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Title: HIFI LO Software Modifications

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27/10/09	1.0		new
22/11/09	1.1	7	Section 3.4 - included the conclusions of the tests of 29.10.2009 - erased previous preliminary conclusions
		9	Section 3.6 - updated

Reference Documents

Document	Title	Issue
MPIfR/HIFI/TN/2001-521	LO S7S Operation	2.0 24.10.2006
SRC/LCU/PR/2009-0756	FHLCU FM failure investigations done on DIGIT_FS in Warsaw October 2009	1.1 october 2009
SRON-U/LCU/TR/2009-005	Several LCU tests 8-9 October 2009	Draft 09.10.09

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1 Document Purpose

The failure of the LCU FM in flight in August 2009 requires a switch to the redundant system of HIFI. The failure investigation on the LCU hardware and software is ongoing at the time, but the preliminary results indicate a failure scenario which is a concatenation of weak components (diodes in the HRS-4 DC/DC Converter) and a SEU that forced the microcontroller's program to initialize the controller's state. The initialization procedure includes a switch of the standby relay. If the LO subsystem is in operation (full current consumption), the standby relay switch causes an unwanted overvoltage on the converter's primary line, and generates an overvoltage on the above mentioned diodes, beyond their voltage ratings.
The test results on the IMD3 show over-voltages on the primary line of the converter whenever the current consumption of the subsystem is removed fast. The amplitude of the overvoltage defines the level of "stress" for the diodes. As a further result, none of the IMD3 diodes have been damaged by the extensive testing, so that the "weakness" of the flight components is an important assumption for the failure mechanism. Having this considered for the redundant mode, it becomes clear that the number of those switch cycles, even if they show a lower amplitude, has to be minimized in a trade-off between system lifetime and LOU band safety. This document addresses the LCU software change options.

2 Software Change Options

The most harmful condition, we have found so far, is the current reduction of the LSU, which cannot be software-controlled. Any transition in the subsystem that causes the LSU current consumption to change to significant lower levels should be avoided if possible. These transitions are identified in any procedure that incorporates

1. a standby relay switch
2. any tuning command in nominal mode that modifies the frequency
3. any tuning command in normal mode that modifies the LO subband
4. Primary Power Low Interrupt

Optional modifications on the procedures are discussed in the subsequent sections.

2.1 STANDBY RELAY

Switching the standby relay to state open generates an unwanted overvoltage, if it was in state close before. This transition is incorporated

1. in the microcontroller's boot procedure after primary power-on,
2. in the GOTO STANDBY procedure,
3. in the RESET procedure,
4. and with high probability in a software crash (i.e. generated by SEU)

It is proposed to modify the LCU software in a way that the standby relay cannot be commanded to open at any time after the microcontroller boot procedure. This would avoid unwanted current transitions of items 2.- 4. This modification implies that all software procedures incorporating the relay state transition, have to be modified.

2.2 STANDBY 0, STANDBY 1 AND DISSIPATIVE MODE

The original standby mode is used as the initial mode after primary power-on. It is therefore the initialization mode after the software is loaded from PROM to RAM. At the end of the initialization the standby relay is set to open. This should not have any negative effect on the hardware, as long as the secondary power is off at that time and cannot directly be modified as the boot procedure is burned into the PROM. After the boot procedure there is the opportunity to modify the software in memory such that the command for switching Standby/Nominal relay to Standby position is erased. In fact the modification should be a very simple one – there is only one place in the code where the OFF coil of Standby/Nominal relay is set. The subroutine loads logical "0" to the address of output port dedicated for this coil (line is called N_NOMINAL_DIGIT_OFF), then waits for 10ms and loads logical "1" to the same port. The codes for loading "0" and "1" should be replaced by NOP. Such a simple modification guarantees that the timings of execution of all possible operations will not be changed. This also ensures that the relay can only be commanded to state "Nominal" from then on.

That implies that we deal in principal with two standby modes:

1. **STANDBY 0 MODE**
   is the original STANDBY MODE. This mode shall only be entered at the end in the microcontroller's boot sequence after primary power-on.

2. **STANDBY 1 MODE**
   This mode shall be entered for LCU table upload or any other memory modification, if no primary power cycle was preceded.

STANDBY 1 shall not be used for the regular case when HIFI is commanded to standby due to operation of other HERSCHEL instruments. For this HIFI standby, the LO subsystem shall be commanded to a so-called dissipative mode:

3. **DISSIPATIVE MODE**
   This mode shall be entered, when HIFI is commanded to STANDBY

Table 2-1,2,3 list the transition sequence as well as the accepted commands of each mode. We expect a limited number of STANDBY0 mode transitions, as the number of primary power cycles can be minimized. Given that the LO subsystem is in DISSIPATIVE MODE when HIFI is in standby, also the number of STANDBY 1 MODE transitions is expected to be limited, because it is only used for table/patch uploads and emergency shutdowns. Therefore the number of remaining SUBAND0 commands and their current transitions can be limited to a minimum number.

