If the unit detects no problems, no mis-orientation, and no mis-configuration, it will arm both of the event timers and transition immediately into Launch Detect Mode.

If the PET2+ detects an error during Verification Mode it will NOT transition into Launch Detect mode. Instead it will sound an alarm tone (buzz) and continuously chirp and flash **YELLOW** with an ERROR CODE to indicate what specific error condition was detected. **DO NOT MISTAKE AN ERROR CODE CONDITION** for flight readiness and valid continuity feedback and inadvertently launch your rocket. The error codes are as follows:

Error Code	Error Condition
1	**X-axis triggering and off-axis or off-cal limit**
2	**Y-axis triggering and off-axis or off-cal limit**
3	**Z-axis triggering and off-axis or off-cal limit**
4	**Auto-axis detection and no valid axis/orientation detected**
5	**Breakwire triggering with initial open circuit**

Launch Detect mode

When all previous modes are complete, the unit transitions into launch detect mode. The piezo and the **GREEN LED** indicate the continuity status of the Event 1 and Event 2 output terminals every second as follows:

Status Code	Status Condition
1 Long Beep/Flash	**No continuity on Event1 or Event 2 outputs**
1 Short Beep/Flash	**Continuity on Event 1 output only**
2 Short Beeps/Flashes	**Continuity on Event 2 output only**
3 Short Beeps/Flashes	**Continuity on both Event 1 and Event 2 outputs**

The unit also monitors the accelerometer and/or Breakwire input in order to determine the launch of the rocket. After this event, the unit transitions into timing operation mode.

Timing operation mode

When in Timing Operation mode, the LED flashes fast in **RED (≈6Hz)**. The unit can have one or both timers active at any given time based upon the triggering and timing configuration. This mode of operation remains active until both of the timers have completed a timing cycle and the associated output event has been initiated. Once this occurs, the unit transitions into Post Timing mode.

Post Timing Mode

When in Post Timing Mode, the LED will flash slowly in **YELLOW (≈2Hz)**. The unit will continue in this mode until it is powered off. Keep in mind that if either timer has been configured in "repeat" mode, the repeat timing cycles are active during this mode.

Programming and Configuration

Accessing the Start Menu

Please refer to the **Setpoint and Operations Matrix** reference included in this manual when reading and reviewing this section. Also refer to the **Figure 6- Menu Navigation and Operation Flowchart** for additional help.

To start the interactive operation of the PET2+, press and hold the *SELECT* pushbutton while applying power to the unit. Release the pushbutton after you hear a brief chirp from the piezo. You're now at the **Start Menu** and displaying the first choice (**SLOW FLASHING RED** / **Setpoint Menu**)

Start Menu Navigation

To scroll to the next available choice in the menu, tap the *SELECT* pushbutton. To make a choice in this menu, tap the *ENTER* pushbutton. **(note: a brief chirp acknowledges each button press).**

Start Menu Options

All other menus are accessed from the Start Menu. The available options are:

- *Timer 1 Setpoint Menu* — *Provides verification and adjustment of all user setpoints for Timer 1.*
- *Timer 2 Setpoint Menu* — *Provides verification and adjustment of all user setpoints for Timer 2.*
- *Global Setpoints & Diags Menu* — *Verify/Adjust the PET2+ global setpoints or exercise the PET2+ diagnostic features.*
- *Escape to Flight Mode* — *Exit the Start Menu and return to normal flight operations mode.*

Timer 1 / Timer 2 / Global Setpoint Menus

All user adjustable setpoints are available from these menus. You can verify all setpoints, and you can adjust all setpoints. The PET2+ provides 2 independent and identical groups of setpoints for each timer. The Global Setpoints are applied and used by both timers appropriately. All setpoint values are stored in nonvolatile memory.

