SUPPORT NOTE

SN-125

Safely Powering Instrumentation On and Off

Introduction

There are two main reasons Reedholm test systems are so reliable. Conservative design methods do not stress electronic components anywhere close to their specified limits, so their early wearout is seldom seen. Software design at the lowest levels prevents opening and closing relays while current is flowing (i.e., hot switching), so it is quite rare when relays fail.

After meeting those initial design objectives, diligence in identifying possible system level problems for each RMA repair results in continual improvement in reliability of hardware and software.

Regardless of how reliable a system might be when under control, consideration needs to be given to behavior while powering on and off. Reedholm system training addresses proper techniques for powering instrumentation on and off. This support note was written to augment that training, provide a refresher to those who have been through training, and explains why power-up/down recommendations are made.

Power Supply Control

Two categories of supplies deliver power to instrument modules: low voltage (5V, 12V, and ±15V) for most of the circuitry, and ±120V supplies for output stages. All current through reed relay switches emanate from the ±120V supplies, so relay welding or damage from over heating output stage components can only happen if those supplies are turned on. The power control logic (PCL) assembly assures that the ±120V supplies are enabled only if low voltage supplies are within specified limits.

Power-Up Control with ECR 10/8/2008-1

Prior to the ECR: Disable Automatic 120V Enable at Power Up, the PCL would turn-on if the ±120V supplies were supplying <700mA within 150msec of power application and if the low voltage supplies were close to nominal values. Having uncontrolled ±120V supplies was precarious, so the PCL was modified to prevent turn-on of the 120V supplies without pressing the HV Reset button.

Power Down Protection

When ac power is removed from an instrument set, the 5V logic supply is the first one to come out of regulation. In a representative system, the 5V supply dropped at a rate of 2V/7msec at power-down. When the limit of 4.75V, or 5% below nominal, was reached, the ±120V supplies crowbarred to 0V in <10μsec. In contrast, the other dc supplies (+12V, ±15V, and ±120V) had not budged. Thus, before relays might have started opening from lack of power, or from spurious digital logic behavior, the source of most instrument damage had been crowbarred to 0V and there was no chance of relay hot switching.

Software Initialization

Updated PCL's prevent damage prior to software initialization, but ones built before October 2008 (Rev E) do not. However, neither version provides protection until software initialization.

OS Differences in Software Initialization

In RDS Intranet, initialization occurs when rebooting starts the slave engine and when resetting the test controller from the Tools - Test Controller menu.

In RDS DOS, initialization executes when starting the Reedholm shell with the system powered on or when <Alt F4> (F4 prior to RDS DOS 8.04) is pressed inside most applications.

Initialization with Tripped ±120V Supplies

If the ±120V supplies have been crowbarred (indicated by the red LED on the power panel being on), there is no chance of instrumentation damage regardless of when software initialization is done.

Initialization When HV LED is Off

Systems with unmodified PCL's are at risk of damage if the ±120V supplies turn-on without requiring software initialization. To minimize the chance of damage, initialization needs to be performed as quickly as possible after power is applied.

Initial State of Instrumentation

Because storage registers controlling matrix, mode, and node relays energize in random patterns, some combinations cause direct paths to ground or among system resources. Currents up to 700mA can flow from each 120V supply without causing the PCL to crowbar them to 0V. Then, when software initialization is performed, relays are hot switched; i.e., opened with current flowing.

Repeatable Behavior

Although relay registers are not under control until initialized, their states are likely to be the same each time power is applied. Therefore, initial behavior is consistent for a given instrument set. Thus, systems that do not exhibit hot switching are unlikely to change that tendency unless instrumentation is changed.

Damage Before Initialization

Without initialization, there is little chance of damage even if instrumentation is left uninitialized indefinitely. That is because current limiting circuitry protects output stage transistors. Furthermore, output stage currents are much lower than the specified limits of range, node, and pin relays. However, the chance of damage is not zero. If ac power is turned off for any reason while the system is unattended, an uncontrolled power-on state could exist for some time before initialization. Installing a PCL that automatically crowbars ±120V supplies at power-up avoids the risk of damage from being uncontrolled.

