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VMP 5500/6000 Release Logic

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Product reference: VMP5500/6000 Deep Ocean Profiler

Introduction

The purpose of this document is to explain the logic used to release the weights on the VMP 5500/6000 deep ocean profiler. This instrument has no connection to the ship and falls freely under its own weight. It returns to the surface by dropping 2 steel (or lead) weights that render the instrument buoyant. The release logic or trigger action is highly redundant to assure the return of the instrument.

The release mechanism is activated whenever one or more of the following conditions is satisfied.

1. Pressure > Max_ Pressure — user specified and software controlled.
2. time > Max_time — user specified and software controlled.
3. Pressure > 100 dBar AND dP/dt < 0.2 dBar / s — software controlled.
4. Power off or Main Battery dead — release firmware controlled.
5. time > 214 s ~ 4.5 hours since power on — release firmware controlled.
6. Corrosive link breaks apart — uncontrolled chemical reaction.

Overview

The release mechanism consists of electrical and mechanical components. The weights are held tightly against their brackets on the side of the instrument by a line under spring tension. One end of the line is retained by an electro-mechanical solenoid. When the plunger in this solenoid is moved (by energizing the solenoid coil) the restraint is removed and the weights fall out of their holders. The mass of each release weight is approximately 6.4kg. Dropping the weights gives the instrument about 50 N of buoyancy, depending on the actual configuration of the instrument.

The coil in the solenoid is energized by the release board (P031), which is located inside the instrument. An underwater connector on the aft bulkhead of the instrument pressure case and an underwater cable connect the release board to the solenoid.

The power to activate the solenoid comes from a small 6V gel-cell battery that is dedicated exclusively to the release board. This battery is continuously charged by the main battery in the instrument whenever the instrument is turned on. The electronics on the release board operate from the dedicated 6V battery, and this battery is blocked by a diode from sending any current into the rest of the instrument system.

A logic signal line connects the release board to the Universal Transceiver board (UTRANS, P026) in the instrument, which itself is connected to the PC104 computer (inside the instrument) via a USB link. The logic signal from the UTRANS is optically coupled to the release board. All electronics in the VMP are galvanically isolated from the main and release batteries and from the release board. In addition, neither battery has any connection to the instrument case or seawater. Thus, there is no current path from the solenoid to the instrument, even if the electric cable to the solenoid is damaged and shorted to seawater.

Logic

There are 6 conditions that can cause the release to activate. Three of these conditions are detected by the data acquisition software on the PC104 computer. The PC104 signals the release board when any one of these conditions occurs. This is a software triggered release. Two more conditions are detected by the firmware on the release board. This firmware triggered release is a backup in case the computer fails to function properly or the user has improperly configured the software. The final condition is the chemical dissolution of a corrosive link in the line that binds the weights to the instrument.

Software-Triggered Release Logic

Two of the three software triggers are under the control of the user through the setup file on the PC104 computer. This setup file is in ASCII format and can be edited by the user. As an aside, the computer is configured to automatically start the data acquisition after a boot-up (the instrument is turned on) if there is no Ethernet connection to the PC104 computer. The data acquisition software (ODAS4-IR) reads the setup file and looks for the parameters required for the acquisition of data. There are 3 lines in the setup file that are relevant to the release logic.

- One line that identifies the pressure transducer channel (always channel 10) and contains the 3 calibration coefficients that are used to convert the raw integer samples for the pressure channel into pressure in units of dBar (decibars). One dBar is almost exactly 1 m of depth.
- A second line indicates the maximum pressure (in dBar) of the profile and, hence, the release depth.
- A third line indicates the maximum time between the turn-on of the instrument and the release of the weights.

An example of the three lines is shown below.

Channel:	10,Pres,17.1,0.27074,-2.024e-7,0,0,0,0,0
max_pressure:	150
max_time:	10000

In the first line, the pressure channel is identified as number 10, followed by 8 calibration coefficients. Only the first 3 are used by the software, and the remainder are zeros padded out for a total of 8 coefficients to simplify the parsing. Only commas can be used as delimiters. Spaces and tabs are not allowed to the right of the channel number. The next two lines give the maximum time (in seconds) and pressure (in dBar), respectively. Thus, the user can control the maximum depth and the maximum time of a profile.

