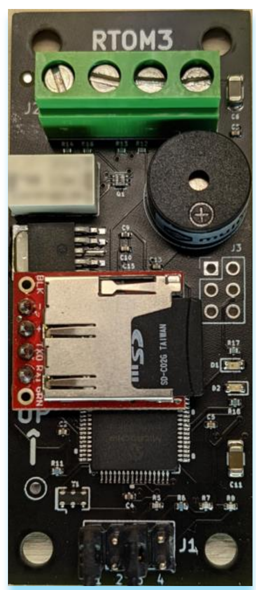
ROCKETILTOMETER™ 3

ATTITUDE-BASED AIR-START IGNITION CONTROL SYSTEM



USER MANUAL **VERSION 1.1.5**

Limited Warranty and Disclaimer

Rocket Electronics warrants the ROCKETILTOMETER™ to be free from defects in materials and workmanship and remain in working order for a period of 180 days. If the unit fails to operate as specified, the unit will be repaired or replaced at the discretion of Rocket Electronics, providing the unit has not been damaged, modified, or serviced by anyone except for the manufacturer.

The ROCKETILTOMETER is sold as an experimental accessory only. Due to the nature of experimental electronic devices, especially when used in experimental carriers such as rockets, the possibility of failure can never totally be removed. The owners, employees, vendors or contractors of Rocket Electronics shall not be liable for any special, incidental, or consequential damage or expense directly or indirectly arising from the customer or anyone's use, misuse, or inability to use this device either separately or in combination with other equipment or for personal injury or loss or destruction of other property, for experiment failure, or for any other cause. It is up to the user, the experimenter, to use good judgment and safe design practices and to properly pre-test the device for its intended performance in the intended vehicle. It is the user or experimenter's responsibility to assure the vehicle will perform in a safe manner and that all reasonable precautions are exercised to prevent injury or damage to anyone or anything.

WARNING: Do not use this device unless you completely understand and agree with all the above statements and conditions. First time use of the ROCKETILTOMETER signifies the user's acceptance of these terms and conditions.

How to Contact Rocket Electronics

Please see web site at: https://Rocket-Electronics.com. There we have the latest versions of the user manuals. We also have several options for you to contact us, including email and shipping address information.

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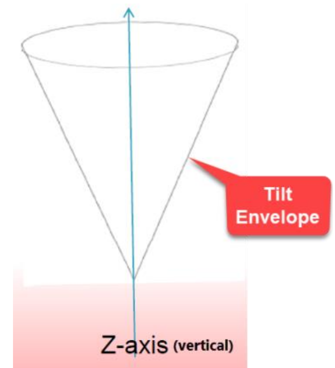
INTRODUCTION

The ROCKETILTOMETER™ 3 (or RTOM3™) utilizes several sensors and a microcontroller to monitor a model rocket's attitude and motion. It uses that information to disable the ignition signal from any triggering device in the event of the rocket's excessive tilt or excessive motion.



Since the ROCKETILTOMETER is able to monitor the angle of the rocket during its flight, it is possible to inhibit the ignition of air-started motors in the event of adverse-attitude or off-axis flights. Through on-board jumpers, the user is able to easily program the system *critical angle,* which defines the associated *tilt envelope,* for angles of 10, 15, 20 or 30 degrees off-vertical.

If the rocket's tilt should exceed this critical angle, the ROCKETILTOMETER is capable of suppressing an applied ignition trigger from *any manufacturer's* external triggering device, such as a timer, altimeter or flight computer. Additionally, new features add the ability to optionally re-enable ignition upon reentry of the rocket to inside the prescribed tilt envelope, and/or disable/re-enable ignition based upon monitoring the rate of change in the rocket's orientation, or, *motion monitoring*.

Avoiding ignition of adverse-attitude rockets is an economic advantage since it can save a motor for a future flight when conditions may be better, or it can reduce a long trek to recover an errant flight. Most importantly, from a safety perspective, inhibiting ignition can possibly prevent property damage or even personal injury.

KEY ATTRIBUTES

- **Simple to use**
    - Two jumpers determine the selectable *critical angle* - 10/15/20/30 degrees
    - Accommodates any external ignition trigger methods (see voltage/current limitations below)
    - Built in launch detection
        - Dynamic – based upon actual rocket launch
        - Static – grounding a solder pad on the board for ground testing
    - No computer interface or soldering required
    - Audible diagnostic tones and LED indicators report monitoring of internal circuits and system options configuration
    - Ignition-circuit-interrupt is terminated on two terminals on the system board – no on or off board splicing required
    - An <u>optional</u> flight data logger with removable microSD card for download of flight data to your computer is available
    - Mount it, connect it, set the critical angle, turn the system on, arm your triggering ignition source and launch!

- **Operating modes**

  - *Note, as with all tilt detection devices, while a rocket may be inside the tilt envelope when ignition is applied by the user's device, by the time the motor pressures up, it is possible the rocket could have moved outside the tilt envelope*

  - A rocket pointing **outside the tilt envelope** will *always* have **ignition disabled**

  - A rocket **inside the tilt envelope** will normally have **ignition enabled**

  - With **motion monitoring** enabled, while the rocket is inside the tilt envelope, if the rocket's motion is excessive, ignition will be disabled for a short period
    - If the motion stays at a high level, ignition will remain disabled
    - If the rocket goes outside the tilt envelope, ignition will be disabled
    - Motion monitoring provides possible early detection of a rocket heading outside the envelope
    - Motion monitoring will also disable ignition for a rocket that is still inside the envelope but demonstrating excessive or adverse motion

    Note: It is possible that motion monitoring could inhibit ignition of a rocket that may ultimately stay inside the envelope, but with the threshold of motion energy that motion monitoring uses to inhibit ignition, this is unlikely

  - If **ABORT** mode is selected, once the rocket goes outside of the tilt envelope, **ignition is inhibited for the remainder of the flight** regardless of the rocket's attitude
    - It is possible to select **ABORT** separately, or **with motion monitoring** enabled

  - If **REENTRY** mode is selected, a rocket that reenters the tilt envelope will have ignition re-enabled after a short reentry-delay
    - After the delay, ignition will be re-enabled unless the rocket once again goes outside the tilt envelope
    - It is possible to select **reentry mode** separately, or **with motion monitoring** enabled

- **Mounting**
  - 4 mounting holes, accepting 4-40 or M3 hardware
  - Arrow must be up (vertical) at launch

    Note: if the motion monitoring feature is to be used, alignment of the RTOM3 with respect to the longitudinal axis of the rocket is important