Tripping ±120V Supplies if On

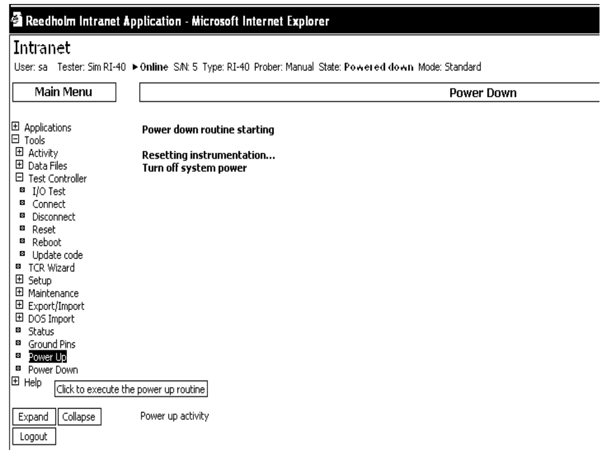
Systems that do not have modified PCL's and power up with ±120V supplies turned on will hot switch relays during initialization. In such cases, the HV Reset button should be pushed to trip the supplies, as indicated by the red LED turning on. Then software initialization can be performed without danger of relay hot switching.

Powering Up and Down w/Options

For systems with the 2kV option, reliability systems using VSM's, or systems running active, long-term reliability experiments, the power up routine should always be run prior to applying system power.

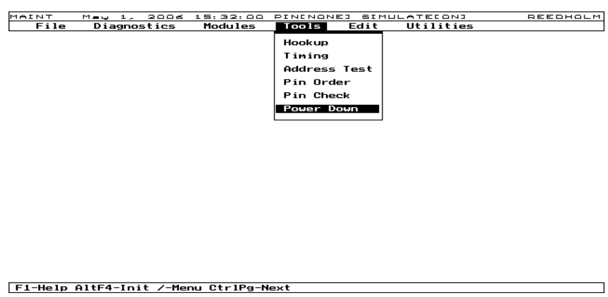
RDS Intranet

In RDS Intranet, the power up routine is accessed from the tools menu, either directly or when prompted at the end of the power down routine as shown in the following image.



RDS DOS

In RDS DOS, a prompt to run the power up routine is displayed at the end of power down, which is accessed from the tools menu in the maintenance application as shown below. The power up routine will also be executed when starting the Reedholm shell with system powered off.



Reliability Experiment Considerations

When there are active, long-term reliability experiments, power down should be executed prior to powering off the system so that test devices are not damaged.

2kV Option

While the 2kV option normally can be powered on and initialized in the same manner as other instruments, use of the power-up utility is recommended since it executes a series of checks ensuring safe output and control. A hardware fault not detected by power up could couple large voltages to the test system and damage instrumentation.

In software versions before RDS DOS 8.04 and Intranet 1.2, power-up erroneously prompted users to disconnect the prober analog cable (PAC) and leave the Kepco power supply powered off while powering on the rest of the system. Neither action is needed.

Instrumentation Considerations

Some instrumentation characteristics directly affect how initialization was designed.

Power-on Reset in Older Modules

Instrument control registers in older instrument modules like the VF-12 and VFIF-12 could be set to an initial state using a common power-on clear signal from the back plane. That resulted in all relays being open after the power-up delay time, thereby preventing excessive current and uncontrolled voltage delivery prior to software initialization.

The Clear line is a potential source of problems if breakdown events have enough energy to couple a logic level change into it. A capacitor added to the DMM-16 reduces sensitivity to breakdown pickup by almost two orders of magnitude (ECR 1/27/2010-1: Reduction in Clear Line Noise Sensitivity).

Modules Without Power-on Reset

Newer instruments were designed with storage IC's that do not have a clear signal. That was done because software initialization is used to set the proper initial state. Most current modules (CPM, DMM-16, VFIF-16, PAM-12, PAM-16, and VSM) are initialized through software to make sure that appropriate relays are open.

Effect of Matrix on Powering Up

At power-up, matrix relays may or may not be closed. Assuming a normal distribution with 50% probability of being on, the large number of relays (48 per matrix module), virtually assures that all nodes will be grounded. Thus, any power sourcing module, including the DMM in current mode, connected to a node will be shorted to ground. If the module is on a high current range, significant current would flow and opening the path would incur hot switching.