The user must make sure that these parameters are accurate and sensible. The software calculates one-second averages of the pressure samples and then converts this average into physical units. This makes the release decision somewhat immune to isolated bad values. Further information on the setup file and the data acquisition software is in the ODAS4-IR User Manual which is supplied with every instrument and is also available at our web site.

The third software condition that triggers the release is the rate of change of pressure. If the pressure increases by less than 0.2 dBar per second for 4 consecutive records (essentially 4 seconds of time), **and** if the instrument is deeper than 100 m (P>100 dBar), then the release signal is sent to the release board. Without this release condition, it would be possible for the instrument to sit on the bottom until the maximum time has elapsed. This will occur, for example, if the user misjudged the bottom depth or erroneously set the maximum depth parameter to a value larger than the actual bottom depth. If the instrument reaches the bottom, the rate of change of pressure will fall to zero and the software will signal the release board. To avoid triggering the release while the instrument is on deck, or being hoisted over the side of the ship, or dangling from a line near the surface, the rate of change of depth is ignored until the instrument is deeper than 100 m. This is not a serious restriction because the VMP 5500/6000 is intended for deep profiling (to 5500/6000 m depth). The software release logic is summarized in (Figure 1).

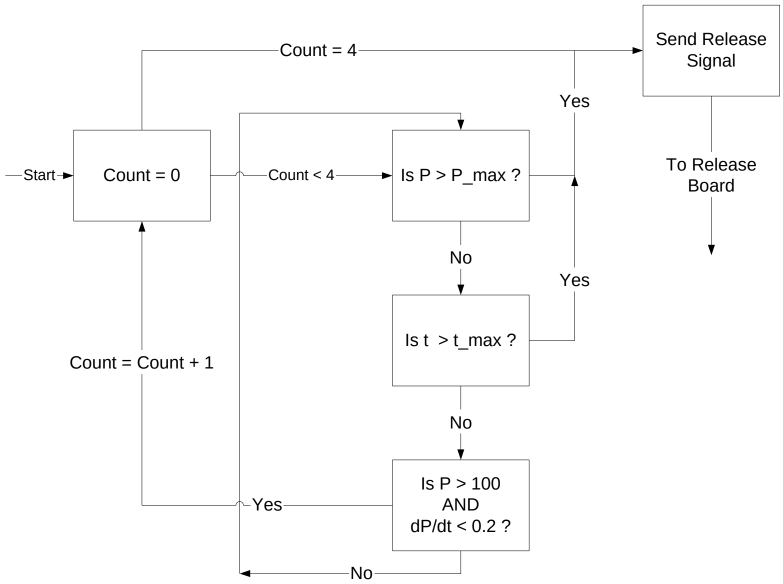


Figure 1. Logic flow chart of software triggered weight release via ODAS4-IR running on PC104 computer in VMP 5500/6000. Pressure and time units in dBar and seconds, respectively.

Firmware-Triggered Release Logic

The release board (P031) provides additional release logic that is independent of the PC104 computer. The release board's programmable logic chip does not rely on an operating system, acts like hardware, and is energized by the dedicated release battery. This firmware logic handles the release signal from the PC104 computer and provides two additional release conditions.

If the main battery power fails, there is no point in further profiling and the release is triggered. If the instrument power has been on for more than 2^{14} seconds (~4.5 hours), which exceeds the maximum duration of a profile to 5500/6000m depth, then the release is also triggered. The firmware release logic is summarized in (Figure 2).

Release Board

The release board monitors the release signal from the PC104 computer. This signal is a single logic bit that is sent from the PC104 computer to the UTRANS via the USB port. The UTRANS passes this signal to the release board via its test point TP7 (P026R00) or connector JP3-2 (P026R01). The release board also monitors the main battery voltage and uses the main battery (12V gel-cell) to maintain the charge on a small (0.5 amp-hour) gel-cell battery that is exclusively dedicated to the release function. This dedicated battery also energizes the firmware logic on the release board. Thus, the release board is always on, even when the instrument has been turned off. A power MOSFET switch on the release board is used to send current from the dedicated battery to the solenoid, i.e to activate the solenoid.