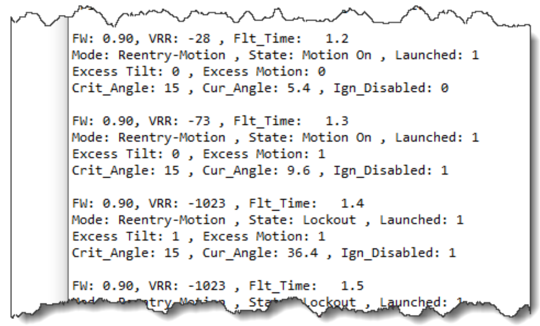
- **Main system components**
  - Microchip dsPIC microcontroller (MCU)
  - 3-axes accelerometer for gyroscope calibration and launch-detect
  - 3-axes MEMS gyroscope for tilt and motion monitoring

- Two jumpers for angle selection
- Two jumpers for selection of operating mode
- High-capacity system ignition circuit capable of passing up to 12 amps at up to 12.5 volts DC for 2 seconds (3S LiPo batteries OK); non-inductive load
- LEDs and toner for system operation and diagnostic feedback
    - Blue LED, when on, indicates ignition is enabled – useful for testing
    - Green LED indicates power (ON), 50 degree test mode (OFF), and launched status (OFF)
    - At startup, beeper indicates selected critical angle (CA), or, emits steady beeps if startup monitoring detects system malfunction
    - After startup, if system is nominal, beeper sounds "heart beat" chirps every 5 seconds until launch detection
- Optional integrated flight data logger with microSD card for easy data retrieval without demounting system; records data from launch through 120 seconds after launch

- **Screw terminal circuits**
    - Two terminals for user's triggering device ignition output can handle virtually any external trigger source (see voltage/current limitations elsewhere)
    - Two terminals for system battery source
        - Protection for battery input and system power
            - Reverse Bias Protection (polarity)
            - Short Circuit Protection
            - Thermal Shutdown
        - The RTOM3 is a relatively high-draw device (average draw is ~ 120 mA). Though we recommend a separate power source, the RTOM3 can be powered from the same source feeding other devices – there are no common connections between RTOM3 power and the RTOM3 ignition inhibit circuit
            - *Verify total load and assure that the RTOM3 power source voltage does not go below the minimum specifications (stated elsewhere), including during the triggering ignition pulse – as always, GROUND TEST YOUR SYSTEM!*

- **Hardware/firmware**
    - High-spin rate compliance – up to 1000 degrees per second for rated performance
    - Gyro cross-coupling typically introduces <2% error
    - Automatic accelerometer-based launch detection
        - Removes accelerometers from gyro calibration circuit
        - Turns off diagnostic indicators to conserve battery
        - Starts data output for optional logger
    - Internal system diagnostics monitor individual circuits at startup for integrity and report any error via system toner
    - Critical angle is determined off true earth vertical, not rocket attitude on launch pad
    - Gyro data acquisition rate is 40 samples per second
        - Data itself is over-sampled (200 Hz per axis) to improve resolution and reduce drift
    - Efficient, attitude-transformation-specific Direction Cosine Matrix (DCM) algorithm which utilizes a third-order matrix Taylor expansion of the non-linear update equations in order to improve accuracy at high rotation rates
        - Gyro drift is effectively *zero* using this method

- Optional data logger output begins at launch detect and records for 120 seconds
    - Configuration
        - Firmware version
        - Selected critical angle
        - Selected operating mode
    - Operation/flight time in 0.1 second increments
        - Vertical (z axis) spin rate
        - Current tilt value
        - Launched condition
        - Excessive tilt flag
        - Excessive motion flag
        - Ignition disabled flag
        - Current state of tilt-engine



- **Ignition interrupt circuitry**
    - Causes the triggering ignition circuit from user device *to be interrupted* in the event of four different, selectable operating modes – see additional information elsewhere:
        - ABORT mode with Motion Monitoring
        - ABORT mode
        - REENTRY mode with Motion Monitoring
        - REENTRY mode
    - Allows user to make system battery and igniter connections prior to pad-ready state – note always GROUND TEST your specific application prior to launch time
    - Allows igniter power from the user's triggering device up to 12 amps, at up to 12.5 volts DC for a period of up to two (2) seconds – non-inductive load
    - User's trigger device ignition circuitry remains unaffected, allowing continuity check

SYSTEM DESCRIPTION

KEY FEATURES EXPLAINED

The ROCKETILTOMETER is comprised of X, Y and Z axes accelerometers and X, Y, and Z axes MEMS (micro-electro-mechanical systems) gyroscopes. It is capable of determining the vertical tilt attitude for a rocket during the period between liftoff and the ignition call for staged or air-started motors. The sensors are integrated using a Microchip dsPIC microcontroller. The system uses an application of the direction cosine matrix attitude solution pioneered by William Premerlani, PhD. A direction cosine matrix (DCM) is a transformation matrix that transforms one coordinate reference frame to another – in this case, one for the rocket and one for the earth.

The device has two jumpers that are used to easily configure the critical angle for allowing or inhibiting motor ignition. Also included are LEDs and a piezo-electric buzzer to provide feedback to the user of the system status during startup and pre-launch conditions.

Using the on-board accelerometers, which are primarily used to calibrate the gyroscopes, the ROCKETILTOMETER is also able to detect a launched condition, at which point the accelerometers are disabled and the system relies exclusively upon the integrated gyroscopes to monitor flight attitude – a typical accuracy of <1% error is achieved. Rocket longitudinal axis (z) spin rates of up to 1000 degrees per second do not affect tilt calculations.

The ROCKETILTOMETER can connect to and interrupt an ignition trigger signal from any manufacturer's external device, such as a flight computer, a timer, other sensor systems, etc. of up to 12 amps at 12.5 volts for a period not exceeding 2 seconds (non-inductive load). The ignition circuit's electrical integrity is unaffected by connection to the ROCKETILTOMETER 3, so any circuit features of the user's device, such as continuity checks, are transparent and will report as designed by the user device.

On-board diagnostics are performed on various portions of the system at startup and the user is alerted and the system will go off-line if something is amiss. After initialization and system checks, if all is well, the system will sound beeps one time to indicate the selected critical angle, and then begin a set of repeating chirps to let the user know that it is in the launch-ready mode. Any ignition circuit integrity checks are to be performed by the user's connected device.

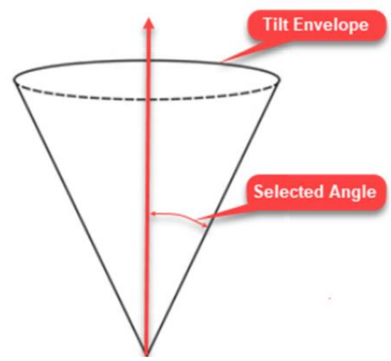
While the rocket is sitting vertical on the pad – we recommend a minimum period of *five minutes* to achieve specified accuracy - the on-board accelerometers are continuously calibrating the gyros for tilt detection. Once launch is detected by the accelerometers, they will be shut off and the tilt detection will rely on the system gyros. For the previous version, the ROCKETILTOMETER 2, a 3-axes magnetometer was implemented to achieve a spin-rate tolerance of up to 540 degrees per second. With the advent of the new ROCKETILTOMETER 3, without the use of a magnetometer, rocket spin rates about the vertical axis (z) of up to 1000 degrees per second will not appreciably impact the accuracy of the tilt monitoring calculations.