Alternatively, if a sourcing module is connected to a node that happens to be open, a potentially large voltage is placed to any pin connected to the node. Grounding of the node during initialization would incur hot switching.

DMM-16 Mode Overlap

Switching between voltage and current modes in the DMM-16 is done with a pair of relays, K12 and K13. The exclusive-or (XOR) function of driving them is done with software in older versions while the latest DMM-16 uses hardware for control.

The software version has a problem because the relays can be closed simultaneously. In such cases, power in R32 can exceed its 1W rating. However, damage can only occur if:

- There is a current path through the meter low relay or another module to ground.
- The 100mA or 1A relay, or both, is closed.
- Pre-initialization current does not trip the ±120V supplies.

An ECO changing the DMM-16 to revision G involves selecting an IC (U16) that assures a power-up condition with both K12 and K13 turned off. This ensures there is no damage to R32.

If system conditions are just right, a DMM-16 that did not exhibit heating of R32 when shipped from Reedholm might do so when installed in a system. In such cases, the DMM-16 should be returned to Reedholm for replacement of U16.

Pushing HV Reset Before Initialization

The HV Reset button should never be pushed until software initialization has been invoked. At best, doing so leads to blown ±120V supply power fuses. At worst, the ±120V supply assembly is damaged as well as the PCL and instrument modules. That is because pressing the button temporarily disables the crowbar circuits that otherwise protects those assemblies.

Disconnecting Reliability Experiments

10V and 100V voltage stress modules (VSM-10 and VSM-100) used in RI-51 and RI-53 reliability test systems can power-up at non-zero voltage while connected to output paths. Instrument enclosures that contain these modules have independent ac power delivery so that matrix and other instrument modules can be powered on and initialized before the VSM's.

Output paths directly rout to load board, other DUT fixtures, or other VSM's in dual stress systems. That is why output cables in reliability systems need to be disconnected before applying power.

To ensure safe operation, the power-up software utility needs to be used with reliability systems, and prompts need to be followed.

Initialization as of December 2009

ECR 11/24/2009-1: Improved Control During DMM Initialization, drove substantial changes to the initialization software. It consolidated previous versions and separated initialization activities into three categories:

- Making instruments safe by zeroing supplies and opening matrix connections.
- Figuring out what instruments are physically in the system.
- Putting instruments into desirable states.

Thus, making instruments safe, identifying them, and initializing are now separate activities. Some of the new procedures and functions were converted into being externally callable.

Major Operational Changes

The major changes made in addition to reorganizing the code are described in the following paragraphs.

DMM Left on 10µA Range

InitDMM is called after the DMM mode or range has been affected so that DMM's are put on the 10µA range when not testing. This has the benefit of keeping meter high (MH) near 0V when the DMM is not being used. Some DMM MH buffers have been seen to float up to >80V. That would not be good when MH was eventually connected.

Pre-emptive Latch-up Prevention of VFIF

With the VFIF latch-up experienced at a customer site, going to the 1mA range or higher was enough to pull the VFIF buffer amplifier out of latch-up. Contrary to the earlier experience, latch-up was in fact seen on power up for a VFIF-16 and DMM-16 combination. Because the VFIF-12 has the same architecture as the VFIF-16, they have the same latch-up issues.

Latch-up happens when the sense buffer op amp inverts, then the composite output amplifier maintains latch-up regardless of voltage range or node connections. Current from the sense buffer through the current range resistor will maintain latch-up as long as the voltage drop is more than the Idac output.

Thus, switching to the 10mA range and maintaining full scale was enough some of the time, but going to 100mA assures that the composite amplifier does not sustain latch-up. So, VFIF's are put on the 100mA range at 100mA for 5msec in case they latched up. With the test station VFIF-16, it took <1msec to come out of latch-up at 100mA.

Pre-emptive DMM Latch-up Prevention

Going to higher currents did not work for the DMM. In fact, it had the opposite effect and made it harder to pull the DMM MH buffer out of latch-up. Fortunately, for ranges below 100µA, the 350pF node capacitance can pull the MH buffer out of latch-up because the feedback range capacitor is 100pF on the 10µA range and smaller on the 1µA and 100nA ranges.