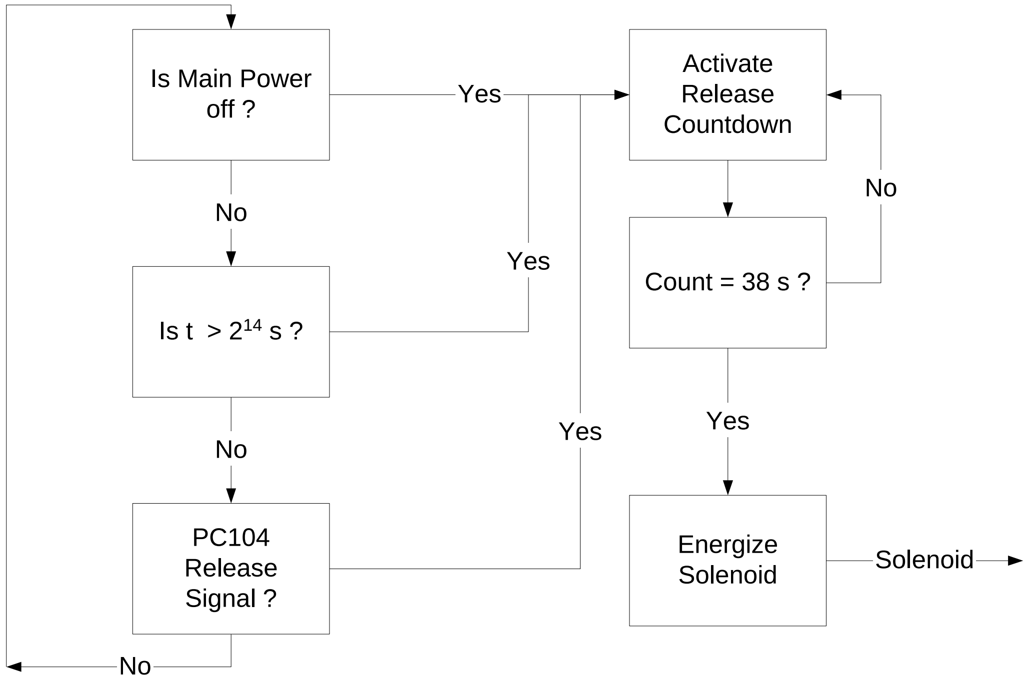


Figure 2. Firmware release logic. Time is in units of seconds.

The release solenoid is not activated immediately after the release board receives a signal. There is a 38 second delay, or countdown, before the solenoid is energized. This countdown is applied to both the software and the firmware release signal. There are several reasons for this "countdown" delay: The conditions that instigate the release might be intermittent. For example, the pressure reading might be erroneous because of a "flyer" in the data stream, or the user might need to momentarily turn-off the instrument for some last-minute servicing before deployment.

However, the most important reason for the countdown delay is the lengthy boot up process for the Linux operating system on the PC104 computer. During most of the boot process the USB port on the PC104 is not energized. Because the UTRANS is energized via the USB cable, the release signal is in a high-impedance state. A pull-down resistor on the release board keeps the signal low to indicate "no release". When the USB port is finally energized, the bit-port used to output the release signal defaults to a "release" value. An additional 10 seconds are required for the ODAS4-IR software to gain control of this bit-port and turn off the release signal. The default state of this bit is set by the manufacturer of the USB chip and completely outside of our control.

If the release signal is removed, the solenoid deactivates immediately and the release board continues to monitor the software and hardware release signals. The software release signal is only removed by terminating and restarting the acquisition software. The firmware release signal is removed by turning the instrument back on (to reverse the battery power failure signal) or by turning the instrument off (to reset the 4.5 hour maximum on-time counter).

Thus, the user must expect the solenoid to be activated 38 seconds after the instrument is turned off unless the release board has previously received a software release signal.

Solenoid Current

After the count down, the solenoid is energized 4 times with a duty cycle of 2 seconds ON followed by 6 seconds OFF. The twenty-five percent duty cycle is used to prevent the solenoid from overheating (it draws 4 amps) and to work the plunger in case it is sticky. After the completion of the fourth ON cycle, the release logic "locks up" and will not send any more current to the solenoid until all release conditions are removed. This assures that the release board draws very little power (~500µA) when the solenoid is inactive.

However, the release board is always ON and the dedicated battery will slowly deplete. If the instrument has not been used for more than 2 weeks, then the instrument **must be turned on for at least four hours before deployment** to give the main battery a chance to recharge the dedicated battery. The charge current is limited to about 0.25 amps and battery capacity is 0.5 amp-hours.