OPERATING MODES. When we developed the first RockeTiltometer (RTOM), the goal was to provide a new tool to the model rocket hobby that would assist in maximizing the altitude gained from staged flights. By monitoring the tilt angle, or deviation from vertical, and triggering ignition just before the tilt began to quickly increase, we could allow the rocket to slow down as much as possible prior to ignition. By doing so, we could optimize the altitude by minimizing the aerodynamic drag on the rocket before starting the sustainer motor. This proved a bit daunting in practice, though still useful in principle.

What became quite clear however was another potential use for the RTOM as a safety device to inhibit sustainer (or any air-started motor) ignition in the event of excessive tilt. Additionally, for the high-flyers, aborting the sustainer or air-start might largely reduce or minimize a long trek out for recovery, or even rocket loss, if the rocket's trajectory was tilted quite a bit. The RTOM1 and RTOM2 were developed with this goal in mind. Safety has always been the prime consideration for the RockeTiltometer devices. The RTOM2 was successful because it performed well in its role of tilt monitoring, but also due to the designed in safety features that made it virtually foolproof and failsafe at the launch pad for the user.

The accuracy and reliability of the RTOM2 is known throughout the hobby, but it has been several years since a RockeTiltometer has been available for sale. With ever more advancement on the electronics front, and some new refinements and developments to our tilt-engine firmware, we decided it was time to release another version. The goal for the latest device, the RTOM3, is the same – safety. However, since access to a tilt monitoring device has been largely out of the reach of many flyers due to cost, a secondary goal for us was to be able to offer a high performance device at a much lower cost. In addition, we designed the RTOM3 to be able to work with any ignition triggering devices, such as a timer, altimeter or flight computer. We feel the RTOM3 accomplishes all those goals while adding some new features and twists for the flyer.

Operating Modes. The difficulty when relying on a tilt monitoring device is having an unknown factor that we do not have any real control over – the time-to-pressure (TTP) of the air-started motor. The TTP is the amount of time it takes from the application of the ignition pulse to the time the motor reaches its designed initial thrust. This period can run from less than a second to several seconds. Even if the rocket is within the *tilt envelope* (see Figure 1.) when ignition is applied, it can be out of the envelope by the time the motor pressures up. One way flyers combat this problem is to limit the selected tilt angle. The downside of this is that it may turn out too conservative for a rocket that flies well but creeps outside the envelope.



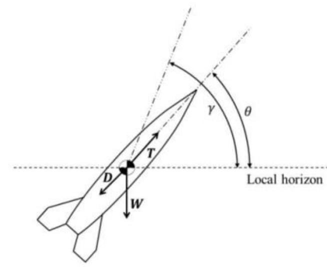
1. Tilt envelope derived from the selected tilt angle.

Another issue with tilt monitoring devices is what to do with a rocket that goes outside the envelope, but returns inside prior to the ignition call. With the RTOM2, we designed it such that if the rocket ever exceeded the selected tilt angle, ignition was disabled for the remainder of the flight. We felt that if a rocket was showing adverse attitude, it was unpredictable and so we took the safest route. Unfortunately, that caused some flights that turned out to be OK not to light the air-start motor – e.g., sometimes a rocketeer’s rocket “kicks” off the rail, but returns to relatively straight flight afterwards. So, with RTOM3, we have added a couple of features that may help with such flights, while still retaining a good margin of safety.

The RTOM3 has added new operating modes in addition to the basic *abort* mode noted above, i.e., inhibiting ignition for the rest of the flight should the rocket exceed the selected tilt angle. We have added a *reentry* mode. If the rocket should exit the tilt envelope, but later return prior to the ignition pulse, the ignition circuit will be re-enabled after a short delay. With this feature enabled, those “kicking” rockets that regain stability may still ignite their air-starts.

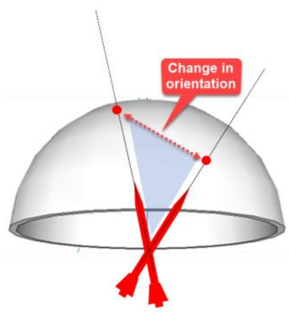
We are also introducing yet another innovation to the model rocket hobby – *motion monitoring*. With motion monitoring, we use the systems sensors to constantly assess the rate of change to the rocket’s tilt and bearing, or more simply, its rate of change in orientation. Motion monitoring can be used together with either the abort mode or the reentry mode.

Motion Monitor. If a rocket were flying in a 2-dimentional environment (see Figure 2.), tracking its rate of tilt change would give us some sense of its stability, and, some notion of whether we could expect it to remain at less than the selected tilt angle long enough to ignite the motor and have it come up-to-pressure. Unfortunately, our rockets fly in a 3-dimensional world (see Figure 3.), making tracking their change in orientation much more difficult to calculate. A rocket's attitude and bearing can move a lot more than just tilting in such a 3D environment.



2. Rate of tilt change.

However, the RTOM3, through some high-powered math working on the raw sensor data from the 6DOF IMU, is able to track such changes. Based upon those changes, we have a better idea of how much energy or rate of change is going into that movement in a given period of time. Using this rate of change information, we gain some idea of the likelihood the rocket will stay inside the tilt envelope. If that motion is relatively high, we can disable ignition even if the rocket is still inside the tilt envelope – i.e., we can anticipate whether it is heading towards an excessive tilt state.



3. Orientation change (exaggerated).

Of course, it is still risky business since the time to pressure for any rocket motor is fairly unpredictable. The type of igniter used, the composition of the propellant, the specific placement of the igniter, the ambient weather, the barometric pressure, and other factors can all change this timing, making any prediction very difficult. But at least through motion monitoring we have additional information and the user can select to use the motion monitoring feature if they feel it will be useful for any specific flight.

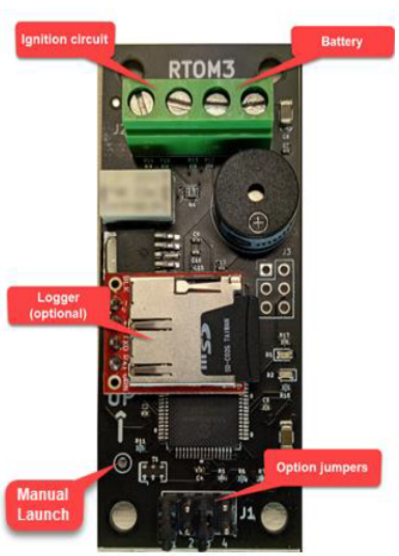
Note - As with all flights where a motor does not ignite, use proper caution during maintenance or recovery to assure there is no danger to yourself or the surrounding environment.

