This application note is applicable to the following Power Supply (PSU) models:

| Model Number | Airflow | Output Power | Main Output (Vdc) | Standby Output Vdc | MPS# |
|---|---|---|---|---|---|
| D1U86T-W-800-12-HB4C | B→F | 800W | 12.0 | 12.0 | M5801 |
| D1U86T-W-1600-12-HB3C | F→B | 1600W | 12.2 | 12.2 | M8176 |
| D1U86T-W-1600-12-HB4C | B→F | 1600W | 12.2 | 12.2 | M8176 |
| D1U86T-W-2200-12-HB3C | F→B | 2200W | 12.2 | 12.2 | M5806, M8177 |
| D1U86T-W-2200-12-HB4C | B→F | 2200W | 12.2 | 12.2 | M5807, M8179 |

Cold redundant (CR) operation aims to maximize efficiency by ensuring the optimum number of PSUs are sharing load in 1+1, 2+2 or 3+1 configurations without compromising redundancy. CR requires a dedicated bus "CR_Bus" and also utilizes the ISHARE bus voltage in determining the on/off status of the output and therefore the QTY of PSUs actively sharing load. Each PSU is assigned a "Role" which in turn determines the order in which the PSUs turn on/off as load increases/decreases.

## Comparison with Intel™ CRPS CR:

Cold Redundancy features offered with this product series follows the Intel™ CRPS method except for these differences:

1. CR_BUS logic is inverted (all PSU outputs active when CR_BUS is high state).
2. PMBus Command 0xE0 is used to configure and active CR mode instead of 0xD0.
3. Programmable on/off thresholds: Command 0xE1 supports 'write' and therefore can be utilized to change the on/off threshold current VCR_ON_EN and VCR_ON_DIS thresholds instead of being confined to manufacturer fixed values.
4. Offline Mode is offered; system/host commands active or cold_standby status manually

The default setting for initial power up is "Conventional redundancy" where by all bus connected PSUs share load actively and the CR_BUS signal is ignored.

## System Requirements for CR operation:

1. PMBus Communications with 'write' capability
2. Provide the connection point (form the bus) for ISHARE
3. Provide the connection point for (form the bus) CR_BUS

## CR_BUS SIGNAL CHARACTERISTICS AND USE:

The CR_BUS is an open collector with internal pullup resistor used exclusively by the PSUs to:

1. Communicate a fault to all load connected PSUs by forcing the CR_BUS to high state
2. Detect fault (high state) and force the output on rapidly for conventional load-share (within 100uS)
3. PSU assigned role of "COLD_STANDBY_x"places it's signal into high state
4. PSU assigned role as "ACTIVE" is always on and provides the "low" CR_BUS state upon successful system / host CR configuration

## PSU REQUIREMENTS FOR CR OPERATION:

- Turn on main output within 100µs of CR_BUS signal being driven HIGH
- Turn off main output ORing FET
- Maintain a pre-ORing capacitors charge level of at least 12.5V
- Maintain PWOK asserted state
- Disconnect any internal parasitic loads that would otherwise cause the output cap to discharge
- Turn off internal fan
- Pre-bias its voltage error amplifier to maximum output (preventing the loop compensation from slowing the turn on process in the event of assertion of the CR bus.
- Keep the PFC stage Operating at the lowest possible operating frequency and the bulk capacitor charged
- No PMBus™ fault or warning conditions reported via STATUS commands
- PMBus™ READ_EOUT (where supported) command shall continue to increment its sample counter and update its power accumulator
- PMBus™ READ_PIN command should continue to report its input power
- If CR_BUS is pulled high, the operating PSU's must share load conventionally. Once the cold redundant "Active" PSU roll is reassigned and the CR_BUS is pulled low, CR mode is restored.

### PMBus™ PSU Role Definitions:

The following table defines the PSU role assignment options for CR mode operation.

| PMBus™ DESCRIPTION | | | |
|---|---|---|---|
| **PSU Role** | **PSU Role Byte** | **PSU output on / off State** | **Description** |
| STANDARD REDUNDANCY | 0x00 | Always on | Turns the power supply ON into standard redundant load sharing mode.<br>The power supply's CR_BUS signal must be OPEN system/host side |
| ACTIVE (Offline Mode) | 0x01 | Always on; Offline Mode | Defines the PSU always active in Offline Mode, also known as "MASTER"<br>Provides the CR_BUS pull-down |
| COLD_STANDBY (Offline Mode) | 0x02 | OFF: CR_BUS is high state<br>ON: CR_BUS low state | ➢ Defines the PSU to be always in COLD_STANDBY mode regardless of load condition.<br>➢ COLD_STANDBY power supply is forced on upon the detection of a fault by the ACTIVE PSU (upon CR_BUS state changing form low to high) |
| ACTIVE (automatic mode) | 0x03 | Always on | Defines the PSU as "always on" in cold redundant configuration, , also known as "MASTER" and provides the CR_BUS signal pull-low state |
| COLD_STANDBY_1 (automatic mode) | 0x04 | Determined by load current | **Level 1** - Defines the power supply that is first to turn on in a cold redundant configuration as the load increases; Threshold current is model specific |
| COLD_STANDBY_2 (automatic mode) | 0x05 | Determined by load current | **Level 2** - Defines the power supply that is second to turn on in a cold redundant configuration as the load increases; Threshold current is model specific |
| COLD_STANDBY_3 (automatic mode) | 0x06 | Determined by load current | **Level 3** - Defines the power supply that is third to turn on in a cold redundant configuration as the load increases; Threshold current is model specific |
| Note: "automatic mode" complies with INTEL™ CRPR CR operation except as noted | | | |