All nodes are discharged for one msec before connecting DMM MH for 5msec. The MH node relay is disconnected afterwards. When the MH relay is closed, the capacitive divider pulls the input down to slightly >20V, thereby putting the amplifier back in control. Had the node been left shorted, there could be welding current through the guard switch.

Prompt for HV Reset

After the system is made safe by zeroing voltages and opening all matrix connections, the user is prompted to press the HV switch.

With the prompt for HV reset, customers do not have to contend with messages from 120V checking. Furthermore, there will be no message unless the 120V supplies cannot be measured, which would indicate a problem with the 120V fuse or supply, DMM#1, or PS#1.

120V Supply Checking

Checking of the 120V supplies is now done without a pause for viewing results. That is because pressing the HV reset button while a DMM was connected to a VFIF-16 and trying to force 95V resulted in the MH buffer latching up.

It is still possible for latch-up to happen if the HV Reset button is somehow pressed during one of the 95V measurements, but that is unlikely. Doing so would require pressing the button during a four millisecond window for each polarity, or eight millisecond overall.

RIinit Flow

An EXCEL file was created to show initialization software flow. It is reproduced in the last page of this note. The following paragraphs briefly describe what is done during certain algorithms within the initialization code.

CalADCs

A/D converters in the 100kHz CMM, DMM-16, and PAM-16 have internal corrections invoked on application of power to the IC. This command initiates calibration for all three and waits 1.441 seconds for the DMM A/D to finish. If it is desirable to invoke this routine for 100kHz CMM operation, the DMM A/D linearity calibration could be skipped because it never drifts by >0.25LSB after the initial one. Before changes, there was no explicit call to DMM A/D calibration.

InitDMM

InitDMM uses SendHdw calls to put the DMM on the 10µA range, open MH relays, and connect ML to ground. Before changes, relays were switched without delays. As a result, non-damaging overlap caused disconcerting voltages when monitoring. Also, the previous version did not open MH. Now the routine is used to assure that a DMM is put on the 10µA range when exiting initialization.

HDWinit

HDWinit was trimmed down to putting instruments into desirable states after making sure they were safe. It is only called once now in RIinit, and is called from ResetInstruments. HDWinit is available from Hookup, but there are no applications that call HDWinit.

LatchupRecovery

Rather than test for whether or not latch-up occurred, both actions are performed after the HV reset prompt, which calls the routine that makes the system safe. It is called only once here although HDWinit does call it again. Previously, the more complex HDWinit was called three times in order to overcome scrambling.

OpenPwrSources

Disconnects PPG node relays, waits 1msec, opens nodes for each standard supply (VF, VFIF, and HVSMU), then finally opens HISMU nodes.

SetVzeroandRange

This procedure is in RI0.pas and uses SendHdw commands that execute regardless of instrument existence. Now it sets supplies to 10V range, sets to 100µA if VFIF, and sets the HISMU to 10V, 30µsec, and continuous. It does not open nodes because those should not be opened until all power sources are disconnected.

ZeroSourcesandOpenPaths

Changed name from ClearAddressSpace because it does something far more than setting aside address space. CalADCs was moved to a higher level because it did not belong here. Previously, this routine caused ML to open for 1.5 seconds during initialization.

All 0's were being written to many address locations, including the DMM. Now the node relays of supplies, HISMU, and DMM's are opened with specific calls instead of being done in a loop with other calls.

SendHdw is still used to send 0's to all CMM, CPM, PAM, SCM, and UFM addresses. Writing 0's to some of the addresses spawn A/D calibrations and conversions that have to be accounted for.