The number of DISSIPATIVE MODE transitions need not to be minimized, as it does include only a normal band tuning and includes restrictions on operation of the subsystem. As one band is quasi-operated in this mode, it shall not be allowed to command tunings in this mode. Apart from that, this mode is more similar to the NORMAL MODE rather than the original STANDBY MODE. The power dissipation of the LSU will be the same as in NORMAL MODE, which also supports the total time for HIFI's thermal stabilization after switch-on (WBS laser). The dissipative band shall be selectable between 1A and 7b to share burn-in times on these bands, but there shall be a default band, which is switched on, when no option is entered with the DISSIPATIVE MODE command. The TUNE BAND DISSIPATIVE command consists of a TUNING MACRO command that uses a frequency index

where the LSU RF output power level is set to minimum, the chain is biased safe (nominal settings, D2V_low).

STANDBY 0		
Transition Sequence		Accepted Commands
1	Disable interrupt LSU LOCK	GOTO STANDBY1
2	Set SUBBAND 0	DUMP MEMORY, CALCULATE CHKSUM
3	SWITCH-OFF CHAIN	WRITE MEMORY
4	Open STANDBY RELAY	REQUEST HK

Table 2-1

STANDBY 1		
Transition Sequence		Accepted Commands
1	Disable interrupt LSU LOCK	GOTO NORMAL MODE
2	Set SUBBAND 0	CALCULATE CHKSUM
3	SWITCH-OFF CHAIN	DUMP MEMORY, WRITE MEMORY
		REQUEST HK

Table 2-2

DISSIPATIVE MODE		
Transition Sequence		Accepted Commands
1	GOTO NORMAL MODE	GOTO NORMAL MODE
2	TUNE BAND DISSIPATIVE	GOTO STANDBY1
		DUMP MEMORY, CALCULATE CHKSUM
		REQUEST HK

Table 2-3

2.3 RESET Command

The original procedure enabled by the RESET command involves the standby relay as it ends finally in STANDBY0. This shall be changed to STANDBY 1.

The reset procedure would then follow the sequence

1. reset command queue,
2. set boot flag in status word,
3. disable interrupts,
4. clear stack pointer,
5. clear command counter buffer,
6. clear status,
7. set SUBBAND0,
8. reset latches,
9. quick clear all supplies,
10. set mask band,
11. activate int0 and int1,
12. goto idle,

and would leave the subsystem in STANDBY 1.

2.4 SUBBAND0 Command

The SUBBAND0 command initiates the LSU to select no output amplifier. This command is used in the various mode transitions to STANDBY0, to STANDBY1 and in the RESET procedure. Each TM command which initiates a band change does contain a SUBBAND0 command in its procedure. Tests performed on 29.10.2009 on the IMD3/LSU_DM/SCOE test setup in Groningen revealed that the undesired transition remains in the hardware procedure sequence, if the subband0 command is erased from the TM. Each band change implies that the active LSU output amplifier is switched of before the selected amplifier is switched on. Therefore the transition sequence does not differ from a subband0 command (all amplifiers off). In conclusion it is recommended, not to change the TM software.

2.5 LCU - External – CHECKSUM HANDLING

The investigations so far indicate that the failure has been triggered by corrupted memory. We therefore shall take the measure that operation is stopped, if a CHECKSUM calculation returns a non expected value.
The LO subsystem should be commanded into the STANDBY 1 MODE.
An investigation on such an event requires a full memory dump on the LCU memory. It is proposed that this would be executed from stack within a DTCP. Automatic handling of CHECKSUM errors can be considered for a later phase when we have gathered more experience on SEU in memory.
Checksum verification shall be initiated for monitoring purpose only. An autonomous function in the OBSW shall command the LCU into standby 1 and stop the communication to the LCU, if a checksum error is notified.