Setpoint and Operations Matrix

LED Legend: **SOLID** (X) **SLOW FLASH** (X) **FAST FLASH** (X) **FLICKER FLASH** (X)

X = LED Color
R = RED / G = GREEN / Y = YELLOW

Start Menu

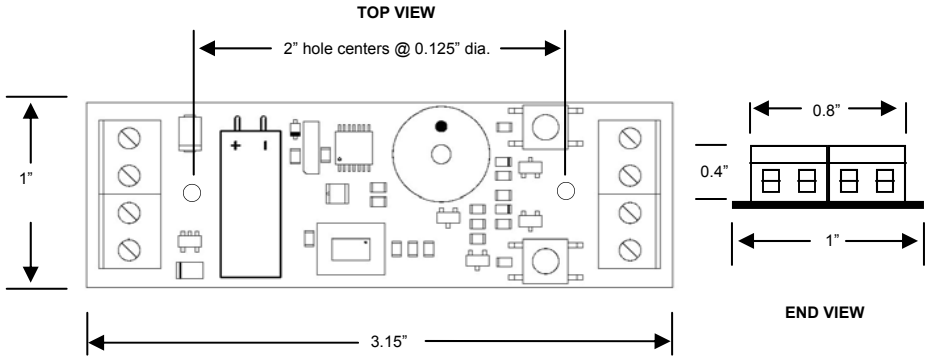
R	Navigate to Timer 1 Setpoint Menu
G	Navigate to Timer 2 Setpoint Menu
Y	Navigate to Global Setpoints and Diagnostics Menu
R G	Exit to Flight Mode

Timer 1 Setpoint Menu	Range	Default value
MEIG Trigger Level	2-5 (G's)	2
SEIG Trigger Level	2-5 (G's)	3
Inertial Trigger Event	1=MEIG / 2=MECO / 3=SEIG / 4=SECO	2
Trigger Integration Time	0.1 - 3.0 seconds (1 to 30)	2
Breakwire Function	1=N/A, 2=Exclusive Trigger, 3=Interlock Trigger	1
Timer Interval	1-100 (Time base dependent)	5
Time Base	1=Fast (0.1 sec), 2=Slow (1 sec), 3=XSlow (2 sec)	1
Output Pulse	0.1 - 3.0 seconds (1 to 30)	5
Timer Operation	1=One-shot, 2=Repeat	1
Exit to Start Menu		

Timer 2 Setpoint Menu	Range	Default value
MEIG Trigger Level	2-5 (G's)	2
SEIG Trigger Level	2-5 (G's)	3
Inertial Trigger Event	1=MEIG / 2=MECO / 3=SEIG / 4=SECO	2
Trigger Integration Time	0.1 - 3.0 seconds (1 to 30)	2
Breakwire Function	1=N/A, 2=Exclusive Trigger, 3=Interlock Trigger	1
Timer Interval	1-100 (Time base dependent)	10
Time Base	1=Fast (0.1 sec), 2=Slow (1 sec), 3=XSlow (2 sec)	1
Output Pulse	0.1 - 3.0 seconds (1 to 30)	5
Timer Operation	1=One-shot, 2=Repeat	1
Exit to Start Menu		

Global Setpoint and Diagnostic Menu	Range	Default value
Inertial Trigger Axis	1=X Axis, 2=Y Axis, 3=Z Axis, 4=Auto Axis	4
Off Axis/Cal Deviation	1-10 (5 Represents ≈ ± 20 degrees)	5
Piezo Tone	1=High Tone, 2=Low Tone	1
Output Test Mode	(N/A)	
Input Test Mode	(N/A)	
Exit to Start Menu		

Figure 5– Mounting Dimensions for the PET2+



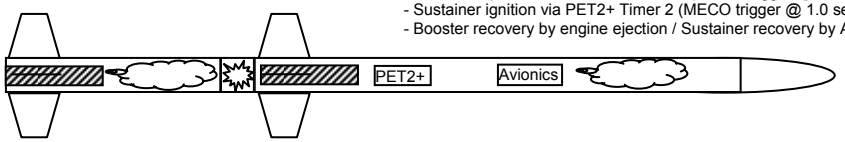
Operating Tips for Success

- Always pre-test your PET2+ as COMPLETELY as possible prior to every flight. This includes a test of the inputs, outputs, and Breakwire system.
- Always pre-test your batteries before each flight and ensure they have adequate power capacity for the anticipated worst case flight profile, including unplanned "on-the-pad" waiting time.
- Always pre-measure your deployment charge initiators. Measure them for a nominal resistance and verify they are not shorted.
- Double check your timing configuration and your anticipated flight profile to ensure you'll reach adequate acceleration levels to properly trigger and initiate your timing sequences.
- Be sure to familiarize yourself with the audible feedback operations of the PET2+, in particular its Error Code and Continuity chirping sequences. The unit will not arm itself in an Error condition, and launching your rocket will result in a failure of the timing operations of your flight. Likewise, ignoring the validity of continuity feedback may produce a failed timing event.
- Flying in extreme hot or cold temperatures may cause drift of the inertial sensor such that an Error Code condition may exist due to this drift exceeding the nominal inertial calibrations stored in the MCU EEPROM. If this condition exists, you can widen the deadband setpoint value (*Off Axis/Cal Deviation)* in order to satisfy the POST verification mode.