Instrumentation Initialization After 1/12/2010

- InitInstrumentation
  - Instrupresent (1st) — Sends PS#1 near zero data $7F & 6% change to $70
  - GetHdwConfigur
    - Instrucheck — Cannot remove next instrupresent because instrucheck can be called independently of initialization.
      - Instrupresent (2nd) — Done 2nd time without CRT display of inability to find PS#1.
      - RIinit
        - Figuration
          - ZeroSourcesandOpenPaths — SendHdw calls used throughout to get instruments to safe state and open the matrix entirely.
            - SetVzeroandRange — First call puts supplies to 0V on 10V range and brute force (all 0's) full scale on 100uA range if VFIF. Nodes are not opened.
            - SetVzeroandRange — Second call sets HISMU on 10V range, continuous, and 30usec.
            - OpenPwrSources — Series of SendHdw's opens PPG nodes followed by opening PS nodes and SMU nodes. One msec delay inserted after each.
            - OpenNEMs — Opens all possible NEM type relays.
            - OpenRest — Sends zeroes to CMM, CPM, PAM, SCM, & UFM registers, initiating A/D calibration in 100kHz CMM and PAM-16's.
            - InitDMM — Sets 10uA range, opens MH, and grounds ML with delays for switch settling.
          - Reset120Vsupplies — Prompt for 120V HV switch to be pressed.
          - LatchupRecovery — Action to eliminate known VFIF & DMM latchup. Only called once although HDWinit was called 3 times. Future version might write to Init.log.
            - ZeroSourcesandOpenPaths — First routine called by Figuration repeated in this routine to get to known starting state.
            - Set VFIF to 100mA & back — Forcing each VFIF to 100mA for 5msec followed by a return to 100uA range forces latchup recovery. Only 1msec is required.
            - Discharge Node 1 — Using pin #1, node 1 is grounded for one millisecond before opening. Long enough for good 0V, but does not discharge DA.
            - Connect MH to Node 1 — MH connected to discharged node 1 to pull MH buffer out of latched condition in ~1msec at 10uA, then MH is opened.
          - CalADCs — Initiates CMM, DMM, & PAM A/D calibrations plus assures 1.441 second delay for DMM-16 A/D calibrations.
          - FindInstruments
            - FindPS — Checks 1st pin register faster than relay response time & leaves pin open in function cage.
            - FindCPMandPAM — Using SendHdw and ReadHdw, determines power supply types. Leaves Idac MSB at $00, or FS, for VFIF.
            - PSVzero — Now that supplies have been found, use this to put them at 0V without regard to range. Redundant, but takes only a couple of msec.
            - PSAzero — Puts VFIF's on 100uA range at 100uA. This routine and PSVzero are used throughout the applications code.
            - FindMax(DMM) — Need to know that we have a DMM for finding the SCM, VF1As, & DMMage.
            - FindDMM1A — For DMM#2, forces 0 to current range byte, but restores range to original 10uA.
            - FindSCM — PS1 forces 40/50uA to 0.5V & uses limit bit to measure 10k. Direct calls used to disconnect PS1 & SCM node relays.
            - FindVF1As — PS1 & DMM1 on node 1 to measure 50V. PSVzero is only a couple of msec, so it is used before disconnect calls.
            - FindAgeofDMMs — PS1 forces 900mV for 2msec. DMM1 finds current 5msec after disconnect. PS1 now disconnected afterwards.
            - FindMax(SMU-UFI) — FindMax used to find SMU, CMM, CMB, PPG, & UFI.
          - HdwInit — FindInstruments does not necessarily put them into an optimal state for testing, so HDWinit does that.
            - ZeroSourcesandOpenPaths — First routine called by Figuration repeated in this routine to get to known starting state after finding instruments.
            - InitRest — Puts instruments except DMM into known condition. Slow actions restricted to being in Figuration. TimeInit must precede 1st sync_measure.
            - PSVzero — PSVzero only takes a couple of msec to run and prevents aborts when switching.
            - PSAzero — Puts VFIF's on 100uA range at 100uA. This routine and PSVzero are used throughout the applications code.
            - InitDMM — Puts DMM back to 10uA range, with open MH, and grounded ML.
        - InlineCalibrations
          - FindDMMzeroes — DMM to Vmode, MH & ML to Node 1, plus ML grounded using SendHdw. Delays now are range dependent along with # of readings.
      - Check120 — PS1 & DMM1 do +95, -95, & 0V checks with no pause. Takes ~10msec, so user would have tough time causing latchup.
        - InitDMM — Puts DMM back to 10uA range, with open MH, and grounded ML.