If the instrument will not be used for longer than 2 weeks, then

a. fully charge the dedicated battery by turning the instrument on and connecting the 12V battery charger to the instrument for at least 4.5 hours,
b. disconnect the dedicated battery from the release board by unscrewing one of the leads at connector J2 (P031R00), or by disconnecting the Molex connector at J2 (P031R01), and
c. protect the loose battery cable (P031R00) from shorting to other objects with a piece of tape.

Both the main and the dedicated battery will then be fully charged and the instrument can be placed into long term storage. The user must follow all other storage recommendations presented in the Microstructure Measurement Instruments User Manual. **Do remember to reconnect the dedicated battery before deploying the instrument.**

Lead-acid batteries, including the gel-cell type, should not be stored for more than 6 months without a short re-charge. Therefore, the user should arrange to “top up” the batteries twice per year. If there is any doubt about the state of the batteries, then they should be tested by running the instrument in the lab for ~4.5 hours. A healthy and fully-charged 12V battery produces 12.8V at no load and no less than 12.4 V shortly after the instrument is turned on. If there is any doubt about the condition of the batteries, please replace them with new ones.

Corrosive Link Triggered Release

Because both the software- and firmware-triggered release signals depend on electricity and because they are both completely dependent on the proper operation of the solenoid and its associated mechanisms, the corrosive link is used as a final backup. This link is small, cheap and very effective. The release that we supply is model A2 manufactured by International Fishing devices, Inc. (www.underseareleases.com). Its rate of dissolution is slightly temperature dependent and ranges from 24 hours at 3ºC to 18 hours at 7ºC. The release time is not specified for warmer water but will be shorter than 18 hours. After more than 8 hours of use, the link should be replaced to avoid a premature release of the weights.

Testing the Release Mechanism

Software Maximum Time

The release mechanism can be quickly tested by turning on the instrument and connecting the Ethernet cable. The user logs on to the system using PUTTY. The setup file (or a copy) can be edited to change the “maximum time” parameter to a short value. The ODAS4-IR data acquisition can then be started manually (see the ODAS4-IR User Manual) and the activation of the release should occur when the maximum time plus 38 seconds have elapsed. An example of the max_time parameter in the setup file for testing the release is shown below.

Channel:	10,Pres,17.1,0.27074,-2.024e-7,0,0,0,0,0
max_pressure:	150
max_time:	10

The release signal will be sent by the PC104 computer 10 seconds after the start of data acquisition and the solenoid should be activated 38 seconds later.

Software Maximum Pressure

The pressure release trigger can be tested by manipulating the calibration coefficients for the pressure channel. The pressure signal will be very small because the instrument is in air. The user should set the first coefficient (the offset coefficient) of the third-order polynomial to a value larger than the maximum pressure. An example of the setup file parameters for the pressure release test is shown below.

Channel:	10,Pres,200.1,0.27074,-2.024e-7,0,0,0,0,0
max_pressure:	150
max_time:	10000

With the intentionally erroneous pressure transducer calibration coefficients, the software will calculate that the instrument is at about 200 dBar of pressure (even though it is in air at zero pressure). This exceeds the maximum pressure value of 150 dBar and the release signal should be sent immediately on the start of data acquisition. The solenoid should activate 38 seconds later.

Software Fall-Rate Release

The fall-rate trigger can be tested by setting the first pressure coefficient to a value larger than 100 and setting the maximum pressure to a value that is larger still. The rate of change of pressure will be very small. Four seconds after the start of data acquisition, the software should signal the release board and 38 seconds later the solenoid should activate. Appropriate entries for the setup file are shown below.

Channel:	10,Pres,150.1,0.27074,-2.024e-7,0,0,0,0,0
max_pressure:	200
max_time:	10

The software will think that the instrument is at 150 dBar and, because the pressure is steady, the rate of change of pressure will be very small (much less than 0.2 dBar per second).

Firmware Power Failure

The power failure trigger can be tested by setting the pressure channel coefficients to their correct values (if they have been intentionally set to erroneous values) and, if necessary, setting the max_time and max_pressure parameters to sensible values. Start the data acquisition and then turn off the instrument. Thirty-eight seconds later the solenoid should activate.

Firmware Timeout

The firmware time out is best tested by turning on the instrument and running it from the charger. This way the main battery will remain energized indefinitely. The user should then come back 4 or more hours later to see if the release has been activated. The software max_time parameter must be set to a value larger than 17000 seconds so that the firmware release activates before the software release. Do not exceed a value of 65536. Appropriate entries for the setup file are shown below.

