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## Revision history

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<th>Revision date</th>
<th>Page</th>
<th>Change</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/16/2005</td>
<td></td>
<td></td>
<td>Initial release</td>
</tr>
</tbody>
</table>

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This publication explains the protocol design of the PLUS+1 CAN I/O communication. It will show the necessary parts of the design and their interaction.

### Applicable documents

| DM  | SPRS1741 (i) | TMS320F2810 TMS320F2812 - Digital Signal Processors Data Technical Information (Texas Instruments) |

### References

| SFS  | D-270405-1, 1.14 | Smart Flash loader Specification (Smart GmbH) |
| DS301 | DS301, 4.00 | Application Layer and Communication Profile CiA (CAN in Automation) 2.0 |
| J1939 | J1939-21 | Surface Vehicle Recommended Practice – J1939-21 (SAE) |

### Definitions and abbreviations

| CAN  | Controller Area Network |
| CRC  | Cyclic Redundancy Check |
| CPU  | Central Processing Unit |
| ECU  | Electronic Control Unit |
| EEPROM | Electrically Erasable and Programmable Read Only Memory* |
| Kernel | Set of hardware dependant driver functions and operating system |
| OTP  | One-Time Programmable |
| RAM  | Random Access Memory |
| ROM  | Read Only Memory |
| LSB  | Least Significant Byte |
| MSB  | Most Significant Byte |
| PDO  | Process Data Object (CAN Open Terminology) [DS301] |
| Tx   | Transmit |
| Rx   | Receive |
| I/O  | Input/Output |
| MC   | Master Controller in the network (for example: MC024-010 or MC050-010) |
| 0x   | In front of a number defines a base 16 number (hexadecimal) |
| CAN-Bx | CAN Data Byte number X, counting of these bytes start from zero |

* This phrase is still used, even if the selected device is re-programmable
Besides the programmable members of the microcontroller family like the MC024-010 and MC050-010, the PLUS+1 platform needs different I/O expander modules. There is always the chance that some additional requirements will need extra inputs or outputs to the system. If the controllers already in the system are out of I/O, it may make sense to add an inexpensive I/O module to the system rather than stepping up to a higher performance controller.

**CAN-architecture**

![CAN-architecture diagram](image)

**SYSTEM CONTEXT**

**PLUS+1 family with five different I/O units**

<table>
<thead>
<tr>
<th>Module Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX012-010-00000</td>
<td>12 pin input</td>
</tr>
<tr>
<td>IX024-010-00000</td>
<td>24 pin input</td>
</tr>
<tr>
<td>OX012-010-00000</td>
<td>12 pin output</td>
</tr>
<tr>
<td>OX024-010-00000</td>
<td>24 pin output</td>
</tr>
<tr>
<td>IOX012-10-00000</td>
<td>12 pin input/output</td>
</tr>
</tbody>
</table>

You can use more than one I/O device in the same network. It is also possible in *Sauer-Danfoss only networks* to replace one unit without additional service actions.

**CAN-bus with several PLUS+1 MC and I/O Modules**

**Service tool interface**

![CAN-bus diagram](image)

The I/O modules have a bootloader program. You can update the firmware using the PLUS+1 service and diagnostic tool. Use the downloader from the service tool to load a new .Ihx file.

*Sauer-Danfoss only network means that only PLUS+1 compliant units are connected on the CAN-bus.*
Service tool interface (continued)

You can also use the service tool to change the default addressing mode of the I/O modules. This might be necessary in some circumstances. The service tool and the desired I/O module must be the only devices on the CAN-bus. You can also use the service tool to monitor the configuration and status of the outputs.

To use the service tool, you must first save the diagnostic (.p1h) file for the specific I/O module hardware that you are using. This file is available under the misc files in the hardware tab on the right side of the PLUS+1 GUIDE screen. Right click on the file and save it to your local hard drive.

PLUS+1 miscellaneous files screen example

Now that the file is saved to the local hard drive, open it with the service tool.

Remember that it is a .p1h file, not a .p1d file. (.p1h indicates that it is associated with a particular hardware, not an application.)

When you open the .p1h file you may get the following dialog box.

PLUS+1 GUIDE dialogue box example
Service tool interface (continued)

Simply click the drop down box on the right and select the actual hardware that is in your system. The reason for this is that the CAN-ID of the numeral 0 (zero) on the left doesn’t match the CAN-IDs that are in your system. You need to tell it where the I/O module that you are selecting is located.

Next, you can click on the Parameter function for your I/O module in the diagnostic navigator. This will bring up a parameter list for the I/O module.

This parameter screen will allow you to view and change all of the configuration data for the I/O module.

PLUS+1 GUIDE parameter list screen example

Any change of the communication parameters requires a restart of the I/O device for the changes to take effect.
**CAN-ID**

To minimize the number of CAN identifiers (CAN-ID) used, each I/O device uses just one CAN-ID to transmit data.