Example Usage of the PET2+

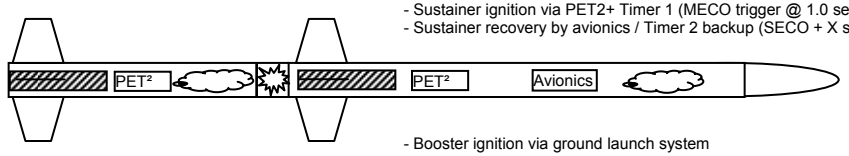
Basic 2 Stage Rocket

- Booster ignition via ground launch system
- Booster separation via PET2+ Timer 1 (MECO trigger @ 0.1 sec)
- Sustainer ignition via PET2+ Timer 2 (MECO trigger @ 1.0 sec)
- Booster recovery by engine ejection / Sustainer recovery by Avionics



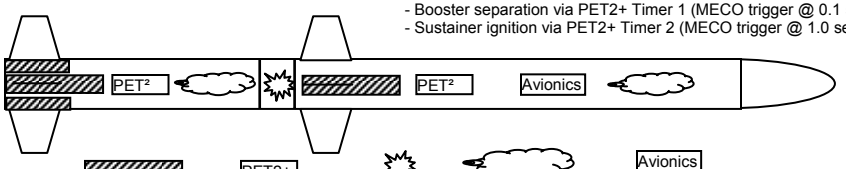
Advanced 2 Stage Rocket

- Booster ignition via ground launch system
- Booster separation via PET2+ Timer 1 (MECO trigger @ 0.1 sec)
- Booster recovery via PET2+ Timer 2 (MECO trigger @ 3.0 sec)
- Sustainer ignition via PET2+ Timer 1 (MECO trigger @ 1.0 sec)
- Sustainer recovery by avionics / Timer 2 backup (SECO + X seconds)



Advanced 2 Stage Airstart Rocket

- Booster ignition via ground launch system
- Airstart Ignition via PET2+ Timer 1 (MEIG trigger @ 2.0 sec)
- Booster recovery via PET2+ Timer 2 (MECO trigger @ 3.0 sec)
- Booster separation via PET2+ Timer 1 (MECO trigger @ 0.1 sec)
- Sustainer ignition via PET2+ Timer 2 (MECO trigger @ 1.0 sec)



Setpoint Menu Navigation and Setpoint Adjustment

To scroll to the next available setpoint choice in the menu, tap the *SELECT* pushbutton. To choose a setpoint, tap the *ENTER* pushbutton. After a setpoint has been chosen, the piezo and LED will repeatedly flash/chirp the current value of the setpoint (for verification).

Tap the *SELECT* pushbutton to scroll to the next setpoint in the menu, *OR* tap the *ENTER* pushbutton to modify the chosen setpoint value. If you've elected to modify a setpoint, the unit is now awaiting the new setpoint value.

Tap the *SELECT* pushbutton according to the newly desired value (example: tap the button 10 times for a value of TEN), then tap *ENTER* when complete. Alternatively, tapping ENTER without making any new input will reset the setpoint value to its default value.

The unit will now chirp back the newly entered setpoint value. Tap the *SELECT* pushbutton to scroll to the next available setpoint or repeat the programming operation by tapping *ENTER* again.

Setpoint Nomenclature

The timer uses the following acronyms to define specific flight events that are used for timer triggering. These acronyms are defined as follows.

MEIG — **M**ain **E**ngine **IG**nition. This is the 1st trigger event that occurs upon ignition of the rocket's main engine (or first stage) when acceleration meets/exceeds the timer's MEIG setpoint (2-5 G's).

MECO — **M**ain **E**ngine **C**ut-**O**ff. This is 2nd trigger event that occurs upon burnout or cut-off of the rocket's main engine when acceleration falls below the +1G calibration point.

SEIG — **S**econd **E**ngine **IG**nition. This is the 3rd trigger event that occurs upon ignition of the rocket's second engine (or second stage) when acceleration meets/exceeds the timer's SEIG setpoint (2-5 G's).