## AUTOMATIC MODE

CURRENT THRESHOLDS BY MODEL:

| PMBus™ ROLE Byte | Input Voltage Range: | ON / OFF OUTPUT THRESHOLD LOAD CURRENT EXPRESSED IN ADC | | | | | |
|---|---|---|---|---|---|---|---|
| | | D1U86T-W-**2200**-12-HB4C | | D1U86T-W-**800**-12-HxxC | | D1U86T-W-**1600**-12-HxxC | |
| | | **ON** | **OFF** | **ON** | **OFF** | **ON** | **OFF** |
| **Level 1 0x04** | High line/DC | 100 | 44 | 45 | 20 | 75 | 32 |
| | Low line | 64 | 26 | 45 | 20 | 50 | 20 |
| **Level 2 0x05** | High line/DC | 108 | 68 | 48 | 28 | 85 | 50 |
| | Low line | 72 | 44 | 48 | 28 | 60 | 33 |
| **Level 3 0x06** | High line/DC | 112 | 80 | 51 | 35 | 100 | 67 |
| | Low line | 78 | 56 | 51 | 35 | 70 | 45 |

**PMBus™ Write Command 0xE0 (CR_MODE) Configuration for each PSU:**

| 1 | 7 | 1 | 1 | 8 | 1 | 8 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE0 | A | ROLE (0x03 or 0x04 or 0x05 or 0x06) | A | P |

**PMBus™ Read Command 0xE0 (CR_MODE) Configuration for each PSU:**

| 1 | 7 | 1 | 1 | 8 | 1 | 7 | 1 | 1 | 8 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE0 | A | Sr | Slave Address | R | A | ROLE (0x03 or 0x04 or 0x05 or 0x06) | A | P |

Role Summary:
**ACTIVE:** (byte 0x03) At least one (1) PSU must be assigned this role, and is "Always On"
**COLD_STANDBY_1:** (byte 0x04) next unit to power load as ISHARE bus increases > threshold / third to shed as load falls
**COLD_STANDBY_2:** (byte 0x05) next unit to power load as ISHARE bus increases > second threshold / second to shed as load falls
**COLD_STANDBY_3:** (byte 0x06) next unit to power load as ISHARE bus increases > third threshold / first to shed as load falls
**CONVENTIONAL REDUNDANCY:** (BYTE 0X00)

**PMBus™ Command 0xE1 (CR_Von/Voff) → To Read ON/OFF Current Thresholds:**
The following command returns the on/off output load current threshold values.

| 1 | 7 | 1 | 1 | 8 | 1 | 7 | 1 | 1 | 48 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE1 | A | Sr | Slave Address | R | A | Von2, Voff2, Von3, Voff3, Von4 and Voff4 | A | P |

**Note:**
1) Reading 0xE1 always returns 6 bytes regardless of QTY of assigned PSUs assigned roles.
2) Returns the following BYTE order: Von2, Voff2, Von3, Voff3, Von4 and Voff4
3) Returned threshold currents are expressed as 1Amps/unit for 800W and 1600W PSU (2Amps/unit for 2200W PSU), i.e. for actual (real world) PSU "ON" high line/DC current threshold of 100A, would return "50"; applies to each of the 6 bytes for 2200W PSU.

**PMBus™ Command 0xE1 (CR_VonVoff) → To Change ON/OFF Current Threshold values:**
The following command returns the on/off output load current threshold values.

| 1 | 7 | 1 | 1 | 8 | 1 | 48 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE1 | A | Von2, Voff2, Von3, Voff3, Von4 and Voff4 | A | P |

**Notes:**

1) Writing new thresholds via command 0xE1 requires 6 bytes regardless of QTY of assigned PSUs assigned roles. Expressed as real world threshold current. Written in order: Von2, Voff2, Von3, Voff3, Von4 and Voff4
2) CAUTION: The Von, Voff default values are defined based on our test result for optimizing efficiency of a system with 2 to 4 PSUs. It therefore recommended the user use these default thresholds rather than write new thresholds.

## OFFLINE MODE:

In some applications, for example 1+1 redundant systems, it may be desirable to operate one PSU all the time and turn on the second PSU only in the event of a fault, including loss of AC while maintaining redundancy. In this case the system/host assigns one PSU as the Master, role "0x01" and then the remaining PSU as Cold-Standby role "0x02". Upon successful assignment, the Cold_Standby PSU rapidly turns off output and will rapidly become active upon occurrence of any fault, within 100uS (before output bus falls out of regulation).