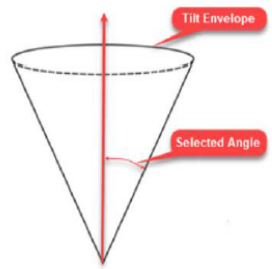
RTOM3 OPERATING MODES SUMMARY CHART

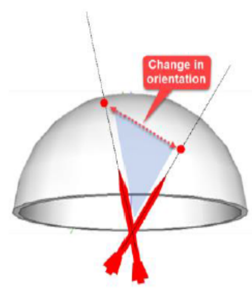
RTOM3 OPERATING MODES

CONSERVATIVE	Selected Angle*	JUMPER 1	JUMPER 2
MOST	10		
↑	15		X
↓	20	X	
LEAST	30	X	X

CONSERVATIVE	JUMPER 3	JUMPER 4	MODE
MOST			1 - ABORT WITH MOTION MONITORING
↑		X	2 - ABORT
↓	X		3 - REENTRY WITH MOTION MONITORING
LEAST	X	X	4 - REENTRY







Selected Tilt Angle
The angle from vertical that, if exceeded, will always cause ignition to be disabled.

Tilt Envelope
A cone defined by the Selected Tilt Angle.

Abort Mode
Once the rocket's attitude exceeds the Selected Tilt Angle, ignition is disabled througout the rest of the flight.

Reentry Mode
When the user selects one of the Reentry modes, if the rocket should exceed the Selected Tilt Angle, ignition will be disabled as long as the rocket remains outside of the Tilt Envelope. Should the rocket reenter the Tilt Envelope, ignition will be re-enabled after a reentry-delay.

Motion Monitoring
When the user selects to apply Motion Monitoring, the system microcontroller collects data from the system sensors to continuously calculate and assess the rate of change to the rocket's orientation, as illustrated in the exaggerated example to the left. If the motion associated with that change is excessive, ignition will be disabled until such time that the motion has moderated, as long as the rocket remains inside the Tilt Envelope.

Note: If you chose to employ the Motion Monitor, pay very careful attention to your mounting of the RTOM3 - keep the RTOM3 aligned as closely as possible with the longitudinal (Z) axis of the rocket.

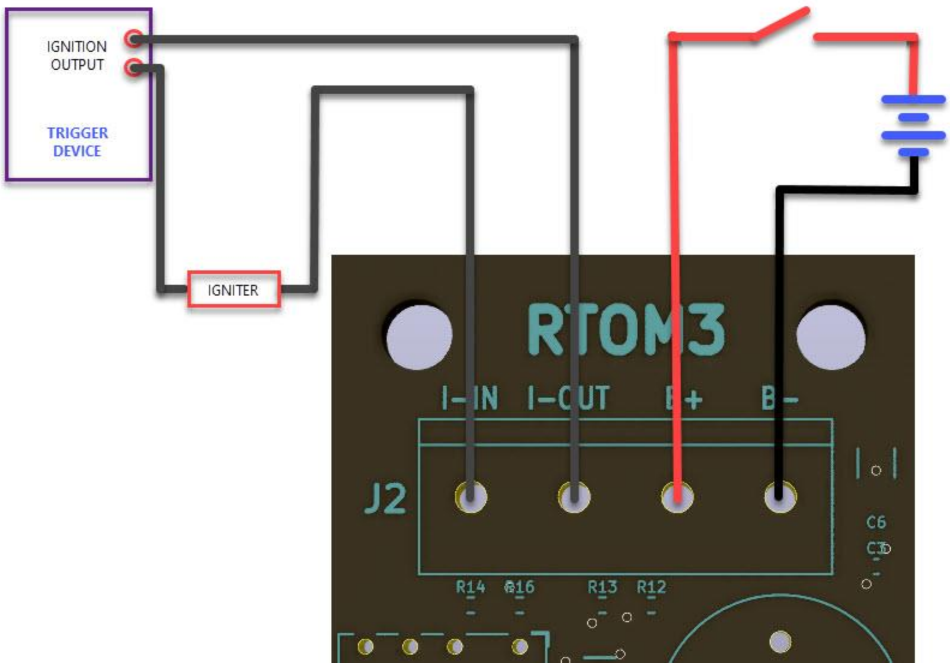
* Allow a minimum of five minutes warmup time after first powering up the RTOM3 to allow the gyros to calibrate.

8/12/2021

Table shows the various operating modes for the RTOM3 and how to configure the jumpers to enable any particular feature...

CONNECTIONS AND TEST POINT

TERMINAL BLOCK J2 - MAIN POWER AND IGNITION-INTERRUPT



Connections to the RTOM3 are straight-forward:

B+ and B-: connect your battery here…observe polarity…input voltage: minimum 5 volts, maximum 20 volts…average current drain is 120 mA…note – you may use your trigger device battery for the RTOM3, just be sure to observe the requirements listed here…a 2S LiPo battery (7.6 volts) is ideal…

Note: The RTOM3 is a relatively high current draw device (average 120 mA) – be sure to size your RTOM3 battery's capacity appropriately for your particular flight conditions, including the expected waiting time while system is active on the launch pad prior to the actual launch! A fresh 9-volt alkaline battery should last a minimum of 2-3 hours.

Note: The RTOM3 uses a terminal strip designed to accept a wide variety of wire (from 30 up to 12 gauge wire) – be sure that your connections a snug – give your wires a good tug!

I-IN and I-OUT: connect ***ONE*** leg of your trigger device's ignition output to these terminals, i.e., in/out – see diagram above…polarity is not important…your ignition output through the RTOM3 is limited to 12 amps at 12.5 volts, for a period of less than 2 seconds (two high-current, 5-6 amps each igniters, such as *Rocketflite's MagneLite* series test okay)…

Ground test your battery(s), switch wiring and igniter combination to assure they are functional and the igniter of choice will fire with the battery and ignition circuit wiring of choice.

Be sure your ignition battery is of sufficient capacity to handle the required igniter current pulse, not to exceed the specifications above

Be sure your batteries are at full capacity prior to flight by testing with a meter.

Always check for proper resistance of your igniter prior to connecting to the ignition circuit.

If a continuity test is provided during startup of your triggering device to detect the presence of your battery and igniter, the RTOM3 will not in any way affect those tests once it is upright and operating normally

Use wiring of a proper gauge for your ignition circuit switches, battery and igniter to assure minimum voltage drop.

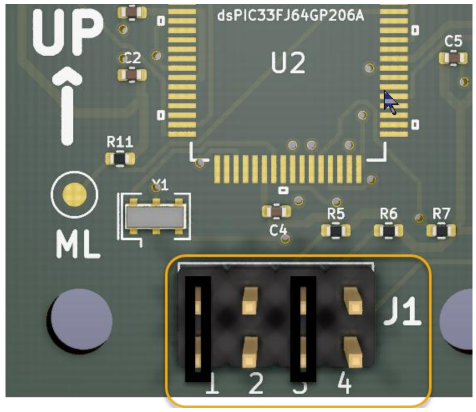
Follow the proper ignition arming sequence for your system triggering device

Do not use an inductive load

If the audible toner is indicating constant repeating beeps or no beeps at all, do not continue – the system has malfunctioned and you must troubleshoot before continuing your launch procedure.