SECO — **S**econd **E**ngine **C**ut-**O**ff. This is 4th trigger event that occurs upon burnout or cut-off of the rocket's second engine when acceleration falls below the +1G calibration point.

Timer 1 / Timer 2 Setpoint Menu Options

MEIG Trigger Level — *Inertial acceleration trigger setpoint for the MEIG event. It is adjustable between +2G's and +5G's of acceleration (represented by a value of 2 to 5).* ***Must*** *be set for MECO/SEIG/SECO triggers.*

SEIG Trigger Level — *Inertial acceleration trigger setpoint for the SEIG event. It is adjustable between +2G's and +5G's of acceleration (represented by a value of 2 to 5).*

Trigger Event — *Defines the inertial trigger event used to trigger the timer. It is adjustable between 1 and 4 as follows:* ***1 = MEIG*** *trigger /* ***2 = MECO*** *trigger /* ***3 = SEIG*** *trigger /* ***4 = SECO*** *trigger.*

Trigger Integration Time — *Defines the amount of time that the inertial trigger level must be sustained for a valid trigger event. This time is adjustable between 0.1 seconds to 3.0 seconds (0.1 sec increments / a value of 1 to 30). The timer applies to both inertial and Breakwire inputs.*

Breakwire Function — *Defines the trigger operation of the Breakwire input. There are 3 valid setpoint options:*

1 - N/A	*Not Applicable / Breakwire input is not used.*
2 - Exclusive Trigger	*Timer is triggered exclusively by Breakwire input (no inertial trigger).*
3 - Interlock Trigger	*Breakwire AND Inertial trigger are interlocked (both must be valid).*

Timer Interval — *The timer value (1-100), used in conjunction with one of three specific time base setpoints.*

Time Base — *The timer time base value, defining the programmable Timer Interval and resolution of the timer:*

1 - Fast	***(0.1 seconds / 0.1 to 10.0 seconds)***
2 - Slow	***(1.0 seconds / 1 to 100 seconds)***
3 - Extra Slow	***(2.0 seconds / 2 to 200 seconds)***

Output Pulse — *Determines the amount of time the output event is energized when the timer countdown is compete. This time is adjustable between 0.1 seconds to 3.0 seconds (0.1 sec increments / a value of 1 to 30).*

Timer Operation — *This setpoint defines if the timer operates as a "one-shot" event, or in a repeat mode operation:*
1 - One Shot operation
2 - Repeat operation

NOTE: All setpoints can be initialized to Factory Defaults by pressing both pushbuttons and performing a power-up. The unit quickly chirps and flashes the LED. Release both pushbuttons to complete the reset.

Global Setpoints and Diagnostics Menu

From this menu, you can access the PET2+ global setpoints. The unit can also be placed into various modes to verify the basic operational integrity of the unit, including the continuity circuits and output controls.

Global Setpoints and Diagnostics Menu Navigation

To scroll to the next available setpoint or diagnostic choice in the menu, tap the *SELECT* pushbutton. To choose a setpoint or diagnostic, tap the *ENTER* pushbutton. The piezo and LED will flash/chirp the appropriate setpoint value or based upon the type of diagnostic chosen. Tap the *SELECT* pushbutton to scroll to the next setpoint in the menu. The Input and Output test "dead end" and require a restart of the unit when you're completed.

Global Setpoints Menu Options

Inertial Trigger Axis — *Determines the timer orientation and accelerometer axis to be used for Inertial triggering. This setpoint applies to both timers. The Trigger Axis setpoint is adjustable between 1 and 4 as follows:* ***1 = +X axis*** *trigger /* ***2 = +Y axis*** *trigger /* ***3 = +Z axis*** *trigger /* ***4 = Auto Detect*** *axis (+X,+Y, or +Z)*

Global Setpoints Menu Options (continued)

Off Axis/Cal Deviation — *This setpoint allows you to specify a deviation deadband to ensure the rocket is within ±20 degress of vertical for launch operations and to ensure the accelerometer calibration has not drifted in excess from the initial calibration process. The valid range is from 1 to 10, with a value of 5 representing ≈ ±20 degrees range. If the altimeter fails this test, you will receive the error codes as outlined in the* ***Modes of Operation*** *section.* ***NOTE: Operating the unit in temperature extremes may cause the unit to drift outside of nominal calibration limits and induce an Error Condition.***

Piezo Tone — *This setpoint controls the tone of the Piezo. This feature is useful when running multiple audible avioincs or it's difficult to hear the standard 4KHz tone.*
1 = 4KHz tone (high tone)
2 = 4KHz and 1250Hz DTMF tone (low tone)

Diagnostic Options

Input Test Mode — *This feature allows the user to verify the operation of the continuity input circuits. It operates identical to launch detect mode. Chriping/Flashing is as follows:*

Long Beep/Flash	**No continuity on Event 1 or Event 2**
1 Short Beep	**Continuity on Event 1 only**
2 Short Beeps	**Continuity on Event 2 only**
3 Short Beeps	**Continuity on Event 1 and Event 2**

Output Test Mode — *This feature allows the user to manually activate the Event1 and Event 2 circuits. When this diagnostic is selected, the piezo will emit a WARNING TONE for 5 seconds, and the LED will flash rapidly in* **RED** to alert the user that output test mode has been selected. After the warning tone is complete, the unit is ARMED. Press the *SELECT* pushbutton to activate the EVENT1 output. Press the *ENTER* pushbutton to activate the EVENT2 output.

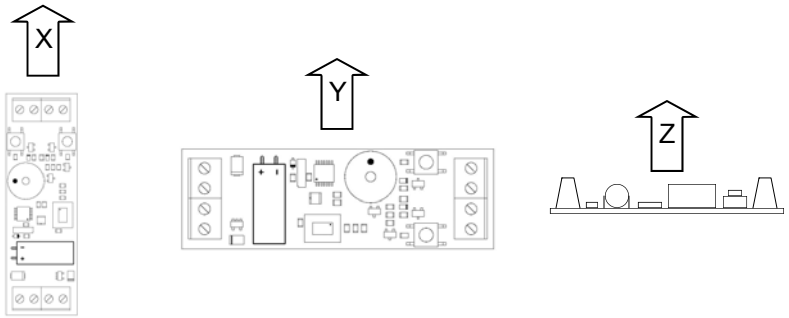
Note: A useful accessory for testing the outputs are 12-volt DC panel lamps. The lamps will allow you to observe the operation of the outputs without the use of pyrotechnic devices.
IMPORTANT: Always exercise caution if using live pyro charges in the output test mode.

Escape to Start Menu — *Exit the Diagnostics Menu and return to the Start Menu.*

IMPORTANT: After selecting the Input/Output Test Mode diagnostic feature, you must power off the unit prior to flight, additional testing, or usage of the altimeter.

Accelerometer Orientation
The PET2+ can be flown in any one of three orientations for inertial triggering. This flexibility allows the designer to utilize the rocket payload space in more effective manner as opposed to the single axis/axial orientation required by other timer systems. The Figure 2 diagram illustrates these orientations in reference to the airframe nose cone:

Figure 2 - +X/+Y/+Z orientation of the PET2+



Battery and Power Source Considerations
The PET2+ is intended to be operated using a standard 9-volt alkaline battery, however because of it's wide voltage input range, battery packs from 6V to 14V are compatible.

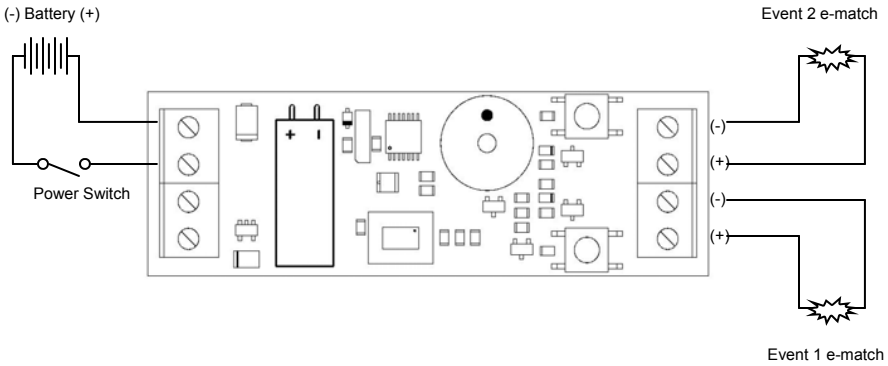
IMPORTANT: Always use a battery system less than 14 Volts to avoid damaging the PET2+.

IMPORTANT: Always load-test your battery prior to flight to ensure adequate power reserve for reliable operation and ignition of the ejection charges. Inadequate sizing of an external battery system or high-current demands on the battery system during event initiation may lead to power and processor brown-out conditions, resulting in recovery failure.

To load-test a 9V battery, you will require a DC multimeter capable of DC amp measurement with a 10-amp capability. A 9-volt alkaline battery can easily source in excess of 5 amps. Briefly connect the meter leads across the battery terminals to measure the DC current capacity. If the measurement is close to or drops below 2 amps, do not use the battery. Nominal load during operation is about 6 ma; and during output firing, the unit can draw well over 1 amp with low current e-matches.

Wiring Diagram/Low Current e-matches
Figure 3 depicts the recommended low-current wiring convention for PET2+. This configuration activates the e-matches using the same battery that powers the microcontroller and accelerometer system. The success of this configuration relies on the voltage remaining relatively stable when firing a low-current e-match. If the voltage sags too low, this may result in a brown-out or other timing operation malfunction.

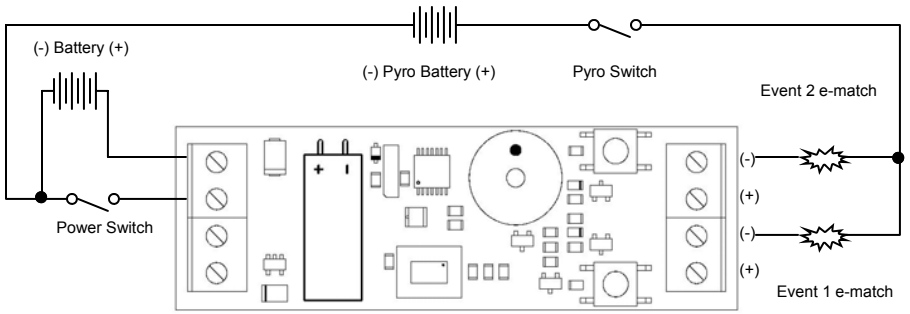
Figure 3 - Low-Current Wiring Diagram for the PET2+



Wiring Diagram—High-Current/Dual-Battery
Figure 4 depicts the recommended high-current/dual-battery wiring convention for the PET2+. When your timing system pyro charges do indeed require higher current, or if you want to configure the most robust and reliable configuration, use the dual-battery configuration as shown. Ensure that the negative sides of each battery are connected together to form a single common. Observe the proper output terminal connections, using the (-) leg of the Event 1 and Event 2 outputs.

IMPORTANT: Never exceed 20VDC for the secondary pyro battery to avoid damaging the PET2+.

Figure 4 - High-Current Wiring Diagram for the PET2+



The unit has silkscreen labeling showing the designation of all the terminals and the associated polarity for each terminal where applicable. Stranded 20-22 AWG wire is recommended for the battery and power switch terminals.

Breakwire Circuit and Operation
When using the Breakwire circuit, always use a *"dry contact"* connection between the (+) and (-) terminals. The Breakwire circuit uses the *BATTERY VOLTAGE* to operate. The PET2+ uses the Breakwire circuit for trigger operation by detecting when the circuit is *OPEN*. When used in your timer triggering scheme, the Breakwire circuit must be *CLOSED* initially on the pad when the PET2+ is initialized, and subsequently open via some other external event or operation. The Breakwire circuit and the **ENTER Pushbutton** operate in parallel to one another (a closed Breakwire circuit can be simulated by pressing the Enter button).

Mounting Considerations
The payload section or electronics bay used for the PET2+ should be sealed to isolate the electronics from the ejection-charge or engine heat and residue.

IMPORTANT: Inadequate sealing of the electronics bay or exposure of the electronics to ejection charge heat, BP residue, or pressure will cause the PET2+ to malfunction.

IMPORTANT: Black powder residue is extremely corrosive to the circuit board and its components. Always clean off any inadvertent residue immediately to avoid long-term damage to the unit.

Physical Mounting Dimensions
Figure 5 depicts the physical mounting requirements for the PET2+. 4/40 screw hardware is recommended to mount the unit into the payload section of the rocket or through a rocket airframe. Nylon standoffs or insulated neoprene washers are also recommended for mounting against a hard back plate or sled.

When designing your airframe, avioincs bay and mounting the PET2+, ensure that it is oriented in one of the three allowable orientations as depicted in Figure 2.