PMBus™ Role assignment:

**Step one:**

| 1 | 7 | 1 | 1 | 8 | 1 | 8 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE0 | A | ROLE 0x01 (Master PSU) | A | P |

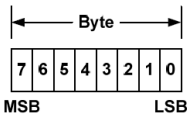
**Step two**

| 1 | 7 | 1 | 1 | 8 | 1 | 8 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|
| S | Slave Address | W | A | 0xE0 | A | ROLE 0x02 (Cold_Standby PSU) | A | P |

**Role Summary:**
**MASTER** (byte 0x01) At least one (1) PSU must be assigned this role, aka "Always On"
**COLD_ STANDBY:** (byte 0x02) wakes up upon any fault raised by the master by forcing CR_BUS high.

## PMBus™ Protocol Definitions (Reference PMBus part 1 Revision V1.2)

| Symbol | Meaning |
|---|---|
| 7 | A vertical rectangle indicates a single bit sent from the host (bus master) to a slave |
| 7 | A vertical rectangle with a shaded interior indicates a bit sent from a slave device to the bus master. |
| 7 | A rectangle with a number over it represents one or more bits, as indicated by the number |
| S | The START condition sent from a bus master device |
| Sr | A REPEATED START condition sent from a bus master device |




| Symbol | Meaning |
|---|---|
| A | An Acknowledge (ACK) condition send from the host |
| NA | A Not Acknowledge (NACK) condition sent from the host |
| A | An Acknowledge (ACK) condition sent from a slave device |
| NA | A Not Acknowledge (NACK) condition sent from a slave device |
| P | A STOP condition sent by a bus master device |
| 7 SLAVE ADDRESS | The first seven bits of the address byte, generally corresponding to the physical address of the device. |
| R | The bit [0] of the address byte with a value of 1, indicating the device is being addressed with a read. |
| W | The bit [0] of the address byte with a value of 0, indicating the device is being addressed with a write. |
| 7 BROADCAST ADDRESS | The SMBus broadcast address to which all devices must respond. The value is 0000000b. This is always used only with the bit [0] equal to 0 (write). |

## General CR Notes:

1) Extraction of a PSU will not cancel CR mode as long as it is not the ACTIVE & MASTER and does not cause OCP Fault
2) Power supply insertion: A previously configured COLD_STANDBY PSU can be extracted and re-inserted without issue as long as AC input remains connected as the input power maintains secondary side DSP operation. Likewise if input voltage be removed, the PSU "forgets" it's CR role and will power up as STD redundancy. In that situation, the other PSUs are operating in CR mode, and so the last PSU inserted will attempt to load share, but to what degree is indeterminate. Therefore that PSU role needs to be reassigned.
3) Recycling of AC or DC input has this effect:
    a. ACTIVE & MASTER PSU will force the CR_BUS to HIGH state and cancel CR mode.
    b. The other PSUs will turn on their main outputs and share load conventionally.
    c. If a COLD_STANDBY unit has it's input recycled, CR operation will continue and the connected PSUs will maintain their status/role.. Upon applying the input voltage, this PSU will need it's role reassigned otherwise it's load share degree is indeterminate.
4) System/host can cancel CR mode and force standard redundancy by re-assigning COLD_REDUNDANT or MASTER PSU as STANDARD REDUNDANCY ( role byte: 0x00)
5) PMBus™ FAULTS, cancel CR mode by forcing the CR_BUS high
6) PMBus™ WARNINGS do not impact CR mode.
7) "Cold_Redundant_x" Roles can be assigned either of the three "x" levels, useful in deployments of <4 PSUs. However the PSU assigned the role as "ACTIVE" must be assigned first.
8) The first PSU role assigned must be assigned role MASTER PSU
9) Once the COLD_REDUNDANT and MASTER PSU roles have been set, the CR_BUS must be set to high state by the Mater and cleared in order to reassign this role.
10) Conventional sharing mode is activated (CR mode cancelled) upon any of these events:
    a. PSU fault (Pull CR_BUS HIGH, causing all PSU's to be on within 100uS)
    b. Reassigning the MASTER PSU to COLD_STANDBY_x
    c. Loss of input power to the MASTER PSU
    d. Extracting the MASTER PSU
11) Indicators of CR mode operation:

| VISUAL INDICATION PMBUS™ REGISTER & OR VISUAL | ACTIVE_MASTER / ACTIVE & SLAVE COLD REDUNDANT ACTIVE | COLD STBY / FORCED STBY |
|---|---|---|
| LED (Visual) | On Solid | Blinks 2hz |
| Fan (PMBus™) | Fan rotation | No fan rotation |
| Output current main (PMBus™) | Output load detected | No load current |
| Main output voltage (PMBus™) | Nominal 12VDC output | Nominal 12VDC output |

Murata Power Solutions, Inc.
129 Flanders Road
Westborough, MA 01581
ISO 9001 and 14001 REGISTERED