ALWAYS GROUND TEST YOUR SYSTEM PRIOR TO LAUNCH!!

J1 - CRITICAL ANGLE AND OPERATING MODE SELECTION JUMPERS



Use the following table to select an angle between 15 and 30 degrees (**ON** means one of the included jumpers is placed over the respective pin (lower row) and the GROUND pin directly above it)

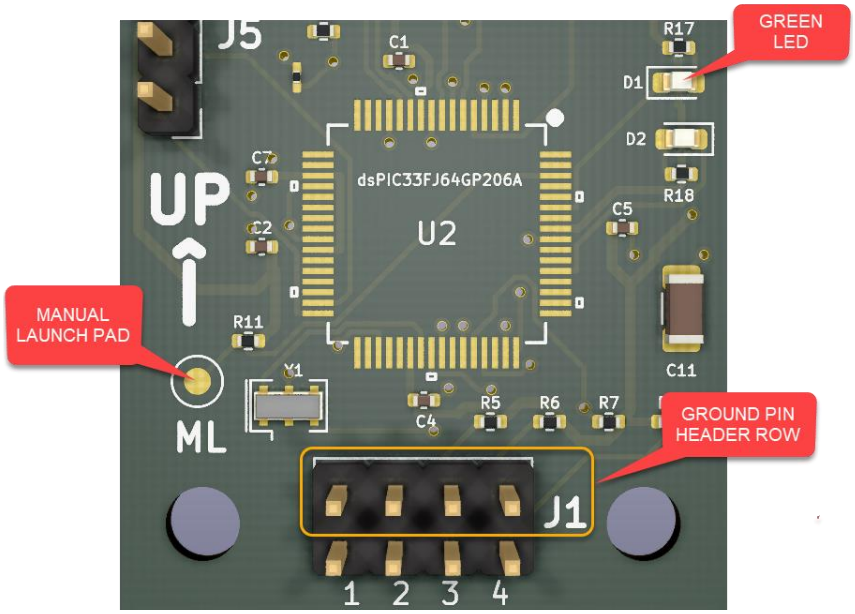
Angle in degrees	PIN 1	PIN 2
10	**OFF**	**OFF**
15	**OFF**	**ON**
20	**ON**	**OFF**
30	**ON**	**ON**

Use the following table to select the Operating Mode – see elsewhere for definitions of the Operating Modes available (**ON** means one of the included jumpers is placed over the respective pin (lower row) and the GROUND pin directly above it)

JUMPER		MODE
3	4	
		1 - ABORT WITH MOTION MONITORING
	X	2 - ABORT
X		3 - REENTRY WITH MOTION MONITORING
X	X	4 - REENTRY

Note: As an example, in the jumper diagram at the top of the page, the Critical Angle is set to 20 degrees and the Operating Mode has been set to REENTRY with Motion Monitoring.

TESTPOINT ML - MANUAL LAUNCH



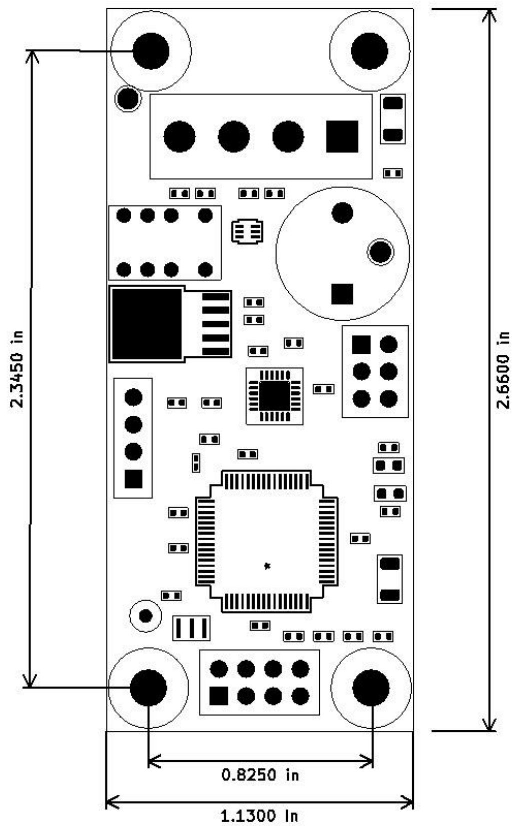
For test purposes, *momentarily* shorting this pad to a system GROUND point, such as a header terminal pin (upper row of pins on J1) will manually create a launched condition in the RTOM3. Note that the green LED will extinguish as an indication that the RTOM3 is in *launched* mode…

FOR GROUND TESTING ONLY! DO NOT LEAVE PAD SHORTED AFTER TESTING

USING THE ROCKETILTOMETER 3

MOUNTING

THE ROCKETILTOMETER MUST BE MOUNTED WITH THE SILK-SCREENED ARROW IN THE LOWER LEFT-HAND CORNER POINTING TOWARDS THE NOSECONE AND ALIGNED WITH THE VERTICAL AXIS OF THE ROCKET.



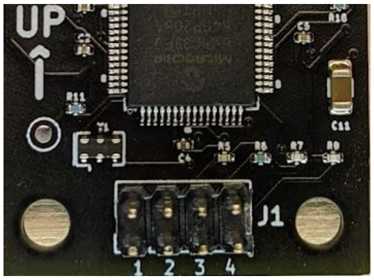
Though not critical, the closer the ROCKETILTOMETER's sensors are to the lateral-middle of the airframe the better.

Notes:

- The RTOM3 can slip fit (snuggly) into a 29mm airframe.
- Use 4-40 or M3 hardware.
- *If you are going to use the motion monitoring feature, closely aligning the RTOM3 along the vertical (the Z or longitudinal axis) axis is important for accuracy!*

CONFIGURATION AND OPTIONS

CRITICAL ANGLE



There are two jumpers at the bottom of the circuit board. You must select a desired tilt angle *prior* to starting the ROCKETILTOMETER – the choices are from 10, 15, 20 or 30 degrees from vertical.

Once the initialization and calibration process has begun, the ROCKETILTOMETER will ignore any changes to the selection jumpers. If you determine that you have selected a wrong angle, you must turn the system off, re-select the angle, and then re-start the system.

Angle in degrees	PIN 1	PIN 2
10	OFF	OFF
15	OFF	ON
20	ON	OFF
30	ON	ON

Shortly after the ROCKETILTOMETER is started and finishes its calibration routine, if all is normal, it will sound a *one-time* set of beeps to indicate what angle you have selected. The beeps will sound one long for each ten degrees – e.g., if you selected 20 degrees, you will hear two long beeps; for 30 degrees you will hear three long beeps, as so on. For the 15 degree angle selection, you will hear one long and one short beep. Pay attention at startup to the beep sequence to be sure you have the correct jumpers selected. *It only sounds once at startup.*

Again, if you hear a series of angle beeps that is inconsistent with what you desire, you cannot re-select while the system is still running – you will need to power down, check and re-select the proper jumpers and then power up again.