3 Verification and Test

3.1 Removal of Standby position of Standby/Nominal Relay

The test should be initiated from primary power on, then the proper booting procedure should be observed. LCY should stai in STANDBY 0 Mode. The memory patch should be done with the code erasing the N_NOMINAL_DIGIT_OFF line. Then the following kind of the tests should be performed:

1. Verification of the execution of the command for transition from Standby to Normal Modes. This command should not affect the primary power consumption at all, the whole set of LSU power rails should be stable before and after the command execution. The voltage programmed for Main Heater should be stable also. The software flag should change from Standby to Normal.
2. Verification of the execution of the command for transition from Normal to Standby Modes. This command in actual design switch off the power for most rails of LSU. After the modification the power reduction should not be observable. The verification should show, that:
   a) If the chain was switched on before the command, the proper switch off the band should be performed with slow ramps for drains, gates and biases, then the software flag should be changed to Standby, if there was no active band then only the software flag should be changed to Standby
   b) The voltage programmed on Main Heater should not change
   c) The LSU voltages: +17V5, +10V5, +9V5, +7V5 and -7V5 should be the same before and after the execution of the command
3. The changes of primary LCU current (if any, due to switch off the band) should be enough slow not to observe any additional peak on primary voltage at LCU input. The only one exception can

be for SubBand0 on LSU (tbd if this command has to be activated prior to switching off the active chain).

4. Verification of the LCU behavior during the primary power switching off. The verification should include the following tests:
   a) The observation of primary current and primary voltage in case the switch off the power is done in new Standby Mode. This situation should give the two, opposite effects: the current drop can be quite big and could cause the overvoltage peak at LCU input but, on the other hand the primary voltage is going down and the final overvoltage peak is not visible.
   b) The observation of primary current and primary voltage in case the switch off the power is done in Normal/Diagnostic Mode with no chain switched on. This situation should generate the emergency undervoltage interrupt (practically not observable on primary current) and then give the same effect as in the previous point.
   c) The observation of primary current and primary voltage in case the switch off the power is done in Normal/Diagnostic Mode with the chain switched on. This situation should generate the emergency undervoltage interrupt. The interrupt should be observable at LCU input as the drop of primary current due to immediate reduction of drains voltage (fast switching off the active chain). The drop of the current could generate the overvoltage peak. This is to verify that the reduction of the drain voltage is relatively slow (due to big time constant in Drain Generator) and peak is enough small (tbd level). If not, then the algorithm used for fast reduction of drain voltage should be finally modified by adding a tbd intermediate steps between maximum voltage and zero level
   d) The observation of the timings of drains, gates and biases lines (for the active band, if any) in order to proof that the microwave diodes will survive the emergency switch off in new conditions. The important point: in modified design there will be no reduction of LSU power during the undervoltage emergency switch off and the RF power can be visible on the input of the chain much longer that it was tested for actual (not modified) design.
5. The observation of the LCU behavior in Nominal/Diagnostic Mode when the memory corruption (simulation of SEU) is done. The set of the tests done in Warsaw end of October 2009 should be repeated for modified LCU. The special care should be taken for the tests in which the lack of communication and 1.6sec delay between the command and activation of Standby/Nominal relay are observed in actual design. In new design the activation of the relay should not be observed.

3.2 STANDBY0

This state is identical to the original one (as in actual design). It was fully tested for FM model. No additional tests are planned.

3.3 STANDBY 1

The verification should be done in following setup: LCU in STANDBY 1 Mode, LSU DM connected, LOA simulated by Dummy Load. The verification should:

1. check that in this mode there is not possible to switch on the chain (no power on the lines dedicated for chains, all the lines shorted to returns by resistors, LCU doesn't accept the command for switching on the band and answered with ERROR)
2. confirm that the LSU power is active on the all rails
3. measure the power consumption of LO for different values programmed for Main Heater.

3.4 DISSIPATIVE MODE

The verification of the power consumption of LO should be done in the following setup: LCU in DISSIPATIVE Mode, LSU DM connected, LOA simulated by Dummy Load. The dedicated (tbd one) band switched on in LCU, LOA Dummy load connected to the output dedicated for this band, all

biases programmed as in safety table (tbd). The verification should be done for different voltages programmed for Main Heater.

3.5 RESET COMMAND

TBD

3.6 TUNING MACRO COMMAND

1. Prior to detailing the changes in the TM procedures, it needs to be verified, which effect on the primary voltage is generated when switching from one active LO band to another.
   Setup: IMD3 connected to LSU DM, chain dummy, LCU_EGSE software in diagnostic mode and TM commanding via labview.
   Measurement: a) Tune chain 7b and LSU in diagnostic mode. Then tune LSU to chain 1b and record primary current and voltage.
   b) Tune chain 7b and LSU in normal mode via a TM command to the same conditions as under a). then tune chain 1b for the same frequency as under a) and record the primary voltage and current.
   c) compare results of a) and b).
2. further testing on the TM procedures depend on 1. (to be updated)

The above test has been performed on 29.10.2009. The test result showed that a LCU current transition, as initiated by a subband0 command, cannot be avoided in a band change sequence. It is therefore recommended, not to change the TM software part, but to take into account the number of respective transitions initiated by band changes in the further operation planning.