Channel:	10,Pres,17.1,0.27074,-2.024e-7,0,0,0,0,0
max_pressure:	150
max_time:	65000

Corrosive Link

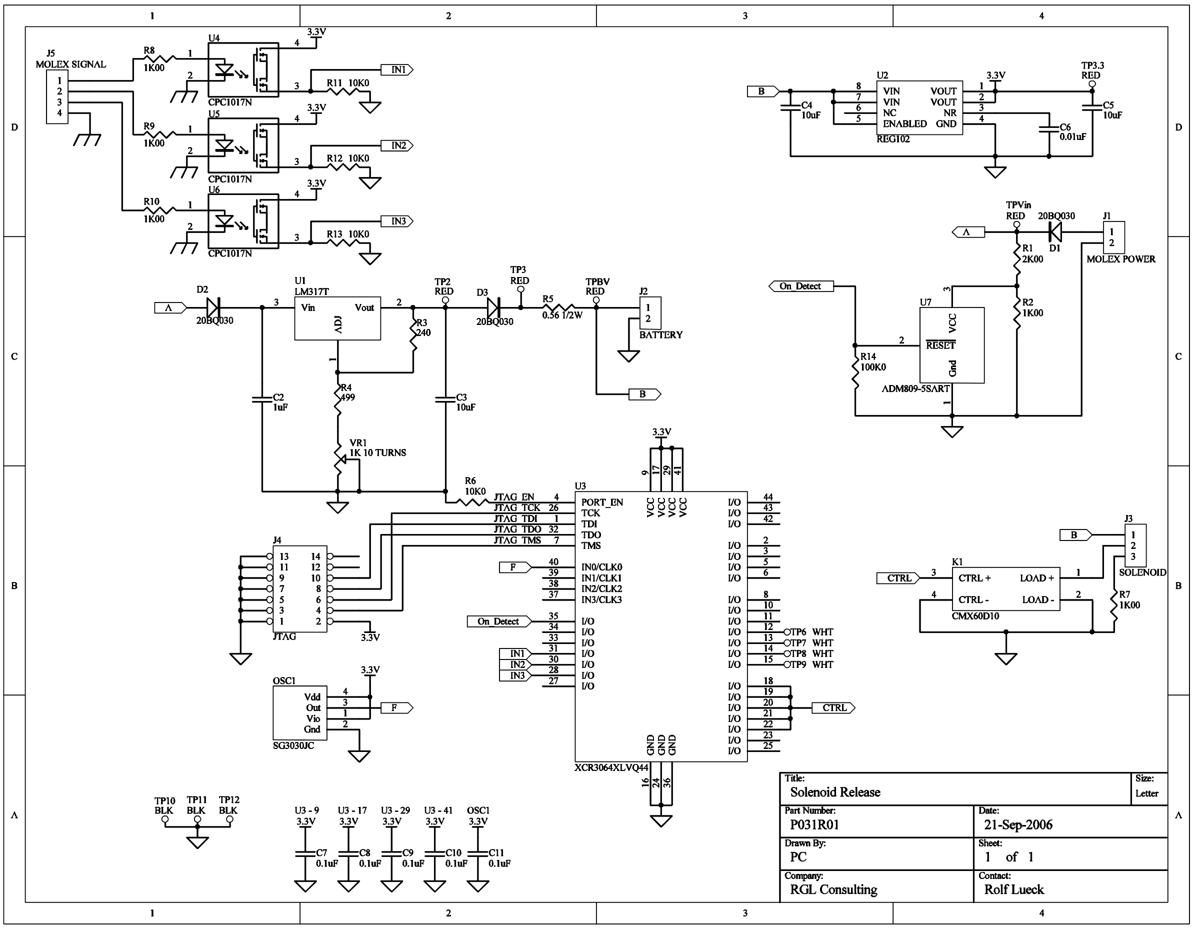
The dissolution time of the corrosive links can be tested by putting them under a tension of more than 50 N (10 pounds) and suspending them in a large body of seawater. We test them by hanging a 5 kg weight from one “eye” and attaching a small line to the other eye. We then lower this assembly into seawater at a local dock. A large container of salt or seawater can also be used. Bubbles should emanate from the corrosive link immediately upon immersion.