OPERATING MODE

Use the following table to select the operating mode prior to startup:

JUMPER		MODE	CHIRPS
3	4		
		1 - ABORT WITH MOTION MONITORING	1
	X	2 - ABORT	2
X		3 - REENTRY WITH MOTION MONITORING	3
X	X	4 - REENTRY	4

Once the sequence of angle selection beeps ends (see above), there will be a short silent period.

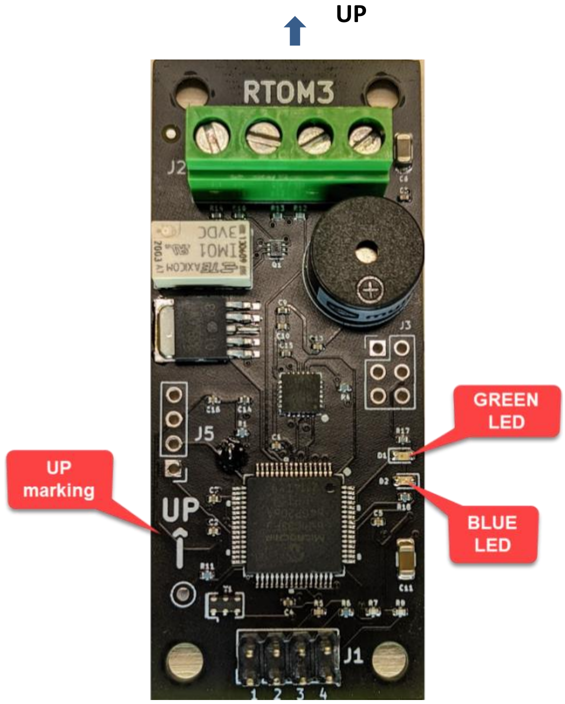
The toner will then sound a series of “heart beat” chirps, based on the selected operating mode, indicating the system is ready for launch, per the table below. These chirps will re-sound every 5 seconds.

SYSTEM MALFUNCTION WARNING

If the system determines something is wrong at startup, rather than sound the selected angle one time, and then the heartbeat chirps (see below) every five seconds, it will immediately discontinue its processing and sound a steady on/off series of beeps until powered down. In that event, shut down the RTOM3 and troubleshoot your system.

ORIENTATION

The ROCKETILTOMETER has been designed to operate in a specific orientation, with the arrow on the upper board pointing in the direction of the nose of the rocket, or the vertical axis. The mounting holes are arranged to mount the device in a typical electronics bay in a similar fashion as the typical flight computer on a vertical sled.



> *Note – if you intend on using the Motion Monitoring mode, be sure to pay attention to how you align the RTOM3 when mounting – for best accuracy, it must align with the longitudinal (vertical) axis of the rocket as well as possible…*

You can apply power to the RTOM3 when the board is sitting other than vertical, such as when the rocket is sitting flat in the rail prior to elevating it to launch position. However, once the board is powered up and prior to actual launch the rocket should be placed at your desired launch angle (somewhere inside the selected critical angle) and remain steady. You should leave the rocket in this position for ***at least five minutes.*** Obviously, the board must be positioned within the tilt envelope to be sure it does not launch in a lockout condition

> *Again, after applying power, the RTOM3 should remain stationary in the launch position for at least five minutes in order to give the firmware time to tightly calibrate the gyros.*

Until launch is detected (either an actual launch or a manual launch generated by grounding the test pin ML for ground testing), the accelerometers are used to provide the correct reference for the calibration. Once launched, the calibration is concluded and the accelerometers are removed from the process. At that point, the gyros become the reference to vertical and any orientation changes.

LEDS

BLUE LED. Prior to a launched condition, once the ROCKETILTOMETER has been allowed to calibrate, when you tilt the device and exceed the selected *critical angle,* the BLUE LED will turn off. When you return to an angle less than the critical angle, the BLUE LED will turn on. This can be repeated indefinitely and is a good way to see just how the ROCKETILTOMETER is working.

Once launched, the BLUE LED will indicate the condition of the ignition circuit: ON indicates ignition enabled…OFF indicates ignition disabled.

GREEN LED. The GREEN LED will turn ON after system initialization and stay on until launched condition is sensed (either by temporarily grounding the ML pad, or after actual launch), whereby it will turn OFF and stay off for the rest of the flight.

For additional testing purposes, it will, prior to launch, also turn OFF any time the board is tilted more than 50 degrees.

BEEPER TONES

NORMAL INITIALIZATION

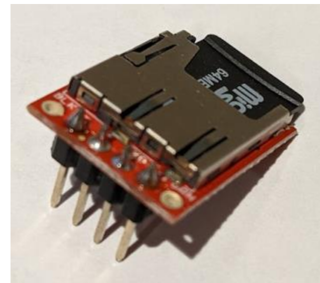
At startup you will hear a series of tones coming from the on-board beeper:

- Once the system initializes (approximately 1-2 seconds), you will hear a *one-time* series of tones indicating the selected ***critical angle*** – one long tone for each 10 degrees of angle and one short for 5 degrees.
- Then, after a short pause, the pad-ready operating mode "heartbeat" chirps will sound *every five seconds* – these chirps will continue until a launched condition occurs.

ABNORMAL INITIALIZATION

If the system determines something is wrong at startup, rather than sound the selected angle one time, and then the heartbeat chirps (see below) every five seconds, it will *immediately* discontinue its processing and sound a steady on/off series of beeps until the RTOM3 is powered down. Shut down the RTOM3 and troubleshoot your system.

APPENDIX A - DATA LOGGER

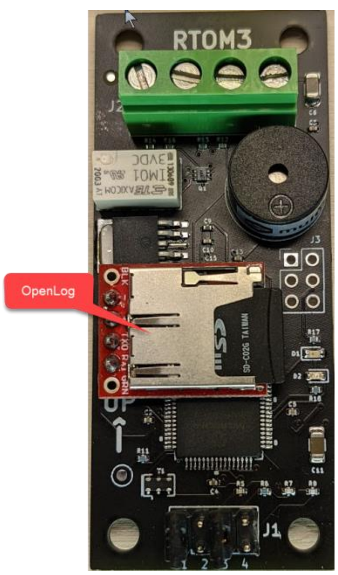


The optional OpenLog data logger (available separately at Rocket-Electronics.com) allows you to record various aspects of your flight. The logger utilizes a microSD card and will record flight events from liftoff to a point 120 seconds into flight, in 0.1 second intervals. If you get the logger from Rocket Electronics, it will have the header pins already soldered.