To run several devices on one network, each needs a different CAN-ID. After production all units start with the same standard default addressing mode. In the default addressing mode the devices scan the CAN-shield pin at startup and measure the voltage level at this pin. The CAN-ID is set based on this voltage. The default startup configuration is designed to create no conflicts with existing higher layer protocols in regards to the CAN-ID usage.

The addressing mode can be changed with the service tool to a set of default identifiers.

*Default configuration flow chart*

1. **Reset**
2. **Startup**
   - **Standard addressing mode**
     - Yes
     - **ID via CAN-shield**
       - Yes
       - **Get N1 out of EEPROM**
       - **SCAN CAN-shield**
         - **Calculate N1**
         - **Evaluate mask**
       - **No**
         - **Get Tx/Rx ID out of EEPROM**
         - **Start I/O protocol**
     - **No**
   - **No**
     - **Get N1 out of EEPROM**
     - **SCAN CAN-shield**
       - **Calculate N1**
       - **Evaluate mask**
     - **Start I/O protocol**
The default startup configuration of I/O devices is designed to create as few conflicts as possible with existing higher layer protocols in regards to the CAN-ID usage. Due to the restricted CAN-ID range, the system will use the first data byte as a kind of sub-identifier. Non time-critical messages and configuration messages use a special sub-identifier (0xFF) to enter a new page of commands. In this page the second data byte works as a sub-command.

**CAN-ID USAGE**

The I/O device can provide up to three different ways of using the CAN-ID.

**Variable identifier usage define with CAN-shield**

In the default configuration the system uses 11-bit identifiers according to CAN2.0 Part A. The usage of 11-bit identifiers means that the communication happens in the proprietary area of SAE J1939. To work in parallel on a CAN-open bus, the addressing scheme works on PDO (DS301).

The CAN-open default PDOs (CAN-IDs) are defined with a function code (bit 10...bit 7) and the node ID (bit 6...bit 0).

**PDO CAN-ID**

<table>
<thead>
<tr>
<th>PDO CAN-ID</th>
<th>Most significant bit</th>
<th>Least significant bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDO1 Tx</td>
<td>0x10+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO1 Rx</td>
<td>0x20+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO2 Tx</td>
<td>0x30+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO2 Rx</td>
<td>0x40+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO3 Tx</td>
<td>0x50+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO3 Rx</td>
<td>0x60+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO4 Tx</td>
<td>0x70+node ID</td>
<td></td>
</tr>
<tr>
<td>PDO4 Rx</td>
<td>0x80+node ID</td>
<td></td>
</tr>
</tbody>
</table>

CAN-open allows the node ID to range from 1 to 127.

The I/O devices will use PDO1 Tx to transmit and PDO2 Rx for receive. This avoids collision if someone in a proprietary system uses a node ID larger than 127.

**PDO Node ID usage**

The node ID consists of 7 bits. The node ID is divided into two sections

a) to address the requirements of different devices on the same network
b) so that one device is able to listen to more than one MC
PDO CAN-ID with divided node-id

**Most significant bit**

<table>
<thead>
<tr>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>P</td>
<td>P</td>
<td>N1</td>
<td>N1</td>
<td>N1</td>
<td>N0</td>
<td>N0</td>
<td>N0</td>
<td>N0</td>
<td>N0</td>
</tr>
</tbody>
</table>

**Least significant bit**

Bit definition

- **P**: 4 bits - PDO
- **N1**: 4 bits - node ID defined by voltage
- **N0**: 3 bits - node ID defined for multi MC receive communication

**N0 definition**

N0 is always set to zero for the PDO1 Tx message. N0 is also zero for the standard PDO2 Rx message, but it is possible to apply the mask value to receive all possible configurations for N0.

**N0 usage in PDO**

<table>
<thead>
<tr>
<th>N0</th>
<th>Tx</th>
<th>Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>Default, valid</td>
<td>Default, valid</td>
</tr>
<tr>
<td>0x01</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x02</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x03</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x04</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x05</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x06</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
<tr>
<td>0x07</td>
<td>Invalid</td>
<td>Only with masking</td>
</tr>
</tbody>
</table>

**N1 definition**

N1 is always assigned at start-up by scanning the analog/shield input. The input range is divided into 16 equal sections, each with a size of 300 mV, starting at 0 V. Any voltage higher than 4.5 Vdc will be interpreted as the highest input value.

**N1 calculation**

<table>
<thead>
<tr>
<th>AD-input low value (mV)</th>
<th>AD-Input high value (mV)</th>
<th>N1</th>
<th>N1 (hex)</th>
<th>N1 (hex pos)</th>
<th>Tx</th>
<th>Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>299</td>
<td>0</td>
<td>0x00</td>
<td>0</td>
<td>0x0180</td>
<td>0x300</td>
</tr>
<tr>
<td>300</td>
<td>599</td>
<td>1</td>
<td>0x01</td>
<td>0x08</td>
<td>0x0188</td>
<td>0x308</td>
</tr>
<tr>
<td>600</td>
<td>899</td>
<td>2</td>
<td>0x02</td>
<td>0x10</td>
<td>0x0190</td>
<td>0x310</td>
</tr>
<tr>
<td>900</td>
<td>1199</td>
<td>3</td>
<td>0x03</td>
<td>0x18</td>
<td>0x0198</td>
<td>0x318</td>
</tr>
<tr>
<td>1200</td>
<td>1499</td>
<td>4</td>
<td>0x04</td>
<td>0x20</td>
<td>0x01A0</td>
<td>0x320</td>
</tr>
<tr>
<td>1500</td>
<td>1799</td>
<td>5</td>
<td>0x05</td>
<td>0x28</td>
<td>0x01A8</td>
<td>0x328</td>
</tr>
<tr>
<td>1800</td>
<td>2099</td>
<td>6</td>
<td>0x06</td>
<td>0x30</td>
<td>0x01B0</td>
<td>0x330</td>
</tr>
<tr>
<td>2100</td>
<td>2399</td>
<td>7</td>
<td>0x07</td>
<td>0x38</td>
<td>0x01B8</td>
<td>0x338</td>
</tr>
<tr>
<td>2400</td>
<td>2699</td>
<td>8</td>
<td>0x08</td>
<td>0x40</td>
<td>0x01C0</td>
<td>0x340</td>
</tr>
<tr>
<td>2700</td>
<td>2999</td>
<td>9</td>
<td>0x09</td>
<td>0x48</td>
<td>0x01C8</td>
<td>0x348</td>
</tr>
<tr>
<td>3000</td>
<td>3299</td>
<td>10</td>
<td>0x0A</td>
<td>0x50</td>
<td>0x01D0</td>
<td>0x350</td>
</tr>
<tr>
<td>3300</td>
<td>3599</td>
<td>11</td>
<td>0x0B</td>
<td>0x58</td>
<td>0x01D8</td>
<td>0x358</td>
</tr>
<tr>
<td>3600</td>
<td>3899</td>
<td>12</td>
<td>0x0C</td>
<td>0x60</td>
<td>0x01E0</td>
<td>0x360</td>
</tr>
<tr>
<td>3900</td>
<td>4199</td>
<td>13</td>
<td>0x0D</td>
<td>0x68</td>
<td>0x01E8</td>
<td>0x368</td>
</tr>
<tr>
<td>4200</td>
<td>4499</td>
<td>14</td>
<td>0x0E</td>
<td>0x70</td>
<td>0x01F0</td>
<td>0x370</td>
</tr>
<tr>
<td>4500</td>
<td>—</td>
<td>15</td>
<td>0x0F</td>
<td>0x78</td>
<td>0x01F8</td>
<td>0x378</td>
</tr>
</tbody>
</table>
**Predefined identifier usage with fixed N1**
In this configuration the N1 portion of the CAN identifier is predefined by Sauer-Danfoss. It can be adjusted by the OEM with the PLUS+1 service and diagnostic tool.

**Fixed identifier usage**
This special configuration works only with fixed identifiers. These identifiers are configurable with the diagnostic tool. Also in this configuration it is possible to apply a mask for receiving messages. It is also possible to select between 11 bit and 29 bit identifiers.

**KWP2000 NODE and NET ASSIGNMENTS**
In addition to the I/O protocol the I/O devices also need to support the PLUS+1 service and diagnostic tool protocol. This is based on KeyWord Protocol 2000 (KWP2000.) Basic parameters for this are the *node* and *net* number. The following sections describe how these numbers are assigned.

**KWP2000 node number**
The node number is assigned by using N1 as the KWP2000 node number as shown below in variable identifier and predefined identifier addressing mode:

<table>
<thead>
<tr>
<th>KWP2000 node number</th>
<th>Least significant bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X N1 N1 N1 X X X</td>
</tr>
</tbody>
</table>

**KWP2000 net number**
The net number is stored as a parameter in the non-volatile memory and can be modified with the PLUS+1 service and diagnostic tool.

**LED HANDLING**
To simplify system diagnostics the I/O device will use its LEDs, if available, to indicate different status conditions.

**Red LED**
The red LED indicates outgoing message traffic from the I/O device. The LED toggles its state with every successfully transmitted frame.

If the device's CAN-bus goes into a *bus off* condition then the LED will be permanently on.

**Green LED**
The green LED indicates that the I/O device is seeing incoming message traffic. The LED toggles its state with every successfully received frame. If no messages are received for more than 10 seconds, then the LED starts to blink at a one Hertz rate. Time critical messages and messages which have to be used all the time are implemented with a sub identifier which has a value from 0 to 0xFE.
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