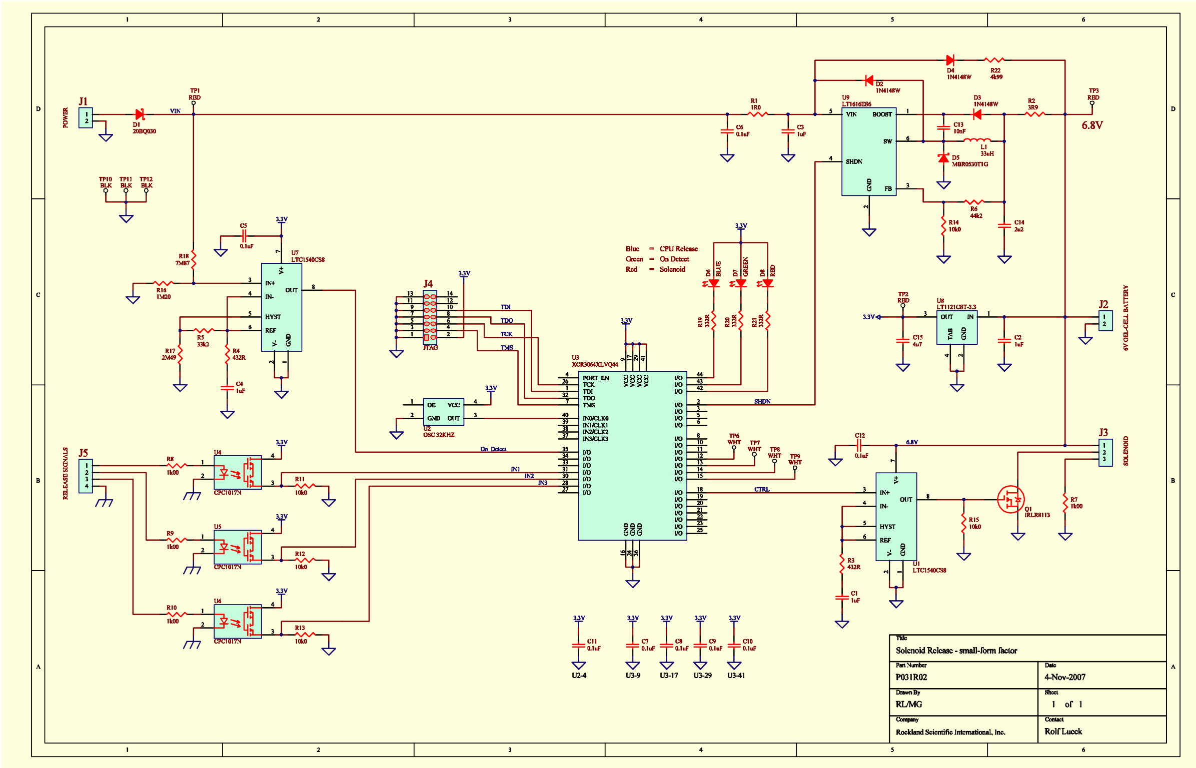
Additional Notes

Because of the countdown delay in activating the release, the user should use a release depth that is shallower than the estimated bottom depth. If the user wants to approach close to the bottom without actually hitting it, then the fall-rate of the instrument should be well established from previous profiles and the user must factor the release delay into the calculation of maximum depth. More importantly, the pressure transducer is calibrated at room temperature. It has a temperature coefficient and the water is cold down deep. A 20 degree change of temperature can produce a depth “error” of about a 10 m at a depth of 5500/6000 meters. The manufacturer of the transducer only specifies that the temperature error is within certain bounds, but the actual value and the sign of the error are not specified. For near-bottom release, the user should calibrate the pressure transducer at a temperature close to that found at the bottom and put the temperature-appropriate coefficients in to the setup file. See the ODAS4-IR User Manual for instructions on the calibration option of the ODAS4-IR software.

If the PC104 computer is powered up with the Ethernet cable connected to a computer or a network, then the auto-startup of the data acquisition software does not activate. During the boot up process, the program "quickinit" is run to turn off the release signal, so that the user is not bothered by unexpected activation of the solenoid.

To prevent injury or damage, the weights should not be mounted on to the instrument unless the user is ready to start a profile or the user is intentionally testing the drop-off characteristics of the weights. Otherwise, the weights might be released inadvertently.





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