You will need to furnish a microSD card and format/configure it as described below. Most any card should work up to 32GB – but be sure to ground test it! Note that the log file records for two minutes after launch is detected and runs about 210KB in size, so even a 1GB card will record thousands of flights.

The microSD card can be formatted and read by virtually any card reader – a micro-to-mini-SD card adaptor may be needed. Format it with the FAT32 file system (usually cards are shipped with that format) – format with iOS, Windows or LINUX.

Configuration file. You may need to change one of the parameters in the ***config.txt*** file that the OpenLog places on the microSD card the first time you use the newly formatted card – if you have trouble after the first or second time you try to log to the card, be sure the content of the ***config.txt*** file looks like the example at right:




```
19200,26,3,0,1,1,0
baud,escape,esc#,mode,verb,echo,ignoreRX
```

The first term of the ***config.txt*** file, *19200* (the baud rate), may need to be changed (default is 9600) – you can use any ASCII text editor, such as Microsoft Notepad, to edit and replace the file. **Be sure to ground test the logger prior to any flights!**

Each time the ROCKETILTOMETER initializes and begins to send data, a new file will be created on the card (existing files remain unless manually deleted by the user). The files are serialized with a file number when written to the card, but are not timed stamped, so you may want to erase any existing files on the card prior to each flight to avoid confusion.

Once you have used the logger, you can place the microSD into a card reader and open the file in any text editor such as Windows Notepad. This is an example of the output:

```
FW: 0.90, VRR: -28 , Flt_Time:   1.2
Mode: Reentry-Motion , State: Motion On , Launched: 1
Excess Tilt: 0 , Excess Motion: 0
Crit_Angle: 15 , Cur_Angle: 5.4 , Ign_Disabled: 0

FW: 0.90, VRR: -73 , Flt_Time:   1.3
Mode: Reentry-Motion , State: Motion On , Launched: 1
Excess Tilt: 0 , Excess Motion: 1
Crit_Angle: 15 , Cur_Angle: 9.6 , Ign_Disabled: 1

FW: 0.90, VRR: -1023 , Flt_Time:   1.4
Mode: Reentry-Motion , State: Lockout , Launched: 1
Excess Tilt: 1 , Excess Motion: 1
Crit_Angle: 15 , Cur_Angle: 36.4 , Ign_Disabled: 1

FW: 0.90, VRR: -1023 , Flt_Time:   1.5
Mode: Reentry-Motion , State: Lockout , Launched: 1
```

FW: - indicates firmware version

VRR: – vertical roll rate (around the longitudinal (Z) axis)

Flt_Time: – time from launch to 120 seconds after launch in 0.1 second increments

Mode: - the selected operating mode

State: - the current tilt-engine action

Launched: - flag, indicates rocket launched

Excess Tilt: - flag, rocket has exceeded selected angle and is outside the tilt envelope

Excess Motion: - flag, motion monitoring threshold has been exceeded

Crit_Angle: - selected critical angle

Cur_Angle: - current rocket tilt angle

Ign_Disabled: - flag, ignition circuit has been interrupted and ignition inhibited due to excess tilt or excess motion

APPENDIX B - CHECKLIST (EXAMPLE ONLY - YOUR SITUATION MAY DIFFER – USE A CHECKLIST!)

1. Pre-launch
    a. Mount the RTOM2 in your e-bay so that it will be vertical (arrow up) with respect to the longitudinal or Z axis of the rocket.
        i. Note: if you plan to use Motion Monitoring, this alignment needs to be done with care for best performance.
    b. Select appropriate type and rated batteries for each device in your system – do not exceed 12.5 volts for the ignition circuit.
    c. Select the critical angle you wish to use – use Jumpers 1 and 2, located at the bottom of the RTOM3, to change the desired critical angle if necessary.
    d. Select the operating mode you wish to use using Jumpers 3 and 4.
    e. If you are using the *optional* data logger, make sure you have a formatted microSD card in the logger socket – the card included from the factory has been pre-formatted.

After having configured and connected the ROCKETILTOMETER and your triggering device, do a thorough ground test - **be sure the terminals are snug on your wiring** – give them a good tug. You are ready to go launch!

USE CAUTION WHENEVER ATTACHING MOTOR IGNITERS TO TRIGGERING DEVICE(S)!!

- Make all your standard airframe/electronics pre-flight inspections
- Once you have the rocket on the rail, upright* and ready to go:
    - Turn on the ROCKETILTOMETER system power and listen for the appropriate audible tones:
    - A few seconds after you apply power to the ROCKETILTOMETER, its beeper will indicate the critical angle with a number of beeps (one long for each 10 degrees and one short for 5 degrees of critical angle), go silent for a bit, then sound repeating chirps every five seconds indicating operating mode – these "heartbeat" tones will sound until launch is detected

If the sounder is not sounding 1, 2, 3, or 4 chirps (dependent upon selected operating mode) at this point, power all systems down and investigate the issue/malfunction before proceeding

- Note, if there is a problem with the RTOM3, once started, it will not sound the critical angle beeps, but rather immediately start sounding a continuing series of steady beeps – if you hear this indication, *DO NOT* continue your flight

** Note: you can apply power to the RTOM3 in a non-vertical position, such as horizontal on the rail prior to raising your rocket for launch (not recommended for safety reasons)*

- *If you should choose to start the RTOM3 in such a manner:*
    - *Note that the ignition circuit will be enabled briefly (approximately 1 second) during RTOM3 initialization for system integrity checking*
    - *Once initialized, the RTOM3 ignition circuit is disabled if the rocket is tilted outside the tilt envelope*

  - *Once initialized, the RTOM3 ignition circuit will be enabled when you raise the rocket to inside the tilt envelope for launch*

- Power your rocket's deployment/recovery electronics and make sure all is well
- Power your air-start triggering device and make sure all is well, including a check to be sure no ignition power, or igniter, is present on the triggering output circuit
- Assuring there is no ignition power on your triggering device output circuit, connect the igniter for your air-start motors(s) to your triggering device and confirm continuity check if available
- Verify there is no power on the launch pad booster ignition circuit
- Connect your booster igniter and make continuity check as appropriate
- *Be sure to allow at least 5 minutes once the rocket is upright/vertical in order to properly calibrate the gyros*
- System is now ready to launch – clear the launch area - Have a great, straight flight!

Have a great flight!!

APPENDIX C - SPECIFICATIONS

Power application:

System power source: Max: 12.5 volts* Min: 5 volts

Ignition power source: Max 12.5 volts DC @ 12 amps for <2 seconds, non-inductive load

OBSERVE POLARITY!! ***GROUND TEST ALL APPLICATIONS!!***

System electronics current draw:

Average ~120 mA

Gyro drift:

Zero

Gyro Cross-coupling

Maximum 5%, typically <2%

Maximum acceleration range for rated operation:

Tested to >40 g vertical, >27 g lateral

Maximum rocket spin rate about the Z-axis for rated accuracy:

1000 degrees per second

Internal launch detection:

Accelerometer based at launch or via a pad on the board for manual testing

Size:

2.66"H (68mm) x 1.13"W (29mm) x 0.5"D (13mm)

Weight:

0.6 oz. (170 grams)

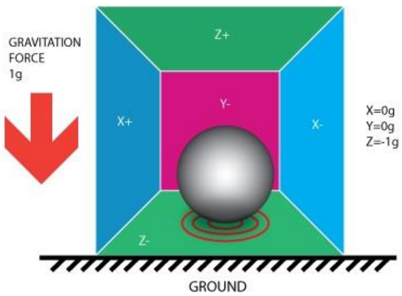
Operating range:

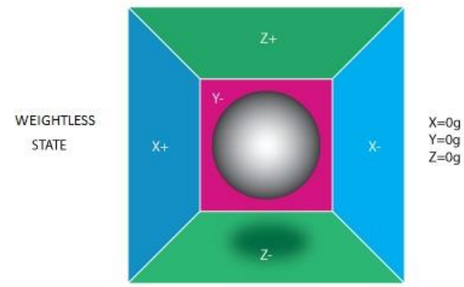
0-85^{o} C

APPENDIX D - THEORY OF OPERATION – TILT MONITORING IN MODEL ROCKETS

Most of the tilt sensors that you may be familiar with rely on earth's gravity as a reference. Usually there is some form of an accelerometer at play. Such devices will not work in a rocket while the motor is under thrust or under coast after motor burnout. Under thrust, the rocket experiences a "g" load greater than 1 (earth's gravity) as it accelerates, and under coast it experiences a g load less than 1 as is slows down. Accelerometers, the typical earth-bound tilt sensors, rely on the 1 g of earth as a reference to work properly.

Acceleration due to gravity with the rocket stationary on the pad, and acceleration while in flight are indistinguishable to an accelerometer and therefore cannot be used to determine the tilt. Once the rocket launches, an accelerometer placed in the rocket no longer has gravity as a reference - it will react to any acceleration or deceleration experienced as a result of the rocket's motion.



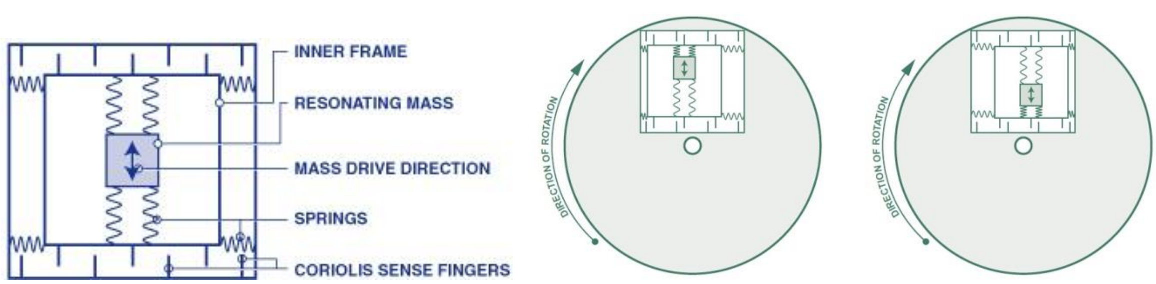


A few non-gravitational-based alternatives exist to act as tilt sensors, such as magnetometers, thermopiles or GPS devices, but the gyroscope offers the most effective solution.

A gyroscope uses the principles of conservation of angular momentum in order to determine orientation. You may be familiar with mechanical gyroscopes; however the ROCKETILTOMETER USES electronic gyroscopes – a device called a MEMS gyroscope.

Inside the MEMS chip is a plate called the *proof mass*, which vibrates when a drive signal is applied to a set of drive capacitor plates. When the rocket rotates about any axis, the proof mass gets displaced along that axis by the Coriolis force. The displacement is recorded through use of the capacitor plates which are mounted under the proof mass and passed along to the system microController.

The ROCKETILTOMETER uses the three MEMS gyros and some calculations processed by the system's microController to provide a reliable, accurate monitoring of the rocket's tilt.



APPENDIX E - PRECAUTIONS

Important Safety Precautions

Checklist - Use a checklist when you set up the ROCKETILTOMETER and your flight computer(s)/timer(s) and when mounting in your rocket and at the launch pad

Dangers from ejection charges - Make safe the ejection charges, or disconnect the power whenever you transport the flight-prepped unit.

Electrostatic discharge - Static electricity may damage or destroy components in your ROCKETILTOMETER. Keep it in an antistatic bag when not in use. Ground yourself before handling it and any other associated electronics. Be especially cautious when using it in low humidity environments.

RF interference – The ROCKETILTOMETER has been found to be relatively immune to RF interference, but like all other potential influences to proper operation, the user should ground test the device in a similar RF environment as that expected at the launch site to assure any such source does not interfere with the operation of the RockeTiltometer or any of the associated electronics in the user's project.

Mount the ROCKETILTOMETER in the correct orientation in your e-bay - otherwise it will not operate properly. The nose up end is indicated on the board with a large arrow. If using Motion Monitoring, be sure the RTOM3 is aligned properly along the longitudinal axis for best accuracy.

Make sure the ROCKETILTOMETER is firmly installed in the rocket payload bay.

Protect the ROCKETILTOMETER from ejection gasses - Ejection gasses are corrosive and will damage the unit. Ejection gas damage will void your warranty.

Use good batteries - If you are using non-rechargeable batteries, we recommend using Duracell brand. Because many lower-cost batteries have press-fit contacts, vibration and sudden acceleration might cause them to come loose, resulting in a momentary or permanent break in your power connection. Losing power will result in a fail-safe condition, i.e., the ignition circuit will open and ignition will be prevented. Do not overcharge any re-chargeable batteries – this can lead to overheating and possible fires.

Make sure your batteries are properly secured to prevent them from pulling wires out of the terminal block pins and always use good quality battery connectors.

Recommended Battery Sizes:	**Minimum**	**Optimum**	**Maximum**
RTOM3 System	5 volts	7.4 volts	12.5 volts
Trigger device ignition	n/a	n/a	12.5 volt DC, non-inductive load

Standby - After arming the system and bringing the rocket to vertical, allow at least 5 minutes to pass prior to altering its orientation/launching the rocket.

Ground testing – Always ground test all system components to assure proper form, fit and function.

Beeper feedback - Once the sequence of beeps ends at system initialization, there will be a short silent period, and then the toner will sound one to four chirps indicating the operating mode and that all is well with the system. If the chirps are not sounding, something is wrong and you must stop and trouble-shoot the system – DO NOT LAUNCH!

Recovery sizing – Keep in mind that in the event of aborted ignition, the descending rocket will weigh much more since the engine propellant will not have been consumed – adequately size your recovery scheme to allow for this potential situation.

NOTES: