DS1104 R&D Controller Board

Hardware Installation and Configuration

For DS1104 and CP1104/CLP1104 Connector Panels

Release 4.1 – March 2004

How to Contact dSPACE

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How to Contact dSPACE Support

dSPACE recommends that you use dSPACE Support Wizard to contact dSPACE support.
It is available

- On your dSPACE CD at \Diag\Tools\dSPACESupportWizard.exe
- Via Start – Programs – dSPACE Tools (after installation of the dSPACE software)
- At http://www.dspace.de/goto?supportwizard
  You can always find the latest version of dSPACE Support Wizard here.

Software Updates and Patches

dSPACE strongly recommends that you download and install the most recent patches for your current dSPACE installation. Visit http://www.dspace.de/goto?support for software updates and patches.

Important Notice

Contents

Documentation Overview

dSPACE offers different types of documents: see *Documentation Types* on page 8.

For a brief description of this document, see *About This Document* on page 10.

For more information on the documents that are available when you work with the DS1104 R&D Controller Board, see *Related Documents* on page 11.

Documentation Types

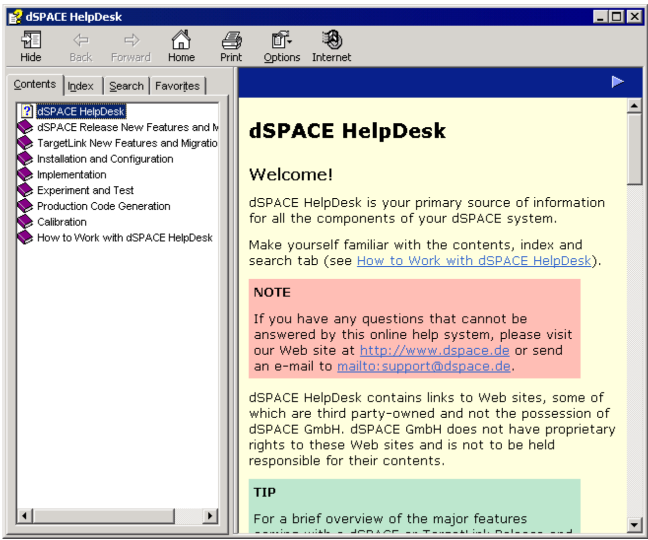
After you install your dSPACE system, you can access the entire documentation as online help or printable Adobe PDF files. You will also receive a printed version of some important documents.

dSPACE HelpDesk

The dSPACE HelpDesk is your primary source of information on both the hardware and the software of your dSPACE system.

To open dSPACE HelpDesk

➤ Select **dSPACE HelpDesk** from the **dSPACE Tools** program group of the Windows Start menu.



From each HelpDesk page, you can easily search and navigate to the desired information. You also have direct access to printable Adobe PDF files: see *How to Work with dSPACE HelpDesk* in the dSPACE HelpDesk.

Only the documents of the products installed on your system are available. The entire product documentation is available if you open the HelpDesk on the dSPACE CD.

HelpDesk structure

The structure of the documents in the HelpDesk reflects the different phases of your work:

- Installation and Configuration
- Implementation
- Experiment and Test
- Production Code Generation
- Calibration

The topics that are shown depend on your dSPACE system.

Context-sensitive help

When you work with any dSPACE software, you can get context-sensitive help via the F1 key and/or Help button.

PDF Files

All documents are also available as printable Adobe PDF files in the `%DSPACE_ROOT%\Doc\Print` folder: see *How to Work with dSPACE HelpDesk* in the dSPACE HelpDesk.

Printed Documents

You will receive a printed version of the documents that are essential for working away from your PC.

About This Document

This document will show you the installation of the DS1104 R&D Controller Board and CP1104/CLP1104 Connector Panels.

It describes the hardware installation procedure, shows how to configure the system, and explains how to get started with your dSPACE system using an appropriate example. It also gives you information about connecting external devices to the dSPACE system.

Knowledge in handling the host PC and the Microsoft Windows operating system is presupposed.

Legend

The following symbols are used in this document.

Warnings provide indispensable information to avoid severe damage to your system and/or your work.

Notes provide important information that should be kept in mind.

Tips show alternative and/or easier work methods.

Examples illustrate work methods and basic concepts, or provide ready-to-use templates.

Related Documents

The following provides a list of documents that you are recommended to read when working with the DS1104:

Software Installation and Management

- *dSPACE Software Installation and Management Guide* provides detailed instructions on installing and handling the dSPACE software. It also shows you how to manage dSPACE licenses.

Features

- *DS1104 Features* provides feature-oriented access to the information you need to implement your control models on your real-time hardware.

RTI and RTI-MP

- *RTI and RTI-MP Implementation Guide* gives detailed information and instructions on how to use Real-Time Interface (RTI and RTI-MP) to implement your control models.
- *RTI and RTI-MP Implementation Reference* offers reference information on the various dialogs, files, options, etc. of Real-Time Interface (RTI and RTI-MP) for dSPACE systems. It also describes the blocks introduced by RTI-MP.
- *DS1104 RTI Reference* provides concise information on the board's RTI library.

RTLib

- *DS1104 RTLib Reference* provides detailed descriptions of the C functions needed to program RTI-specific Simulink S-functions or implement your control models manually via C programs (handcoding).

ControlDesk Standard

- *ControlDesk Experiment Guide* introduces you to the experiment features provided by ControlDesk Standard.
- *ControlDesk Automation Guide* shows you how to automate the features provided by ControlDesk Standard.
- *ControlDesk Reference*, *ControlDesk Instrument Reference* and *ControlDesk Automation Reference* provide detailed information on the menus, context menus, dialogs and Python libraries contained in ControlDesk Standard.

AutomationDesk

- *AutomationDesk Automation Guide* introduces you to the automation features provided by AutomationDesk.
- *AutomationDesk Tutorial* has several lessons that guide you through using AutomationDesk.

- *AutomationDesk Reference* provides detailed information on the menus, context menus, and dialogs contained in AutomationDesk.
- *AutomationDesk Library Reference* provides detailed information on the libraries supported by AutomationDesk.

Interface libraries

- *MLIB/MTRACE MATLAB-dSPACE Interface Libraries* contains detailed reference information and instructions on the experiment features of MLIB/MTRACE.
- *CLIB C Interface Library* contains detailed reference information on the C Interface Library CLIB, which contains C functions to access the dSPACE processor and controller boards from the host PC.

Introduction to the DS1104

The dSPACE system based on the DS1104 R&D Controller Board comprises hardware and software.

- For a short introduction to the hardware components of the DS1104, refer to *Hardware* on page 14.
- For information on the software, refer to *Software* on page 16.

Hardware

The DS1104 R&D Controller Board is a standard board that can be plugged into a PCI slot of a PC. The DS1104 is specifically designed for the development of high-speed multivariable digital controllers and real-time simulations in various fields. It is a complete real-time control system based on a 603 PowerPC floating-point processor running at 250 MHz. For advanced I/O purposes, the board includes a slave-DSP subsystem based on the TMS320F240 DSP microcontroller.

For purposes of rapid control prototyping (RCP), specific interface connectors and connector panels (see below) provide easy access to all input and output signals of the board. Thus, the DS1104 R&D Controller Board is the ideal hardware for the dSPACE Prototyper development system for cost-sensitive RCP applications.

To demonstrate control design and implementation, demo equipment (VCFP Simulator) is available for the DS1104.

Easy access to input and output signals

Using an adapter cable you can link your external signals from the 100-pin I/O connector on the board to Sub-D connectors. So you can make a high-density connection between the board and the devices of your application via Sub-D connectors.

Specific interface connector panels provide easy access to all the input and output signals of the DS1104 R&D Controller Board.

- The CP1104 **C**onnector **P**anel provides easy-to-use connections between the DS1104 R&D Controller Board and devices to be connected to it. Devices can be individually connected, disconnected or interchanged without soldering via BNC connectors and Sub-D connectors. This simplifies system construction, testing and troubleshooting.
- In addition to the CP1104, the CLP1104 **C**onnector/**L**ED Combi **P**anel provides an array of LEDs indicating the states of the digital signals.

Shipment

The DS1104 R&D Controller Board is a single-board system. The hardware package contains:

- One PCI-slot board with a bracket including a 100-pin I/O connector.
- One adapter cable with two 50-pin female Sub-D connectors. The adapter cable is optional.
- Only if ordered: CP1104 (or CLP1104) Connector Panel with adapter cable to the I/O connector of the board.

Software

The dSPACE software, such as the implementation and the experiment software, comes on CD-ROM and has to be installed first. For information on the software package, the installation and license handling, refer to *Introduction to dSPACE Software* in the *dSPACE Software Installation and Management Guide*.

Safety Precautions

To avoid risk of injury and/or damage to the dSPACE hardware, read and ensure that you comply with the following safety precautions.

Safety Precautions for Installing and Connecting the Hardware

Installation sequence

- Install the components of your system in exactly the order stated. Any other sequence may lead to unpredictable results or even damage the system.
- Read the instructions carefully before starting installation.
- Note all warnings given.

Handling boards

dSPACE boards contain sensitive electronic devices. Before unpacking, installing and removing them, take the following precautions to avoid damage caused by high electrostatic voltage:

- Make sure that you and all material the board comes in contact with are properly grounded.
- During storage or handling, place the board on conductive foam or in a protective bag.
- Do not touch the board connectors.

Improper handling will damage the fan of the board.

- Do not touch any components of the fan, neither during operation nor when it has stopped.
- Do not try to stop a rotating fan with your fingers or with the help of tools.
- Do not apply pressure to the fan bearing during installation and removal of the board.

Installing hardware

Before doing any installation work, make sure that:

- The power supply of the host PC is switched off.
- No external devices are connected to the dSPACE system.

Connecting devices

To avoid risk of injury and prevent damage to the hardware:

- Do not connect any high-voltage devices to the I/O connectors of the hardware.
- Do not apply voltages/currents outside the specified ranges to the connector pins.
- Do not connect or disconnect any devices while the dSPACE System is powered up and/or external devices are switched on. Make sure that the PC and external devices are turned off beforehand.

Safety Precautions for Using Connector Panels

To avoid damage to the hardware and to achieve safe and trouble-free operation, the following guidelines must always be observed:

- Before connecting a panel to a board, make sure that the PC is turned off and no external devices are connected to the panel.
- No chemicals other than alcohol (ethanol or isopropanol) should be used to remove writing from the panel templates, since they might damage the permanent print on the templates or even corrode the panel.
- Guard against foreign objects (staples, etc.) falling or blowing into the unit, or liquids being spilled into it.
- Do not expose the panel to excessive dust or moisture.

Before You Start

Before you start:

- Make yourself familiar with the installation and configuration procedures of the DS1104 R&D Controller Board. Refer to *Installation and Configuration Overview* on page 22.
- Check if your system fulfills the system requirements. Refer to *Checking the System Requirements* on page 24.

Installation and Configuration Overview

CAUTION! Changing the installation sequence may lead to unpredictable results or even damage the system.

- Install the components of your system in exactly the order stated.
- Read the instructions carefully before starting installation.
- Consider all warnings given.

Installation sequence

Installing the DS1104 requires the following steps in the specified order.

1. Check whether the software has been installed on the host PC.

   You must first install the software before installing any hardware component in the host PC. For detailed instructions on installing the software, refer to *Installing dSPACE Software* in the *dSPACE Software Installation and Management Guide*.

   You need administrator rights to install dSPACE software.

2. Check whether your hardware meets the requirements for DS1104. Refer to *Checking the System Requirements* on page 24.
3. Now you can install the hardware. Refer to *Installing the Hardware* on page 25
4. To verify that your system works correctly, it is recommended that you load a check application to your board. For detailed instructions, refer to *Verifying the System* on page 31.

If you encounter any problems during installation and configuration:

- Check the description again.
- Contact dSPACE support using the dSPACE Support Wizard. It is available
  - On your dSPACE CD at `\Diag\Tools\dSPACESupportWizard.exe`
  - Via **Start – Programs – dSPACE Tools** (after installation of the dSPACE software)

External devices

For information on connecting external devices of your application to the dSPACE system, refer to *Connecting External Devices to the dSPACE System* on page 71.

Checking the System Requirements

Before installing dSPACE's hardware, you have to check whether your hardware meets the system requirements.

Host PC

Your host PC must fulfill the system requirements concerning the dSPACE software, other required third-party software and the hardware equipment.

For details, refer to *Checking the System Requirements* in the *dSPACE Software Installation and Management Guide*.

It is not possible to install the DS1104 in an expansion box.

Installing the Hardware

The DS1104 must be installed in the host PC. For detailed instructions refer to *How to Install the DS1104* on page 26.

If you use a connector panel for connecting the external devices to the dSPACE system, refer to *Connecting a Connector Panel to the Board* on page 28.

You can install the connector panels in a standard 19” industry rack. For details, see *How to Mount a Panel in a 19'' Rack* on page 30.

How to Install the DS1104

The following instructions will guide you through the installation of the DS1104 R&D Controller Board.

You install the board at your own risk. In the event of any damage caused by improper handling, dSPACE cannot be held liable.

Working with more than one dSPACE board in plug & play configuration may cause assignment problems. For details, refer to *Problems with Multiple Plug & Play Boards* on page 165.

You can install as many DS1104 boards as free PCI slots are available in your host PC.

Preconditions

- The host PC is switched off.
- Precautions are taken to avoid damage by high electrostatic voltages. For details, refer to *Safety Precautions for Installing and Connecting the Hardware* on page 18

Method

To install the DS1104 in the host PC

WARNING! Hazardous voltages.

Risk of electric shock and/or damage to the hardware.

Before doing any installation work, make sure that:

- The power supply of the host PC is switched off.
- No external device is connected to the dSPACE system.

1 Open the enclosure of the PC.

CAUTION! Improper handling will damage the fan of the board.

- Do not touch any components of the fan, neither during operation nor when it has stopped.
- Do not apply pressure to the fan bearing during installation and deinstallation of the board.

2 Select an unused 32-bit PCI slot.

PCI slots are shorter than ISA or EISA slots and typically white.

3 Unscrew and remove the bracket that covers the card-slot opening on the rear side of the enclosure.

4 Insert the board in the slot. Press it down firmly so that the contacts are securely seated in the slot.

5 When the board is firmly seated in the slot, secure the bracket with the screw you removed in step 4.

6 Close the enclosure and reconnect the PC to the power supply.

7 Turn on the host PC.

The host PC should boot as usual. Now you can run ControlDesk to verify the installation, see *Verifying the System* on page 31.

If the PC does not boot, switch off the power supply immediately and check that the board is inserted firmly.

For information on connecting external devices to the I/O connector of the DS1104, see *How to Connect External Devices to a Board* on page 72.

Connecting a Connector Panel to the Board

The CP and CLP connector panels provide easy-to-use connections between the board and external devices. Devices can be individually connected, disconnected or interchanged without soldering. This simplifies system construction, testing and troubleshooting.

The CLPs additionally provide arrays of LEDs, which indicate the states of the digital signals.

Connecting CP/CLP to a board

After you have installed the board in the host PC, you can connect the accompanying panel to the board. For detailed instructions, refer to *How to Connect a Panel (CP, CLP) to a Board* on page 29.

Mounting panels in a rack

As a standard, the CP and CLP connector panels are installed in a desktop box made from aluminum profiles. They can optionally be mounted in a 19" industry rack. For instructions, refer to *How to Mount a Panel in a 19'' Rack* on page 30.

For the connector pinouts of CP1104/ CLP1104, refer to *CP1104/CLP1104 Connectors* on page 88

How to Connect a Panel (CP, CLP) to a Board

For safe and trouble-free operation of the panels, various guidelines must be observed. For details, refer to *Safety Precautions for Using Connector Panels* on page 19.

Precondition The system is switched off.

Method **To connect a panel to the DS1104**

CAUTION! Connecting external devices while the power supply is switched on may damage the dSPACE hardware.

- Do not connect or disconnect any device while the power supply is switched on.
- Turn off the host PC and the external devices beforehand.

1. If the panel is to be mounted in a 19" rack, this should be done first (see *How to Mount a Panel in a 19'' Rack* on page 30).
2. Plug the CP1104 or CLP1104 to the DS1104 and tighten the lock screws. Take care not to mix up the connectors of the DS1104. Connectors are installed correctly when ribbon cables are not twisted and do not cross over each other. Furthermore, the connectors are marked by labels P1A, P1B, etc.
3. Put templates on the panel. Turn the black clips on the panel through 90 degrees to secure the templates to the panel.
4. Now you can connect devices to the panel. For detailed instructions, refer to *How to Connect External Devices to a Connector Panel* on page 74.

Next step Now you can switch on the dSPACE system.

How to Mount a Panel in a 19'' Rack

As a standard, the CP1104 or CLP1104 Connector Panels are installed in a desktop box made from aluminum profiles. They can optionally be mounted in a 19" industry rack.

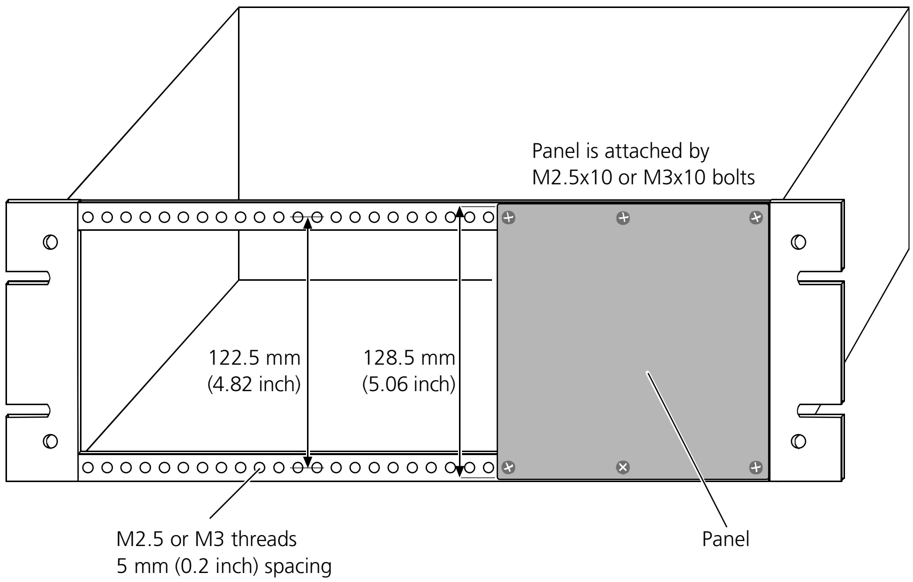
Preconditions

- The system is switched off.
- All connections to external devices are removed.

Method

To mount panels in a standard 19" industry rack

1. Remove the aluminum box. To do so, unscrew one of its side panels (4 screws). If there is a ribbon cable strain relief at the bottom of the box, it must be cut open.
2. Bolt the panel to the front of a 19" rack as shown below. Depending on the rack used, several M2.5x10 or M3x10 bolts are required.



Verifying the System

After the DS1104 R&D Controller Board is installed (see *How to Install the DS1104* on page 26), no further configuration is necessary.

Nevertheless you should check if your board is ready to run real-time applications.

Running ControlDesk

The dSPACE real-time hardware is managed by the Platform Manager integrated in ControlDesk. For information on how to access the Platform Manager, see *How to Run ControlDesk* on page 32.

Board properties

To view the current settings and properties of the boards in your system, see *How to View the Board Properties* on page 34.

Installation check

After you set the working board, check if your board is ready to run real-time applications: see *How to Verify the Installation* on page 37.

Updating the firmware

The DS1104 contains firmware installed in the flash memory of the board. If you install a new dSPACE Release it may contain newer firmware. In this case the firmware must be updated. Refer to *Updating the Firmware* on page 38.

How to Run ControlDesk

After installing the dSPACE software, ControlDesk is available in the Windows **Start** menu and as an icon on the desktop.

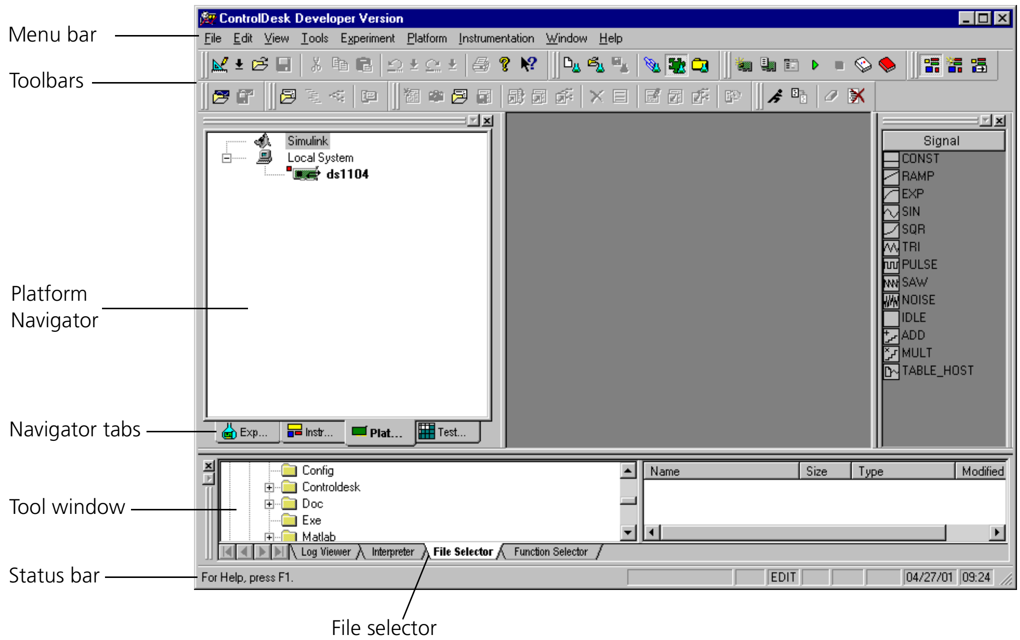
To start ControlDesk

1 In the Windows **Start** menu, choose **Programs** – **dSPACE Tools** – **ControlDesk**.

2 In the Navigator, click the **Platform** tab.

The Platform Navigator appears and displays the installed DS1104 R&D Controller Board icon.

The first DS1104 is named "ds1104". All following DS1104 boards are named "ds1104_xx" (xx = 2 ... 9).



With the Platform Navigator, it is possible:

- to register other dSPACE boards in your system that do not support plug & play.
- to download applications to your simulation platform manually.

For more information on ControlDesk and its features, refer to the *ControlDesk Experiment Guide*.

Working with more than one dSPACE board in plug & play configuration may cause assignment problems. For details, refer to *Problems with Multiple Plug & Play Boards* on page 165.

How to View the Board Properties

After installation, the board properties can be checked.

To view the board properties

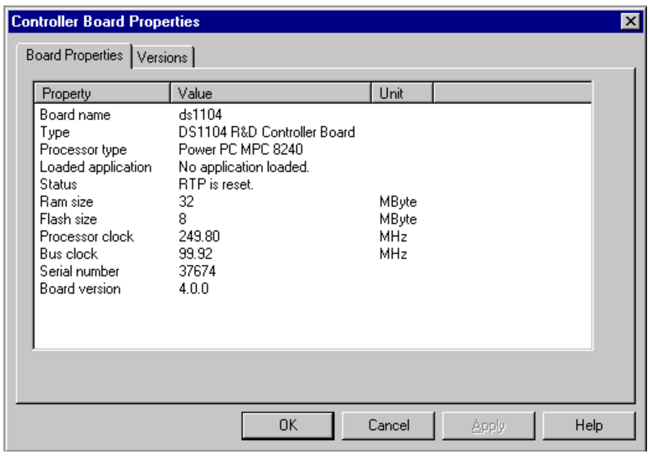
1. In the Platform Navigator, double-click the corresponding DS1104 icon to open the Controller Board Properties dialog.
2. In the **Controller Board Properties** dialog, check the accompanying pages.

You can also select the board on the **Platform** page of the **Navigator** and choose **Platform** – **Properties** from the menu bar.

The displayed entries cannot be changed.

Board Properties page

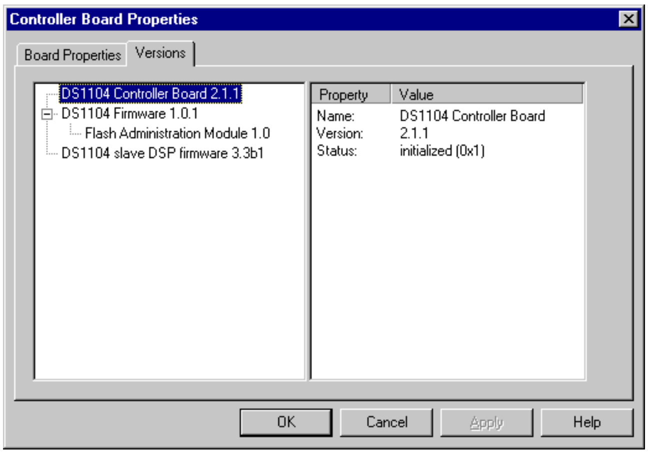
This page provides information on the hardware and the status of the board.



Versions page

This page provides information on the hardware and firmware versions that you currently use.

If an application is currently running, there is also information on the module versions it is based on.



dSPACE.ini file

The `dSPACE.ini` file describes the configuration - mostly board properties - of the platforms already registered, in the form of key-value pairs.

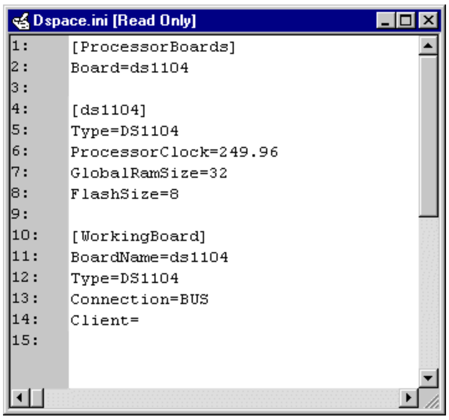
Initializing a DS1104 some properties of the board are entered into the `dSPACE.ini` file.

If you delete this file, you will have to reregister any boards that do not support plug & play. This does not apply if you use no other than DS1104 boards from dSPACE.

To view the dSPACE.ini file

➤ From ControlDesk's menu bar, choose **View – dSPACE.ini**.

The **Dspace.ini** window opens.



How to Verify the Installation

To verify whether your DS1104 R&D Controller Board works correctly, it is recommended that you load the system check application `smd_1104_ch.sdf`.

To verify the installation

1. In ControlDesk's **File Selector**, change to `%DSPACE_ROOT%\Demos\DS1104\Check\`, select the System Description file (SDF), and drag & drop it onto the DS1104 icon in the Platform Navigator.
2. In the Tool Window, select the **Log Viewer** page.

If no error message is displayed in the **Log Viewer**, the board is installed correctly.

Now your system is ready to run real-time applications on the DS1104.

Updating the Firmware

Usually your DS1104 board contains the latest firmware. If you install a new dSPACE Release it may contain newer firmware. In this case the firmware can be updated.

After you install the dSPACE Release, you can update the firmware.

The table below shows the path of the firmware installed from the dSPACE Release. You have to specify this path if you update your firmware manually.

Board	Firmware Type	Path of Firmware Coming with the dSPACE Release
DS1104	– Boot firmware – Slave DSP firmware	`%DSPACE_ROOT%\Ds1104\Firmware` `%DSPACE_ROOT%\Ds1104\SlaveDSP\Firmware`

Current version The firmware installed in the board's flash memory is the *current firmware version*. It is detected automatically by the Platform Manager.

Available version The firmware contained in your current dSPACE installation is the *available firmware version*. The Platform Manager detects it automatically.

Required version The firmware needed by an application you download to your real-time processor is the *required firmware version*. This information is shown on the Advanced page of the Firmware Management dialog.

The firmware is downward compatible: You can download an application to your hardware if the current firmware version is higher than or equal to the required firmware version.

Boot firmware Since Release 3.4, the flash application is no longer deleted by a firmware update. The flash application and the bootstrap code are saved before and loaded after the update.

Firmware update

If you download an application requiring a higher firmware version than the current one, you will get an error message. If your board contains user firmware, you will get an error message if the required firmware version is higher than that displayed in the **Based on dSPACE version** field in the **Current Firmware** frame of the Firmware Management dialog. In these cases, you have to update the firmware.

Automatic update

If you use the firmware provided by dSPACE, ControlDesk's Platform Manager will automatically update its firmware to the available version if the current version is lower than the available one. This is the default setting after you install the dSPACE software.

You can also switch off automatic updating. For details, see *Platform Manager Page* in the *ControlDesk Reference*.

Manual update

If you use user firmware or switched off automatic updating you will be prompted to update your firmware if the application you want to download requires a firmware version higher than the current one.

Verify boot firmware

Platforms that support boot firmware provide the Verify Boot Firmware command. You can call this feature via the context menu in the Platform Navigator and in several cases it is performed automatically. Refer to *Verify Boot Firmware* in the *ControlDesk Reference*.

How to Update the Firmware

You can update your firmware manually.

Method

To update the firmware manually

1. Select **Update Firmware...** from the context menu of the corresponding board in ControlDesk's Platform Navigator.

   The **Firmware Management** dialog opens.
2. From the **Select Firmware Type** list, select the firmware type you want to update.
3. In the **Object file** edit field, specify the path of the firmware to be downloaded to your board. Use the Browse button for this purpose.

The firmware path is set by default from the RTLib installation.

4. Click the **Update Firmware** button.

   The firmware will be updated to the available version.
5. When the update is complete, the **Close** button on the **Firmware Management** dialog is enabled. Click it to close the dialog.

You have to update the firmware for each firmware type individually.

Implementing and Handling Applications

After you install your system, you are ready to implement, download and experiment with your control algorithm.

Development Steps

1. The first step is to implement your control algorithm. For this purpose, you can either embed the blocks provided by dSPACE's Real-Time Interface (RTI) in a Simulink model or use RTLib's functions to handcode your application directly in C. For some basic information on this step, see *Implementing Models* on page 43.
2. Then build your model and download it to your dSPACE real-time hardware. For detailed instructions on how to download, start and stop an application, see *Handling Real-Time Applications* on page 50.

3. As soon as the real-time application is running on your hardware, you can use ControlDesk to experiment with it. For some basic information on how to create a ControlDesk experiment and observe the variables and change parameters of a running real-time application, see *Experimenting with ControlDesk* on page 59.

Implementing Models

Basically, there are two ways to create real-time applications to be implemented on your dSPACE hardware.

Using RTI

If you use MATLAB/Simulink for constructing control models, the C code is automatically generated by the Real-Time Workshop in conjunction with dSPACE’s Real-Time Interface (RTI). RTI is the interface between Simulink and the various dSPACE platforms. See *Implementing Simulink Models Using Real-Time Interface* on page 44.

Handcoding

An algorithm can also be handcoded in C. In addition to the necessary compilers, the tools required to generate object files are part of the dSPACE software. See *How to Implement C Models* on page 49.

Implementing Simulink Models Using Real-Time Interface

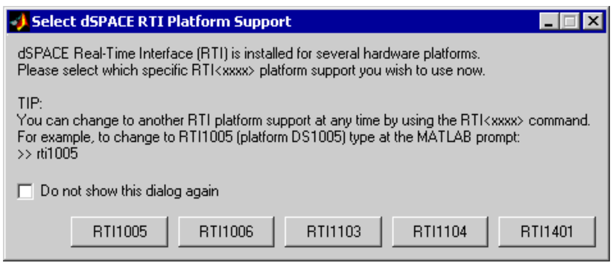
It is assumed that MATLAB, Simulink, Real-Time Workshop, and Real-Time Interface (RTI) for the DS1104 R&D Controller Board (RTI1104) are properly installed. See below and *How to Work with a Model* on page 46.

How to Start RTI1104

To start RTI1104, the following instructions apply.

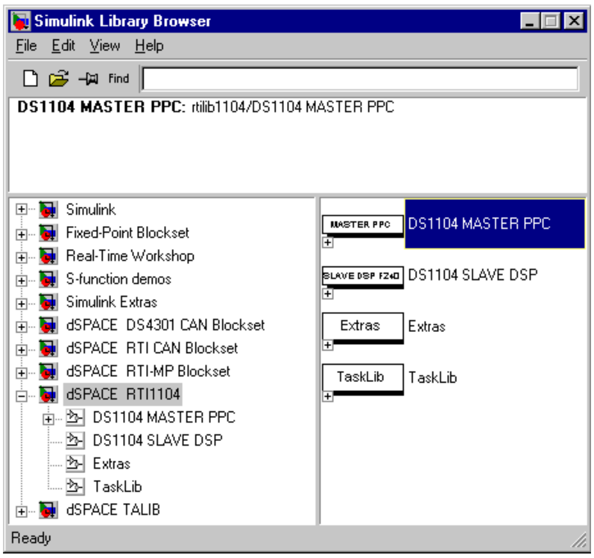
To start RTI1104

1. Make sure that the required licenses are available and activated. For information on handling the license mechanism, refer to *Protected Products and Required Licenses* in the *dSPACE Software Installation and Management Guide*.
2. Open ControlDesk (via **Programs – dSPACE Tools – ControlDesk** in the Windows **Start** menu) and specify the DS1104 as the working board (via **Platform – Set Working Board** from the menu bar). For details, see *How to Set the Working Board* in the *ControlDesk Experiment Guide*.
3. Start MATLAB.
4. In the **Select dSPACE RTI Platform Support** dialog, select **RTI1104**.



5 At the MATLAB prompt, enter **`simulink`**.

The **Simulink Library Browser** appears in a separate window.



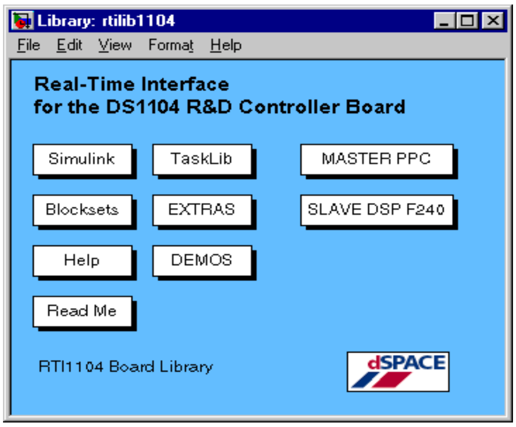
6 In the **Simulink Library Browser** window, you can click the +/– signs to browse through the dSPACE RTI1104 library.

You can also right-click a library icon and choose from the context menu **Open the <Name of the Library> Library** to open the corresponding library.

To open a dSPACE board library from the MATLAB prompt

➤ In the MATLAB Command Window, enter `rti1104`.

The dSPACE board library for the DS1104 is displayed.



The DS1104 board library contains information, demos and the icons available with the DS1104. Double-click the items to obtain more information.

To switch to another board library

➤ In the MATLAB Command Window, enter **`rti<Name of the Library>`** to start the appropriate library, for example **`rti1103`**.

How to Work with a Model

In the following, the demo model smd_1104_sl is used to describe how to use the RTI1104 board library. It simulates a damped spring-mass system stimulated by a square-wave signal. It does not require any I/O hardware and thus serves as a ready-to-use example. If you want to use a handcoded application, use the smd_1104_hc demo – with the `smd_1104_hc.sdf` SDF file – instead (see *How to Implement C Models* on page 49).

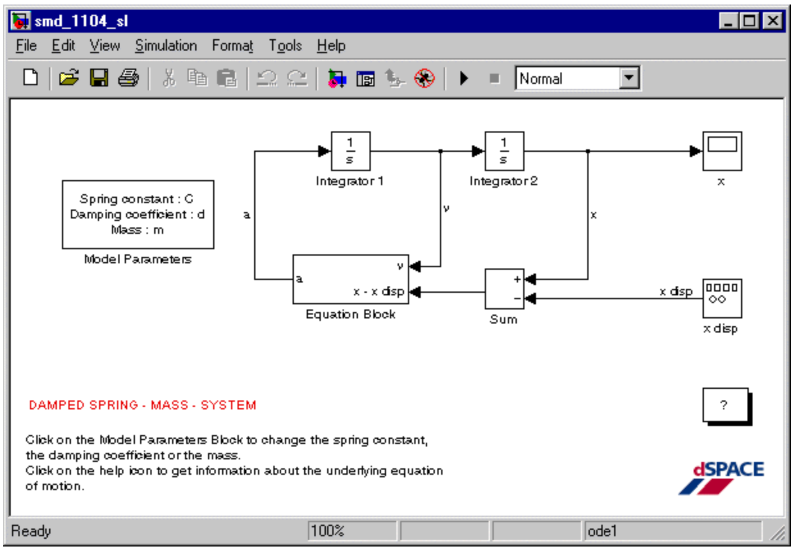
The related files are located in the directories `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode` or `...\GettingStarted\Simulink`.

To work with a model

1 In the **Library: rtilib1104** window, double-click **DEMOS**.

2 Double-click the box titled **Spring - Mass - Damper** in the **Library: rti1104demolib** window to open the Simulink model smd_1104_sl.

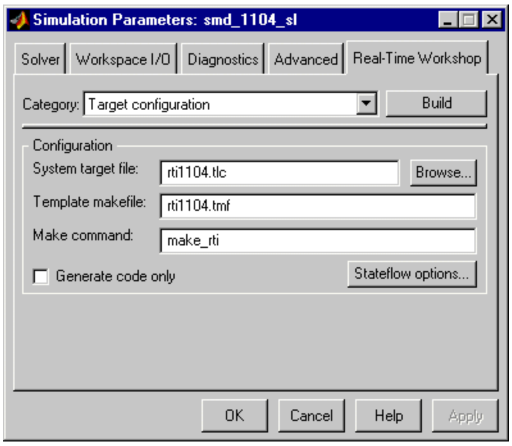
The Simulink model smd_1104_sl is displayed in an extra window.



3 To examine the model, double-click its blocks.

4 From the menu bar of the Model window, choose **Tools – Real-Time Workshop – Options** to view the simulation parameters.

The **Simulation Parameters** dialog opens.



5 On the **Real-Time Workshop** page, check if the system target file `rti1104.tlc`, the template makefile `rti1104.tmf`, and the make command `make_rti` are specified. If necessary, change the entries (according to the illustration above).

6 Click **Build** to build and download the real-time application to the DS1104.

The `smd_1104_sl.sdf` system description fileand the real-time application are created. The latter is downloaded to the DS1104 and started automatically.

7 Use ControlDesk to stop and restart the real-time application. Refer to *Experimenting with ControlDesk* on page 59.

If the real-time application - stored in the current MATLAB working folder - is stopped, it can be downloaded to the DS1104 again using the SDF file in ControlDesk. A new build process is not needed if you do not change the Simulink model in the meantime.

To find out the current MATLAB working folder

➤ In the **MATLAB Command Window**, enter **`pwd`**.

How to Implement C Models

To demonstrate how to proceed without MATLAB and Simulink, the C-coded example `smd_1104_hc.c` is used. This model does not require any I/O hardware. It simulates a damped spring-mass system stimulated by a square-wave signal. The parameters are spring, mass and damper.

To compile and link the application, you can use the `down1104` utility in a DOS window to call the makefile. After the object file is downloaded and started, the RTP error check utility is called automatically.

To edit and download an application

1. Open the file `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode\smd_1104_hc.c` using a text editor of your choice.
2. Browse through the source code, but do not alter the code yet.
3. To invoke `down1104`, in a DOS window change to the directory `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode` and type **`down1104 smd_1104_hc`**

   The object file `smd_1104_hc.ppc` is generated, downloaded and started.
4. Use ControlDesk to stop the real-time application:

   Select the DS1104 in the Platform Navigator, and click the Stop RTP/Simulation icon in the Platform toolbar.

Handling Real-Time Applications

Handling real-time applications on the DS1104 means downloading, starting and stopping applications on the real-time processor.

Booting characteristics

The DS1104 contains a global and flash memory. For some basic information about the booting characteristics, see *Basics of Booting the DS1104* on page 51.

Global and flash memory

On the DS1104, the application can be loaded to the global memory or flash memory. For instructions on how to start, stop and reload applications on the DS1104, see:

- *How to Handle Applications for the Global Memory* on page 53
- *How to Handle Applications for the Flash Memory* on page 55

scoutcmd

To download and start applications on the real-time hardware, it is possible to use the Platform Manager as a batch client using the command **`scoutcmd -b <dsxxxx>`** (<dsxxxx> denotes the board you want to download the application to) and additional parameters (see *How to Use Scoutcmd to Load and Start Applications* on page 58 and *Handling Applications Using Command Line Parameters* in the *ControlDesk Experiment Guide*).

Basics of Booting the DS1104

If you power-up or perform a hardware reset of the host PC, the board always starts executing the boot firmware contained in the flash memory. The boot firmware checks for an application program currently stored in flash memory. If it finds one, this application is started. If it does not detect an application, the loader enters the idle state.

- If power is turned off, any application that was previously loaded to global memory is lost.
- To avoid having the DS1104 execute an application stored in flash memory after power-up, the flash memory must be cleared (see *Clearing an application* on page 57).

Warm boot/reload

If the DS1104 is in the idle state after power-up or if an executing application has been stopped by ControlDesk, you can start a new application by loading it to the global or flash memory. If you load an application to the flash memory, it is copied to the global memory before it is started. Any application already in global memory is overwritten.

If you start the application again using ControlDesk's Reload Application/Start Simulation toolbar button, you can reload the most recently loaded application to the global memory. If the most recently loaded application was loaded to the flash memory, it is copied to the global memory. Then, the application is started automatically.

Execution time

If an application is loaded to the flash memory, it is copied to the global memory of the DS1104 before it is started. Thus, it makes no difference to the speed and execution time of the application during run time whether the DS1104 booted the application from the global or the flash memory.

Stopping a real-time application

If you stop an application via ControlDesk's **Stop Real-Time Processor** command, the processor will be reset immediately. Therefore, the termination code will not be executed and the background task will no longer be active. As a result, the I/O will not output the termination values of the application. To avoid problems with undefined termination values, use RTI's simulation control (RUN/STOP mechanism) for stopping and reloading applications (see *Simulation Control (RUN/STOP Mechanism)* in the *RTI and RTI-MP Implementation Guide*).

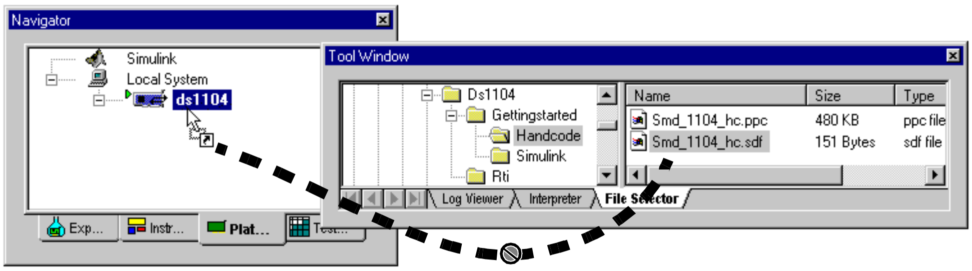
How to Handle Applications for the Global Memory

With ControlDesk's Platform Manager, it is very easy to load real-time applications to the global memory and reload and stop the real-time processor.

To download a real-time application to the global memory and start the RTP

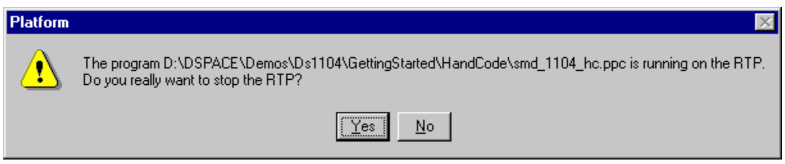
➤ In the **File Selector**, select the system description file (SDF) or the object file (PPC) for the real-time processor and drag & drop it onto the board icon in the Platform Navigator.

The object file is loaded to and started on the real-time processor.



Or you can choose **Platform – Application – Load Application** from the menu bar.

If you drag & drop an application onto the processor board when your system is still running, a dialog similar to the following opens.



If you confirm the message, the running application is stopped before the new application is downloaded and started.

For details on the behavior of Control Desk's **Stop Real-Time Processor** command, see *Stopping a real-time application* on page 52.

To stop a real-time application

1 In the Platform Navigator, select the board.

2 From the menu bar, choose **Platform – Application – Stop Real-Time Processor**.

Or you can click the Stop RTP/Simulation icon in the Platform toolbar.

The program running on the real-time processor is stopped.

To reload a real-time application

1 In the Platform Navigator, select the board.

2 From the menu bar, choose **Platform – Application – Reload Application**.

Or you can click the Reload Application/Start Simulation icon in the Platform toolbar.

The application that was previously downloaded to the global memory is loaded again and started.

How to Handle Applications for the Flash Memory

An application loaded to the flash memory is started automatically when you reboot your system (host PC).

If you want to prevent the system from booting a flash application, you have to clear the application from the flash memory (refer to *Clearing an application* on page 57).

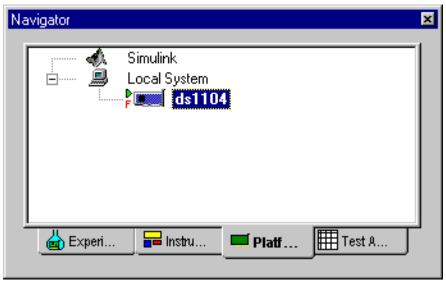
To download a real-time application to the flash memory and start the RTP

1. In the Platform Navigator, select the board.
2. From the context menu of the Platform Manager, choose **Load Application to Flash**.
3. Choose an application (that is, the SDF file or the PPC file) in the **Load Application to RTP** dialog.

If you load an application when your system is still running, a dialog similar to the following opens.

If you confirm the message with **Yes**, the running application is stopped before the new application is downloaded and started.

The **F** next to the board icon in the Platform Navigator indicates that the running application is loaded from the flash memory.



For details on the behavior of Control Desk's **Stop Real-Time Processor** command, see *Stopping a real-time application* on page 52.

To stop a real-time application

1 In the Platform Navigator, select the board.

2 From the menu bar, choose **Platform – Application – Stop Real-Time Processor**.

Or you can click the Stop RTP/Simulation icon in the **Platform** toolbar.

The program running on the real-time processor is stopped.

To reload a real-time application

1 In the Platform Navigator, select the board.

2 From the menu bar, choose **Platform – Application – Reload Application**.

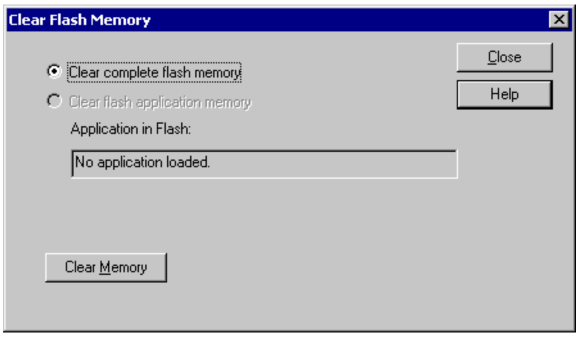
Or you can click the Reload Application/Start Simulation icon in the Platform toolbar.

The application that was previously downloaded to the flash is copied to the global memory again. Then, the application is started automatically.

Clearing an application

To clear an application from the flash memory

1. In the Platform Navigator, select the board.
2. Stop the real-time application running on the board.
3. From the context menu of the board icon, choose **Clear Flash**.



4. In the **Clear Flash Memory** dialog, you have the following options to clear the memory. Select
   - **Clear complete flash memory** to clear the whole flash memory.
   - **Clear flash application memory** to delete only the loaded application from the flash memory. The currently loaded application is displayed in the **Application in Flash** field.
5. Click **Clear Memory** to clear the flash memory according to your selection.

How to Use Scoutcmd to Load and Start Applications

To download and start applications on the real-time hardware, you can use the Platform Manager as a batch client using the scoutcmd command and additional parameters.

To load an application to the global memory using scoutcmd

➤ In a DOS window, enter **`scoutcmd -b ds1104 test.sdf`**

The `test.sdf application` is loaded to the board, and the RTP is started.

To load an application to the flash memory using scoutcmd

➤ In a DOS window, enter **`scoutcmd -b ds1104 test.sdf -fl`**

The `test.sdf` application is loaded to the flash memory (parameter -fl), and the RTP is started.

If the parameter -b is not used with the scoutcmd command, the application is downloaded to and started on the current working board.

For further information on scoutcmd and its parameters, refer to *Handling Applications Using Command Line Parameters* in the *ControlDesk Experiment Guide*.

Experimenting with ControlDesk

To observe the behavior of the real-time application and to change application-specific parameters, use dSPACE's experimentation tool ControlDesk.

For detailed information on ControlDesk and its features, refer to the *ControlDesk Experiment Guide*.

Required files

To experiment with a real-time application, three application-specific files are required: see *How to Generate the Required Files* on page 60.

Demo model

The demo model smd_1104_hc introduces you to ControlDesk's experimentation features. If you want to use a Simulink application, use the demo smd_1104_sl instead.

The related files are located in
`%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode` or
`%DSPACE_ROOT%\Demos\DS1104\GettingStarted\Simulink`

For instructions on how to monitor the variables and change the parameters of a running application using ControlDesk, see *How to Use ControlDesk* on page 61.

How to Generate the Required Files

Three application-specific files are required when working with ControlDesk:

TRC and MAP file The file with the extension TRC provides information on the available variables and how they are grouped. The MAP file, which is always created at the end of compilation, maps symbolic names to physical addresses. It is generated by the Microtec PowerPC compiler. The way TRC files are generated depends on the method used for implementation – either via RTI/Simulink or via handcoding in C.

SDF file The system description (SDF) file specifies which executable is downloaded onto which processor. The way the SDF file is generated depends on the method used for implementation.

When you load an SDF file to your system, the executable and all files related to the experiment are loaded automatically.

Using RTI and Simulink

RTI automatically generates the SDF file, the TRC file(s) and the MAP file when generating and compiling the code.

C-Coded Models

In `smd_1104_hc.c`, services have been included to make the application accessible to ControlDesk. The application-specific SDF and TRC file for ControlDesk must be created manually. You can use an existing file, such as `smd_1104_hc.trc`, as a template to create the TRC file for your application.

For information on how to write your own TRC file, refer to *Syntax of the TRC File* in the *ControlDesk Reference*. To create and edit an SDF file, you can use ControlDesk's *SDF File Editor* or the *Save Current Configuration* command.

How to Use ControlDesk

To observe the variables of a running real-time application, you have to create a ControlDesk layout with an instrument such as a plotter, and connect the instrument to the variables to be observed. For detailed instructions, see below.

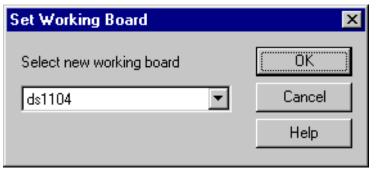
For instructions on how to change the parameters of a running application with ControlDesk, see *To use the demo experiment for ControlDesk* on page 66.

To observe the system behavior

1 Start ControlDesk.

Working with more than one dSPACE board in plug & play configuration may cause assignment problems. For details, refer to *Problems with Multiple Plug & Play Boards* on page 165.

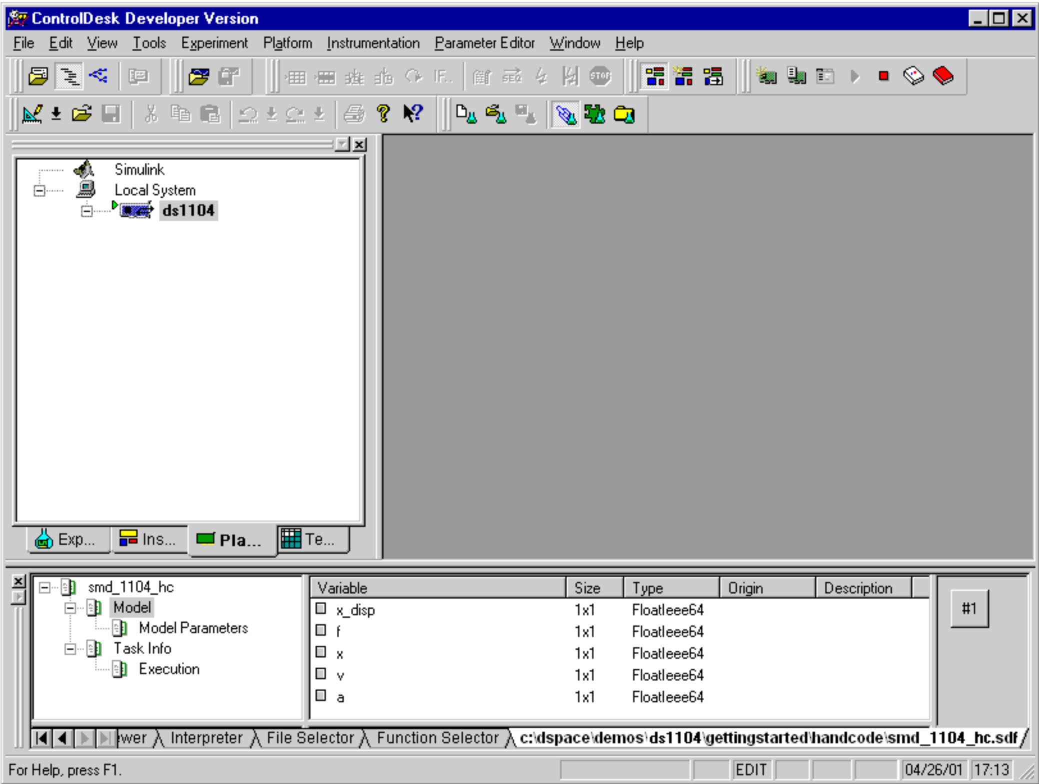
2 If ControlDesk's Platform Navigator displays more than one dSPACE board in your system, it may be necessary to specify the DS1104 as the working board: In the Platform Navigator, you can recognize the working board by its bold print. If the DS1104 is not the current working board, choose **Platform – Set Working Board ...** to call up the Set Working Board dialog.



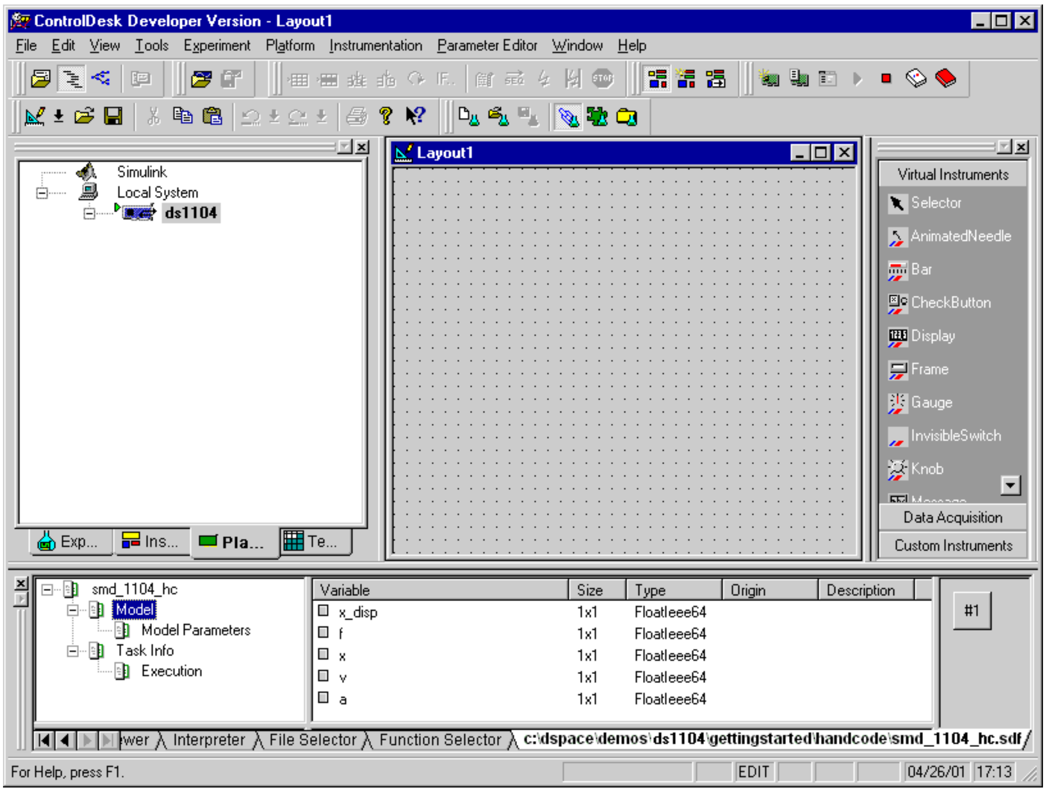
3 Use the Platform Navigator to load the SDF file `smd_1104_hc.sdf` from `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode`. For information on how to download, start and stop a real-time application on your system, see *Handling Real-Time Applications* on page 50.

The hierarchical structure of the model and its variables are displayed in the Variable Browser, a page of the **Tool Window**.

4 In the Variable Browser, click the trace group **Model** to display the variables (a, v, x, f, ...) of that block in the Showlist on the right.



5 To display the behavior of the system, choose **New – Layout** from the **File** menu. Two new windows will appear: The **Layout** window and the **Instrument Selector** (on the right side in the illustration below).

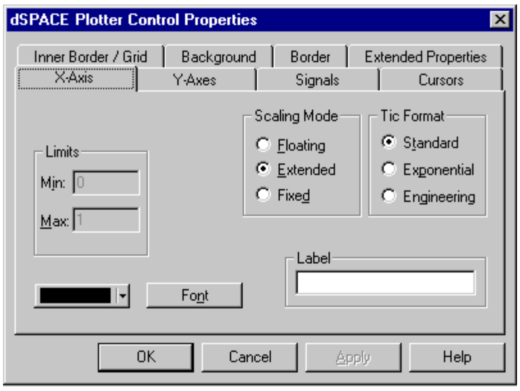


6 Do the following to build an instrument panel within the layout window:

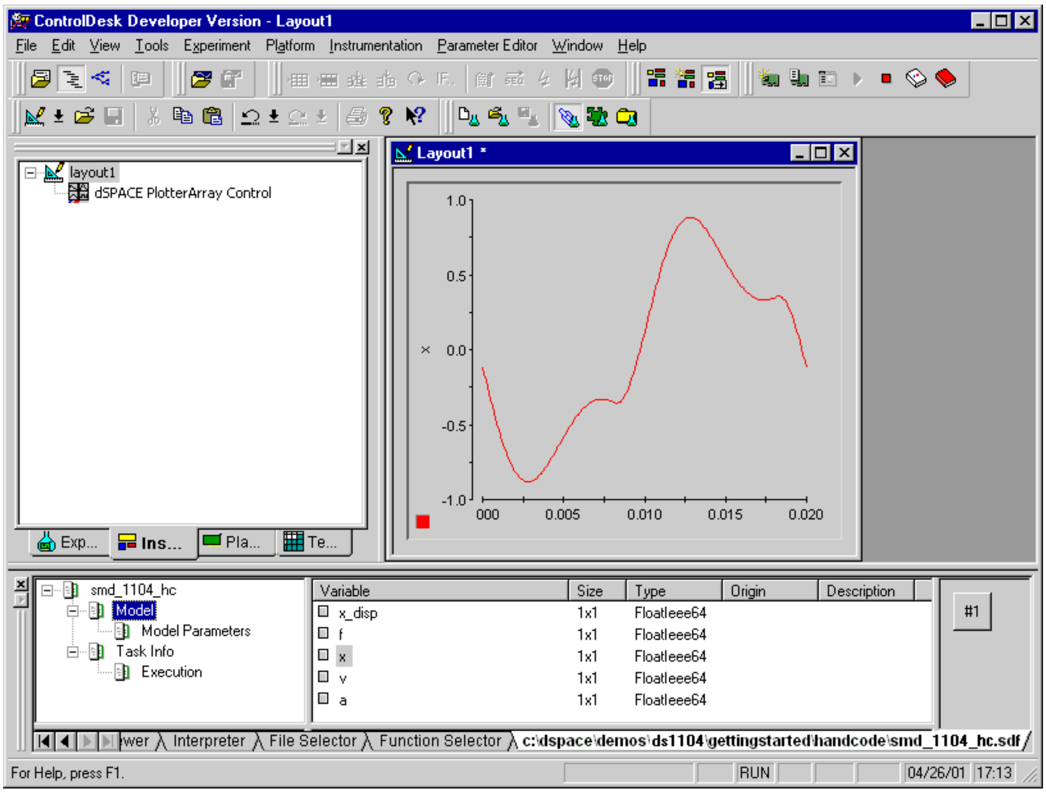
- In the **Instrument Selector**, click the instrument group containing the desired instrument (for example, **Data Acquisition**).
- In the **Instrument Selector**, click the icon of the instrument (for example, a **PlotterArray**).
- In the layout window, draw a rectangle using the mouse.

- The new instrument is opened in the layout window, and an icon for the instrument is added to the **Instrumentation Navigator**. The red frame of the instrument indicates that there is no valid data connection yet.
- In the Variable Browser, choose a signal, and drag & drop it onto the instrument (for example, **x**). The red frame disappears when the connection is built.

7 Select the instrument, and choose **Properties** from the context menu to display or change the properties of the instrument.



8 From the menu bar, choose **Instrumentation – Animation mode** to start the animation. In the following example there is one plotter to display the signal **x**.



9 To add new instruments to the layout or to change the properties of existing instruments, choose **Instrumentation – Edit Mode**.

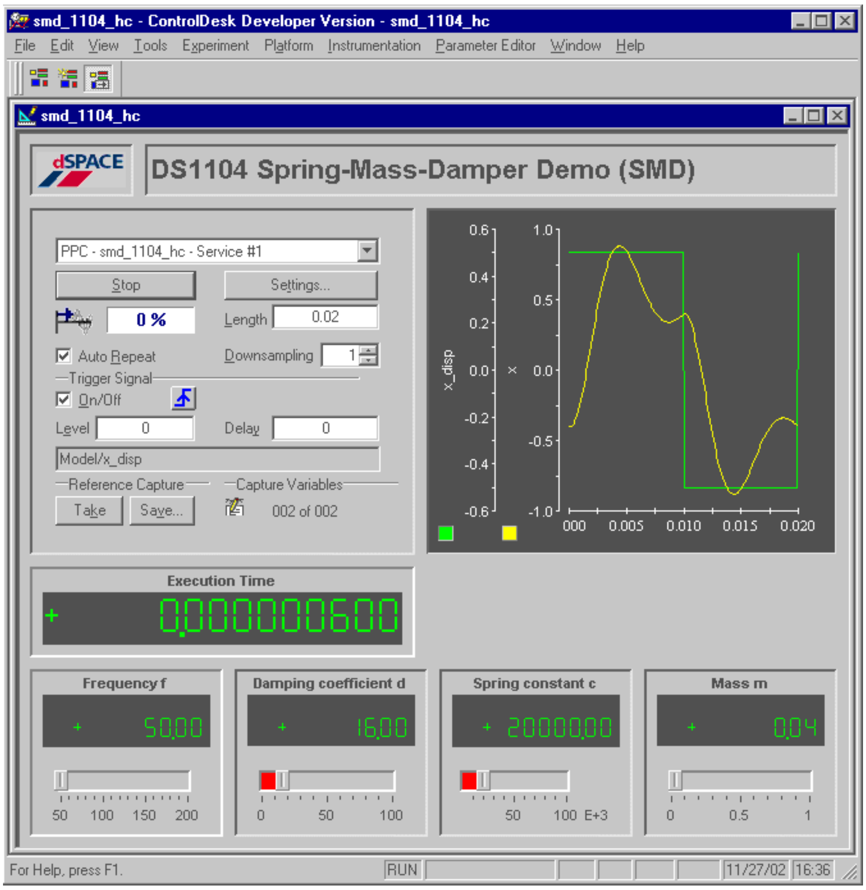
10 From the menu bar, choose **File – Save** to save the new layout.

Data connections describe the connection between variables of the real-time application and a ControlDesk instrument. To save data connections, you should create an experiment and add the layout to it. For further information, refer to *Saving and Loading Instrument Panels* in the *ControlDesk Experiment Guide*.

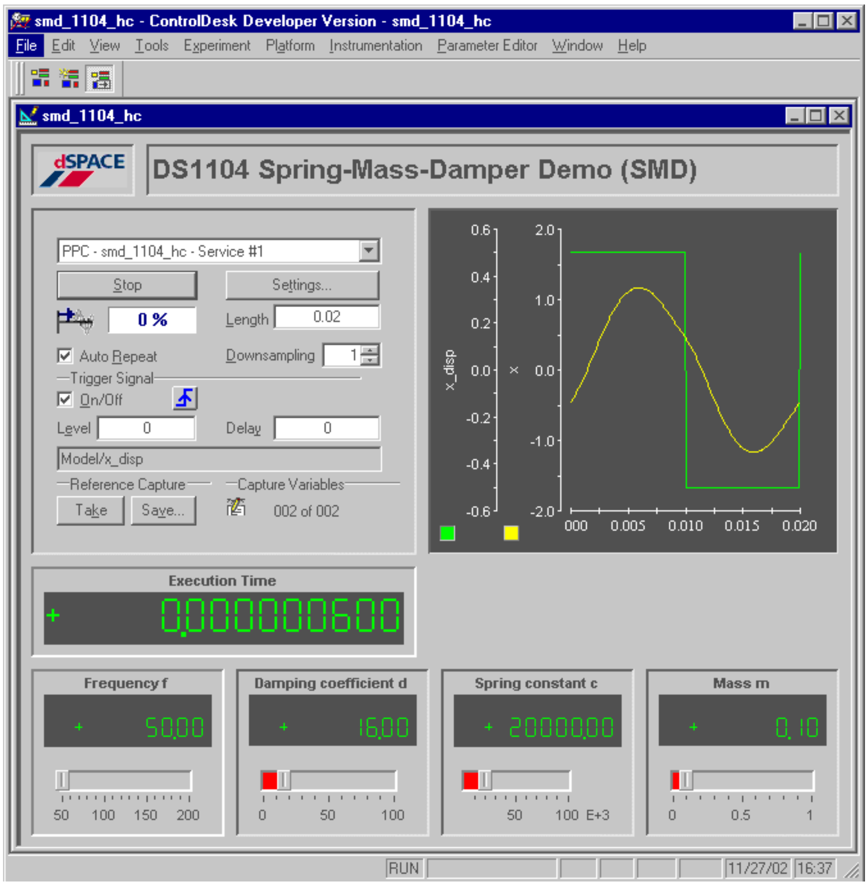
To use the demo experiment for ControlDesk

1. Start ControlDesk.
2. From the menu bar, choose **File – Open Experiment** to open the experiment `smd_1104_hc.cdx` from `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode`.
   ControlDesk will open the experiment together with all the related files.
3. Use the Platform Navigator to load the file `smd_1104_hc.sdf` from the same folder.
4. Close all windows except the instrument panel **DS1104 Spring-Mass-Damper Demo (SMD)**.

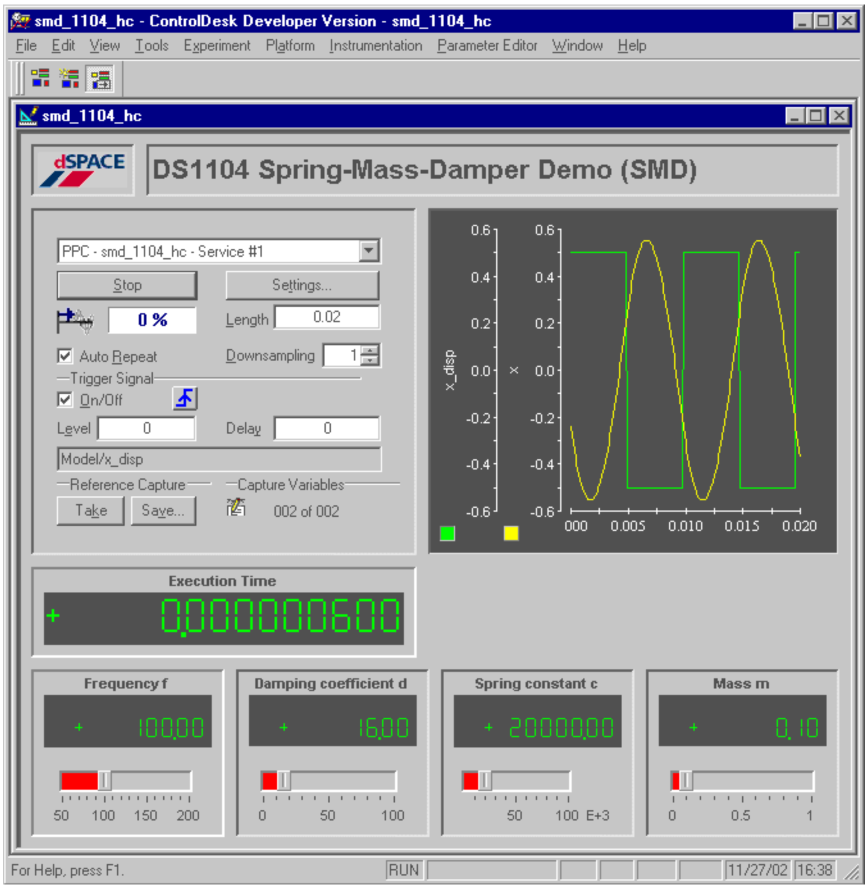
5 From the menu bar, choose **Instrumentation – Animation mode** to start the animation.



6 Change the parameter **Mass m** to 0.10 with the slider, and observe the system behavior in the plotter.



7 Change the **Frequency f** to 100.0 with the slider, and observe the system behavior in the plotter without stopping the Animation mode.



For more information on ControlDesk and its features, refer to the *ControlDesk Experiment Guide*.

Connecting External Devices to the dSPACE System

Prior to connecting external devices to the board or a connector panel, ensure you have familiarized yourself with the related instructions, provided in:

- *How to Connect External Devices to a Board* on page 72
- *How to Connect External Devices to a Connector Panel* on page 74

How to Connect External Devices to a Board

To connect external devices to the DS1104

CAUTION! Connecting external devices while the power supply is switched on may damage the dSPACE hardware.

- Do not connect or disconnect any device while the power supply is switched on.
- Turn off the host PC and the external devices beforehand.

1 Turn off all external devices which are to be connected to the dSPACE system

2 Turn off the host PC.

3 Disconnect the host PC and all devices connected to it from the power supply.

WARNING! Hazardous voltages.

Risk of electric shock and/or damage to the hardware.

- Do not connect any high-voltage devices to the I/O connectors of the hardware.
- Do not apply voltages/currents outside the specified ranges to the connector pins.

4 Connect the devices belonging to your application to the DS1104 via the adapter cable.

Do not mix up the connectors of the adapter cable. They are labeled P1A, P1B.

5 Reconnect the host PC and all external devices to the power supply.

6 Turn on the host PC.

The host PC should boot as usual.

7 Turn on all external devices connected to the dSPACE system.

How to Connect External Devices to a Connector Panel

To connect external devices to a connector panel

CAUTION! Connecting external devices while the power supply is switched on may damage the dSPACE hardware.

- Do not connect or disconnect any device while the power supply is switched on.
- Turn off the host PC and the external devices beforehand.

1. Turn off all external devices which are to be connected to the dSPACE system.
2. Turn off the host PC.
3. Disconnect the host PC and all devices connected to it from the power supply.

WARNING! Hazardous voltages.

Risk of electric shock and/or damage to the hardware.

- Do not connect any high-voltage devices to the I/O connectors of the hardware.
- Do not apply voltages/currents outside the specified ranges to the connector pins. The isolation of the panels has been designed for low-voltage operation only.

4. Connect the devices belonging to your application to the panel.
5. Reconnect the host PC and all external devices to the power supply.
6. Turn on the host PC.

   The host PC should boot as usual.
7. Turn on all external devices connected to the dSPACE system.

Uninstalling the System

All components of a dSPACE system, software and hardware, can be removed from the host PC in the following order:

1. You have to remove the software first. For further information, refer to *Removing dSPACE Software* in the *dSPACE Software Installation and Management Guide.*
2. Afterwards you can remove the hardware from the host PC. Refer to *How to Remove the Hardware* on page 76.

How to Remove the Hardware

Preconditions

- The host PC is switched off.
- Precautions are taken to avoid damage by high electrostatic voltages. For details, refer to *Safety Precautions for Installing and Connecting the Hardware* on page 18.

Method

To remove the dSPACE board from the host PC

WARNING! Hazardous voltages.

Risk of electric shock and/or damage to the hardware.

Before removing any board, make sure that:

- The power supply of the host PC is switched off.
- No external device is connected to the dSPACE system.

1. Disconnect the host PC and all external devices connected to them from the power supply.
2. Unplug any external devices or connector panels from the I/O connector of the DS1104.
3. Open the enclosure of the host PC.
4. Unscrew the bracket of the DS1104.
5. Remove the DS1104 from the slot.
6. Reinstall the original bracket to cover the opening at the rear side of the enclosure.
7. Close the enclosure, reconnect the PC to the power supply, and turn it on.

   The host PC should boot as usual.

Connector Pinouts and LEDs

This chapter provides hardware-related, reference information on the elements of the DS1104 and its optional accessories, the CP1104 Connector Panel and the CLP1104 Connector/LED Combi Panel:

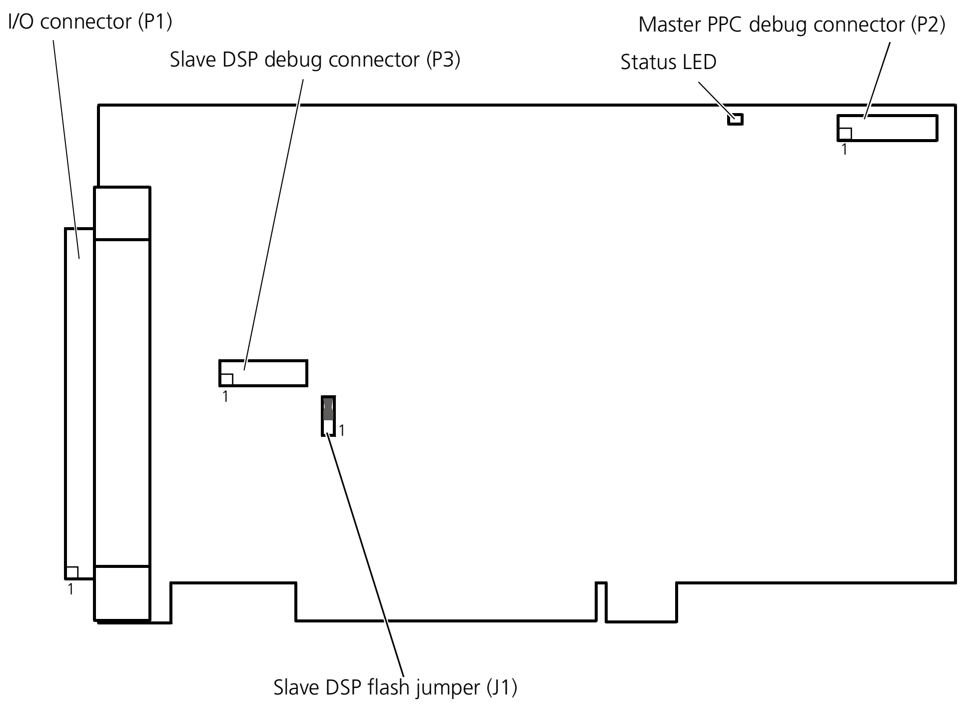
- *Board Overview* on page 78 contains an illustration of the board, showing the location of connectors, jumpers and LEDs.
- *DS1104 Connectors* on page 80 shows the pin assignments of the different board connectors.
- *CP1104/CLP1104 Connectors* on page 88 shows the front view of the connector panel and the pin assignments of the connectors equipped on the panel.
- *CLP1104 LED Assignments* on page 100 shows the LED array of the CLP.

Mapping of I/O signals

Various connector pins can be assigned to RTI blocks and RTLib functions. Refer to *Mapping of I/O Signals* on page 101.

Board Overview

The illustration shows the locations of connectors, jumpers and LEDs on the DS1104. It is not to scale.



The DS1104 contains the following important elements (from left to right):

- The **I/O connector (P1)** is a 100-pin connector. The signals available at this connector are described in *I/O Connector (P1)* on page 81.
- The **slave DSP debug connector (P3)** is a JTAG 1149.1 hardware debug connector and can be used for slave DSP debugging. The signals available at this connector are described in *Slave DSP Debug Connector (P3)* on page 86.

- The **slave DSP flash jumper (J1)** is used to control the protection mode of the flash memory and the watchdog mode: see *Slave DSP Flash Jumper (J1)* on page 87.
- The red **status LED** is equipped for troubleshooting purposes. For details, see *Checking the DS1104* on page 164.
- The **master PPC debug connector (P2)** is a JTAG 1149.1 hardware debug connector and can be used for master PPC debugging. The signals available at this connector are described in *Master PPC Debug Connector (P2)* on page 85.

DS1104 Connectors

The DS1104 is equipped with the following connectors:

- *I/O Connector (P1)* on page 81
- *Master PPC Debug Connector (P2)* on page 85
- *Slave DSP Debug Connector (P3)* on page 86
- *Slave DSP Flash Jumper (J1)* on page 87

Prior to connecting external devices to the board, ensure you have familiarized yourself with the relevant instructions provided in *Connecting External Devices to the dSPACE System* on page 71.

I/O Connector (P1)

The I/O connector (P1) is a 100-pin, high density KEL connector. It is used to obtain access to the I/O signals of the board. The connector is located on the bracket of the DS1104, see *Board Overview* on page 78.

Adapter cable

Using the adapter cable supplied with the board, the I/O connector (P1) can be linked to two 50-pin, female Sub-D connectors (labeled P1A, P1B).

Signal specification

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at the I/O connector, see *Signal Connection to External Devices* on page 119.

For the DS1104, the total load of the connector pins providing VCC (P1 19 and P1 20; P1A 4 and P1B 4 on the Sub-D connectors) must not exceed 500 mA.

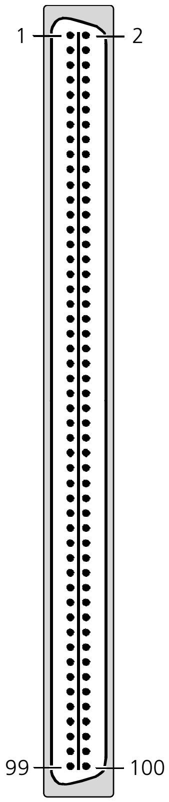
The VCC lines are protected against short circuits by a common multifuse on the DS1104.

If VCC is overloaded or shorted, the multifuse on the DS1104 is heated up by the overcurrent and abruptly raises its resistance. To reset the multifuse to its initial low resistance, turn off the power for some minutes to allow the multifuse to cool down.

Pinout of I/O connector

The following table shows the pin assignment of the I/O connector (P1). It also provides the mapping to the Sub-D connectors of the adapter cable.

Signal names in parentheses apply when the UART is set to the RS422 or RS485 mode.

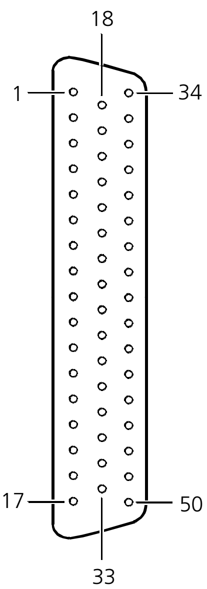
I/O Connector (P1)	Pin	Sub-D Pin	Signal	Pin	Sub-D Pin	Signal
	P1 1	P1B 1	GND	P1 2	P1A 1	GND
	P1 3	P1B 34	DCD (CTS)	P1 4	P1A 34	(RTS)
	P1 5	P1B 18	CTS ($\overline{\text{CTS}}$)	P1 6	P1A 18	RTS ($\overline{\text{RTS}}$)
	P1 7	P1B 2	DSR (RXD)	P1 8	P1A 2	DTR (TXD)
	P1 9	P1B 35	RXD ($\overline{\text{RXD}}$)	P1 10	P1A 35	TXD ($\overline{\text{TXD}}$)
	P1 11	P1B 19	SSOMI	P1 12	P1A 19	SCAP4
	P1 13	P1B 3	SSIMO	P1 14	P1A 3	SCAP3
	P1 15	P1B 36	SSTE	P1 16	P1A 36	SCAP2
	P1 17	P1B 20	SSCLK	P1 18	P1A 20	SCAP1
	P1 19	P1B 4	VCC (+5 V)	P1 20	P1A 4	VCC (+5 V)
	P1 21	P1B 37	ST3PWM	P1 22	P1A 37	SPWM6
	P1 23	P1B 21	ST2PWM	P1 24	P1A 21	SPWM5
	P1 25	P1B 5	ST1PWM	P1 26	P1A 5	SPWM4
	P1 27	P1B 38	SPWM9	P1 28	P1A 38	SPWM3
	P1 29	P1B 22	SPWM8	P1 30	P1A 22	SPWM2
	P1 31	P1B 6	SPWM7	P1 32	P1A 6	SPWM1
	P1 33	P1B 39	GND	P1 34	P1A 39	GND
	P1 35	P1B 23	$\overline{\text{IDX(2)}}$	P1 36	P1A 23	$\overline{\text{IDX(1)}}$
	P1 37	P1B 7	IDX(2)	P1 38	P1A 7	IDX(1)
	P1 39	P1B 40	$\overline{\text{PHI90(2)}}$	P1 40	P1A 40	$\overline{\text{PHI90(1)}}$
	P1 41	P1B 24	PHI90(2)	P1 42	P1A 24	PHI90(1)
	P1 43	P1B 8	$\overline{\text{PHI0(2)}}$	P1 44	P1A 8	$\overline{\text{PHI0(1)}}$
	P1 45	P1B 41	PHI0(2)	P1 46	P1A 41	PHI0(1)
	P1 47	P1B 25	GND	P1 48	P1A 25	GND
	P1 49	P1B 9	IO19	P1 50	P1A 9	IO18
	P1 51	P1B 42	IO17	P1 52	P1A 42	IO16
	P1 53	P1B 26	IO15	P1 54	P1A 26	IO14
	P1 55	P1B 10	IO13	P1 56	P1A 10	IO12
	P1 57	P1B 43	IO11	P1 58	P1A 43	IO10
	P1 59	P1B 27	IO9	P1 60	P1A 27	IO8
	P1 61	P1B 11	IO7	P1 62	P1A 11	IO6
	P1 63	P1B 44	IO5	P1 64	P1A 44	IO4
	P1 65	P1B 28	IO3	P1 66	P1A 28	IO2
	P1 67	P1B 12	IO1	P1 68	P1A 12	IO0
	P1 69	P1B 45	GND	P1 70	P1A 45	GND
	P1 71	P1B 29	DACH8	P1 72	P1A 29	DACH7
	P1 73	P1B 13	GND	P1 74	P1A 13	GND
	P1 75	P1B 46	DACH6	P1 76	P1A 46	DACH5
	P1 77	P1B 30	GND	P1 78	P1A 30	GND
	P1 79	P1B 14	DACH4	P1 80	P1A 14	DACH3
	P1 81	P1B 47	GND	P1 82	P1A 47	GND
	P1 83	P1B 31	DACH2	P1 84	P1A 31	DACH1
	P1 85	P1B 15	GND	P1 86	P1A 15	GND
	P1 87	P1B 48	ADCH8	P1 88	P1A 48	ADCH7
	P1 89	P1B 32	GND	P1 90	P1A 32	GND
	P1 91	P1B 16	ADCH6	P1 92	P1A 16	ADCH5
	P1 93	P1B 49	GND	P1 94	P1A 49	GND
	P1 95	P1B 33	ADCH4	P1 96	P1A 33	ADCH3
	P1 97	P1B 17	GND	P1 98	P1A 17	GND
	P1 99	P1B 50	ADCH2	P1 100	P1A 50	ADCH1

Pinout of Sub-D connectors

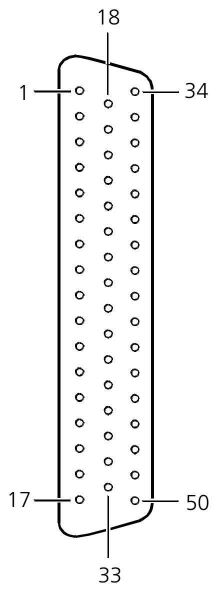
Because the pin numbering used for Sub-D connectors is not standardized, the following illustrations show the numbering used (viewed from the top of a female connector).

Do not rely on the numbers written on Sub-D connectors.

The table below shows the pin assignment of the **Sub-D connector P1A**. Signal names in parentheses apply when the UART is set to the RS422 or RS485 mode.

Connector P1A	Pin	Signal	Pin	Signal	Pin	Signal
	1	GND			34	(RTS)
	2	DTR (TXD)	18	RTS ($\overline{\text{RTS}}$)	35	TXD ($\overline{\text{TXD}}$)
	3	SCAP3	19	SCAP4	36	SCAP2
	4	VCC (+5 V)	20	SCAP1	37	SPWM6
	5	SPWM4	21	SPWM5	38	SPWM3
	6	SPWM1	22	SPWM2	39	GND
	7	IDX(1)	23	$\overline{\text{IDX(1)}}$	40	$\overline{\text{PHI90(1)}}$
	8	$\overline{\text{PHI0(1)}}$	24	PHI90(1)	41	PHI0(1)
	9	IO18	25	GND	42	IO16
	10	IO12	26	IO14	43	IO10
	11	IO6	27	IO8	44	IO4
	12	IO0	28	IO2	45	GND
	13	GND	29	DACH7	46	DACH5
	14	DACH3	30	GND	47	GND
	15	GND	31	DACH1	48	ADCH7
	16	ADCH5	32	GND	49	GND
	17	GND	33	ADCH3	50	ADCH1

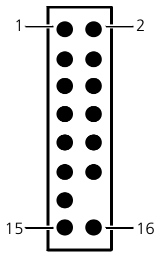
The table below shows the pin assignment of the **Sub-D connector P1B**. Signal names in parentheses apply when the UART is set to the RS422 or RS485 mode.

Connector P1B	Pin	Signal	Pin	Signal	Pin	Signal
	1	GND			34	DCD (CTS)
	2	DSR (RXD)	18	CTS ($\overline{\text{CTS}}$)	35	RXD ($\overline{\text{RXD}}$)
	3	SSIMO	19	SSOMI	36	SSTE
	4	VCC (+5 V)	20	SSCLK	37	ST3PWM
	5	ST1PWM	21	ST2PWM	38	SPWM9
	6	SPWM7	22	SPWM8	39	GND
	7	IDX(2)	23	$\overline{\text{IDX(2)}}$	40	$\overline{\text{PHI90(2)}}$
	8	$\overline{\text{PHI0(2)}}$	24	PHI90(2)	41	PHI0(2)
	9	IO19	25	GND	42	IO17
	10	IO13	26	IO15	43	IO11
	11	IO7	27	IO9	44	IO5
	12	IO1	28	IO3	45	GND
	13	GND	29	DACH8	46	DACH6
	14	DACH4	30	GND	47	GND
	15	GND	31	DACH2	48	ADCH8
	16	ADCH6	32	GND	49	GND
	17	GND	33	ADCH4	50	ADCH2

Master PPC Debug Connector (P2)

The master PPC features a superset of the IEEE 1149.1 JTAG standard emulation port, which can be used for software debugging.

For the location of the connector on the board, see *Board Overview* on page 78.

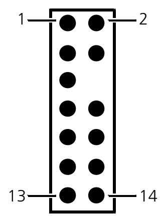
Connector (P2)	Pin	Signal	Pin	Signal
	1	TDO	2	N/C
	3	TDI	4	$\overline{\text{TRST}}$
	5	$\overline{\text{RUN\_STP}}$	6	VDD_SENSE
	7	TCK	8	$\overline{\text{CHKSTP\_IN}}$
	9	$\overline{\text{TMS}}$	10	N/C
	11	N/C	12	N/C
	13	$\overline{\text{HRESET}}$	14	
	15	$\overline{\text{CKSTP\_OUT}}$	16	GND

The dSPACE software does not support the master PPC debug connector.

Slave DSP Debug Connector (P3)

The TMS320F240 slave DSP features a superset of the IEEE 1149.1 JTAG standard emulation port. This emulation port can be used for software debugging. The DS1104 contains a JTAG connector to connect an external emulator such as the Texas Instruments XDS510.

For the location of the connector on the board, see *Board Overview* on page 78.

Connector	Pin	Signal	Pin	Signal
	1	TMS	2	$\overline{\text{TRST}}$
	3	TDI	4	GND
	5	VCC	6	
	7	TDO	8	GND
	9	TCK	10	GND
	11	TCK	12	GND
	13	EMU0	14	EMU1

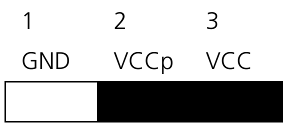
The dSPACE software does not support the slave DSP debug connector.

Slave DSP Flash Jumper (J1)

The slave DSP contains an on-chip flash memory. The flash jumper (see *Board Overview* on page 78) is used to set the protection mode of the flash memory and the slave DSP watchdog mode.

The VCCp pin of the TMS320F240 slave DSP selects the protection mode of the flash memory and the slave DSP watchdog mode:

- If the jumper connects VCCp to VCC (default setting):
  - erase/write operations to the flash memory are enabled
  - the watchdog is disabled
- If the jumper connects VCCp to GND:
  - erase/write operations to the flash memory are disabled
  - the watchdog is enabled



The dSPACE software does not support the watchdog of the slave DSP. For this reason, do not change the jumper's default setting shown above.

CP1104/CLP1104 Connectors

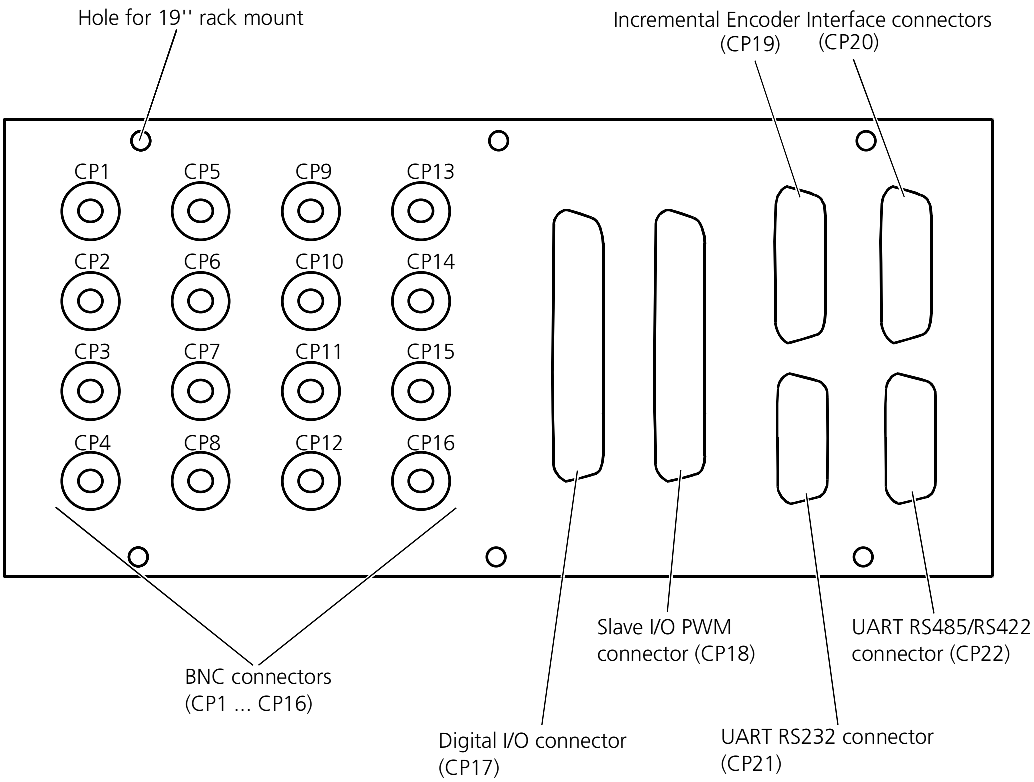
The connector panels CP1104 and CLP1104 provide easy-to-use connections between the DS1104 and devices to be connected to it. Devices can be individually connected, disconnected or interchanged without soldering. This simplifies system construction, testing and troubleshooting.

Prior to connecting external devices to the connector panel, ensure you have familiarized yourself with the relevant instructions provided in *How to Connect External Devices to a Connector Panel* on page 74.

WARNING! Hazardous voltages.

Risk of electric shock and/or damage to the hardware.

- Do not connect any high-voltage devices to the I/O connectors of the panel.



For the CP1104 and CLP1104 Connector Panels, the total load of **all** connector pins that provide access to the PC power supply must not exceed 500 mA (CP1104) or 400 mA (CLP1104).

The VCC lines are protected against short circuits by a common multifuse on the DS1104.

If VCC is overloaded or shorted, the multifuse on the DS1104 is heated up by the overcurrent and abruptly raises its resistance. To reset the multifuse to its initial low resistance, turn off the power for some minutes to allow the multifuse to cool down.

The CP1104 and CLP1104 Connector Panels are equipped with the following connectors:

- *BNC Connectors (CP1 … CP16)* on page 91
- *Digital I/O Connector (CP17)* on page 92
- *Slave I/O PWM Connector (CP18)* on page 94
- *Incremental Encoder Interface Connectors (CP19, CP20)* on page 96
- *UART RS232 Connector (CP21)* on page 98
- *UART RS422/RS485 Connector (CP22)* on page 99

BNC Connectors (CP1 … CP16)

The CP1 ... CP16 connectors are female BNC connectors. Their shells are connected to GND.

Connector	Signal	Connector	Signal	Connector	Signal	Connector	Signal
CP1	ADCH1	CP5	ADCH5	CP9	DACH1	CP13	DACH5
CP2	ADCH2	CP6	ADCH6	CP10	DACH2	CP14	DACH6
CP3	ADCH3	CP7	ADCH7	CP11	DACH3	CP15	DACH7
CP4	ADCH4	CP8	ADCH8	CP12	DACH4	CP16	DACH8

In order to avoid poor performance of the analog subsystems, do not create ground loops within the BNC wiring.

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at the BNC connectors, see *Analog Inputs* on page 120 and *Analog Outputs* on page 122.

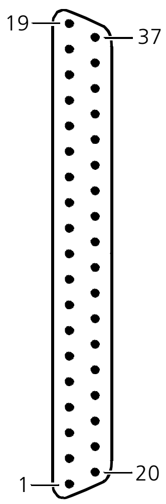
Digital I/O Connector (CP17)

The digital I/O connector (CP17) is a 37-pin, male Sub-D connector located on the front of the connector panel.

Pinout

Because the pin numbering used for Sub-D connectors is not standardized, the following figure shows the numbering scheme used (front view).

Do not rely on the numbers written on Sub-D connectors.

Connector (CP17)	Pin	Signal	Pin	Signal
	19	GND		
	18	GND	37	VCC (+5 V)
	17	GND	36	VCC (+5 V)
	16	GND	35	GND
	15	IO19	34	GND
	14	IO17	33	IO18
	13	GND	32	IO16
	12	IO15	31	GND
	11	IO13	30	IO14
	10	GND	29	IO12
	9	IO11	28	GND
	8	IO9	27	IO10
	7	GND	26	IO8
	6	IO7	25	GND
	5	IO5	24	IO6
	4	GND	23	IO4
	3	IO3	22	GND
	2	IO1	21	IO2
	1	GND	20	IO0

For the CP1104 and CLP1104 Connector Panels, the total load of **all** connector pins that provide access to the PC power supply must not exceed 500 mA (CP1104) or 400 mA (CLP1104).

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at this connector, see *Bit I/O* on page 125.

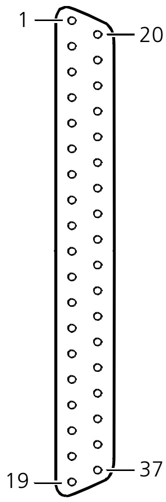
Slave I/O PWM Connector (CP18)

The slave I/O PWM connector (CP18) is a 37-pin, female Sub-D connector located on the front of the connector panel.

Pinout

Because the pin numbering used for Sub-D connectors is not standardized, the following figure shows the numbering scheme used (front view).

Do not rely on the numbers written on Sub-D connectors.

Connector (CP18)	Pin	Signal	Pin	Signal
	1	GND		
	2	SCAP1	20	GND
	3	SCAP3	21	SCAP2
	4	GND	22	SCAP4
	5	ST2PWM	23	ST1PWM
	6	GND	24	ST3PWM
	7	SPWM1	25	GND
	8	SPWM3	26	SPWM2
	9	SPWM5	27	SPWM4
	10	SPWM7	28	SPWM6
	11	SPWM9	29	SPWM8
	12	GND	30	GND
	13	GND	31	GND
	14	GND	32	GND
	15	GND	33	GND
	16	SSIMO	34	SSOMI
	17	SCLK	35	SSTE
	18	VCC (+5 V)	36	GND
	19	VCC (+5 V)	37	GND

For the CP1104 and CLP1104 Connector Panels, the total load of **all** connector pins that provide access to the PC power supply must not exceed 500 mA (CP1104) or 400 mA (CLP1104).

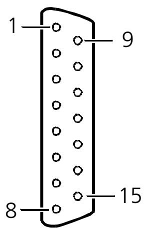
For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at this connector, see *Slave DSP Digital I/O* on page 142.

Incremental Encoder Interface Connectors (CP19, CP20)

The incremental encoder interface connectors CP19 and CP20 are 15-pin, female Sub-D connectors located on the front of the connector panel. Each of the connectors provides the signals for one of the two available incremental encoder channels.

Pinout Because the pin numbering used for Sub-D connectors is not standardized, the following figure shows the numbering scheme used (front view).

Do not rely on the numbers written on Sub-D connectors.

Connector (CP19, CP20)	Pin	Signal	Pin	Signal
	1	VCC (+5 V)		
	2	PHI0(x)	9	VCC (+5 V)
	3	$\overline{\text{PHI0(x)}}$	10	GND
	4	PHI90(x)	11	GND
	5	$\overline{\text{PHI90(x)}}$	12	GND
	6	IDX(x)	13	GND
	7	$\overline{\text{IDX(x)}}$	14	GND
	8	GND	15	GND

x corresponds to the two available incremental encoder channels: Channel 1 is connected to CP19 (x = 1), channel 2 is connected to CP20 (x = 2).

For the CP1104 and CLP1104 Connector Panels, the total load of **all** connector pins that provide access to the PC power supply must not exceed 500 mA (CP1104) or 400 mA (CLP1104).

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at this connector, see *Incremental Encoder Interface* on page 129.

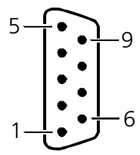
UART RS232 Connector (CP21)

The UART RS232 connector CP21 is a 9-pin, male Sub-D connector located on the front of the connector panel. The pinout has been adapted from the 9-pin RS232 connector of a PC.

The DS1104 supports one serial interface. In RS232 mode the signals are available from the RS232 connector CP21. In RS422/485 mode the signals are available from the RS422/485 connector CP22. CP21 and CP22 are mutually exclusive and cannot be used at the same time.

Pinout Because the pin numbering used for Sub-D connectors is not standardized, the following figure shows the numbering scheme used (front view).

Do not rely on the numbers written on Sub-D connectors.

Connector (CP21)	Pin	Signal	Pin	Signal
	5	GND		
	4	DTR (TXD)	9	Not used
	3	TXD ($\overline{\text{TXD}}$)	8	CTS ($\overline{\text{CTS}}$)
	2	RXD ($\overline{\text{RXD}}$)	7	RTS ($\overline{\text{RTS}}$)
	1	DCD (CTS)	6	DSR (RXD)

Signal names in parentheses apply when the UART is set to the RS422 or RS485 mode. However, you should use the UART RS422/RS485 Connector (CP22) instead, when you are using RS422/485 mode.

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at this connector, see *Serial Interface* on page 136.

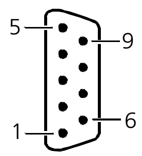
UART RS422/RS485 Connector (CP22)

The UART RS422/RS485 connector CP22 is a 9-pin, male Sub-D connector located on the front of the connector panel.

The DS1104 supports one serial interface. In RS232 mode the signals are available from the RS232 connector CP21. In RS422/485 mode the signals are available from the RS422/485 connector CP22. CP21 and CP22 are mutually exclusive and cannot be used at the same time.

Pinout Because the pin numbering used for Sub-D connectors is not standardized, the following figure shows the numbering scheme used (front view).

Do not rely on the numbers written on Sub-D connectors.

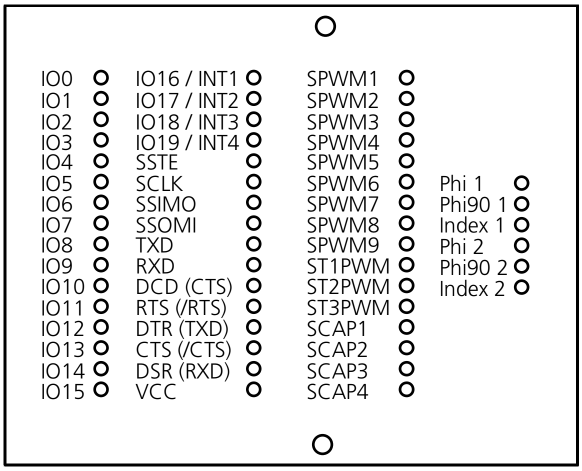
Connector (CP22)	Pin	Signal	Pin	Signal
	5	GND		
	4	$\overline{\text{RXD}}$	9	$\overline{\text{CTS}}$
	3	RXD	8	CTS
	2	TXD	7	RTS
	1	$\overline{\text{TXD}}$	6	$\overline{\text{RTS}}$

For detailed information (I/O circuits, electrical characteristics, etc.) on the I/O lines terminating at this connector, see *Serial Interface* on page 136.

CLP1104 LED Assignments

The CLP1104 Connector/LED Combi Panel additionally provides an array of 54 LEDs, which indicate the states of the digital signals.

In the illustration below you will find the signal names as labeled on the panel template.



The LEDs display the TTL signal level, not the active status of the signal. (TTL "high" ⟶ LED is on; TTL "low" ⟶ LED is off).

In order to keep the loading of the signals as low as possible, the LEDs are run through buffers.

For the incremental sensor signals, there are buffers with true differential inputs. The pulse length of data signals of the UART (RXD, TXD) is extended to make even small blocks of data visible.

The power required by the LEDs is taken from the DS1104's supply voltage (VCC).

Mapping of I/O Signals

The following table lists the I/O signals of the DS1104 by function groups, their electrical specifications, and the mapping of these signals to RTI blocks and RTLib functions.

The table also provides the mapping of the I/O signals to the I/O pins on the DS1104, on the Sub-D connectors (P1A, P1B), and on the CP1104/CLP1104 connector panels.

Conflicting I/O features

Some I/O features of the DS1104 conflict with other I/O features. In the table below, these signals are marked with an asterisk "*". For an overview, see *Conflicting I/O Features* on page 109.

	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on …		
Signal	**Related RTI Block(s)**	**Ch/Bit (RTI)**	**Related RTLib Functions**	**Ch/Bit (RTLib)**	**DS1104**	**Sub-D Conn.**	**CP/CLP**
ADC Unit • Input voltage range: ±10 V • ADCH1 … ADCH4: input for A/D converter with 16-bit resolution • ADCH5 … ADCH8: input for A/D converter with 12-bit resolution • I/O circuit and further electrical characteristics: see *Analog Inputs* on page 120							
ADCH1	*DS1104MUX_ADC*	Ch 1	See *ADC Unit* in the *DS1104 RTLib Reference*	Ch 1	P1 100	P1A 50	CP1
ADCH2		Ch 2		Ch 2	P1 99	P1B 50	CP2
ADCH3		Ch 3		Ch 3	P1 96	P1A 33	CP3
ADCH4		Ch 4		Ch 4	P1 95	P1B 33	CP4
ADCH5	*DS1104ADC_Cx*	Ch 5	See *ADC Unit* in the *DS1104 RTLib Reference*	Ch 5	P1 92	P1A 16	CP5
ADCH6		Ch 6		Ch 6	P1 91	P1B 16	CP6
ADCH7		Ch 7		Ch 7	P1 88	P1A 48	CP7
ADCH8		Ch 8		Ch 8	P1 87	P1B 48	CP8
DAC Unit • Output voltage range: ±10 V • Output current range: ±5 mA • DACH1 … DACH8: D/A converter output with 16-bit resolution • I/O circuit and further electrical characteristics: see *Analog Outputs* on page 122							
DACH1	*DS1104DAC_Cx*	Ch 1	See *DAC Unit* in the *DS1104 RTLib Reference*	Ch 1	P1 84	P1A 31	CP9
DACH2		Ch 2		Ch 2	P1 83	P1B 31	CP10
DACH3		Ch 3		Ch 3	P1 80	P1A 14	CP11
DACH4		Ch 4		Ch 4	P1 79	P1B 14	CP12
DACH5		Ch 5		Ch 5	P1 76	P1A 46	CP13
DACH6		Ch 6		Ch 6	P1 75	P1B 46	CP14
DACH7		Ch 7		Ch 7	P1 72	P1A 29	CP15
DACH8		Ch 8		Ch 8	P1 71	P1B 29	CP16

Signal	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on ...		
	Related RTI Block(s)	Ch/Bit (RTI)	Related RTLib Functions	Ch/Bit (RTLib)	DS1104	Sub-D Conn.	CP/CLP
Bit I/O Unit • TTL voltage range • Output current range: ±5 mA • I/O circuit and further electrical characteristics: see *Bit I/O* on page 125							
IO0	*DS1104BIT_IN_Cx* / *DS1104BIT_OUT_Cx*	Bit 0	See *Bit I/O Unit* in the *DS1104 RTLib Reference*	Bit 0	P1 68	P1A 12	CP17 20
IO1		Bit 1		Bit 1	P1 67	P1B 12	CP17 2
IO2		Bit 2		Bit 2	P1 66	P1A 28	CP17 21
IO3		Bit 3		Bit 3	P1 65	P1B 28	CP17 3
IO4		Bit 4		Bit 4	P1 64	P1A 44	CP17 23
IO5		Bit 5		Bit 5	P1 63	P1B 44	CP17 5
IO6		Bit 6		Bit 6	P1 62	P1A 11	CP17 24
IO7		Bit 7		Bit 7	P1 61	P1B 11	CP17 6
IO8		Bit 8		Bit 8	P1 60	P1A 27	CP17 26
IO9		Bit 9		Bit 9	P1 59	P1B 27	CP17 8
IO10		Bit 10		Bit 10	P1 58	P1A 43	CP17 27
IO11		Bit 11		Bit 11	P1 57	P1B 43	CP17 9
IO12		Bit 12		Bit 12	P1 56	P1A 10	CP17 29
IO13		Bit 13		Bit 13	P1 55	P1B 10	CP17 11
IO14		Bit 14		Bit 14	P1 54	P1A 26	CP17 30
IO15		Bit 15		Bit 15	P1 53	P1B 26	CP17 12
IO16 *		Bit 16		Bit 16	P1 52	P1A 42	CP17 32
IO17 *		Bit 17		Bit 17	P1 51	P1B 42	CP17 14
IO18 *		Bit 18		Bit 18	P1 50	P1A 9	CP17 33
IO19 *		Bit 19		Bit 19	P1 49	P1B 9	CP17 15
Incremental Encoder Interface • TTL or RS422 input voltage range • PHI0(x): digital incremental encoder interface input 0° ($\overline{\text{PHI0(x)}}$: inverted signal) • PHI90(x): digital incremental encoder interface input 90° ($\overline{\text{PHI90(x)}}$: inverted signal) • IDX(x): digital incremental encoder interface index input ($\overline{\text{IDX(x)}}$: inverted signal) • I/O circuit and further electrical characteristics: see *Incremental Encoder Interface* on page 129							
PHI0(1)	*DS1104ENC_SETUP* / *DS1104ENC_POS_Cx* / *DS1104ENC_SET_POS_Cx*	Ch 1	See *Incremental Encoder Interface* in the *DS1104 RTLib Reference*	Ch 1	P1 46	P1A 41	CP19 2
$\overline{\text{PHI0(1)}}$					P1 44	P1A 8	CP19 3
PHI90(1)					P1 42	P1A 24	CP19 4
$\overline{\text{PHI90(1)}}$					P1 40	P1A 40	CP19 5
PHI0(2)		Ch 2		Ch 2	P1 45	P1B 41	CP20 2
$\overline{\text{PHI0(2)}}$					P1 43	P1B 8	CP20 3
PHI90(2)					P1 41	P1B 24	CP20 4
$\overline{\text{PHI90(2)}}$					P1 39	P1B 40	CP20 5
IDX(1)	*DS1104ENC_SETUP* / *DS1104ENC_HW_INDEX_Cx* / *DS1104ENC_SW_INDEX_Cx*	Ch 1	See *Incremental Encoder Interface* in the *DS1104 RTLib Reference*	Ch 1	P1 38	P1A 7	CP19 6
$\overline{\text{IDX(1)}}$					P1 36	P1A 23	CP19 7
IDX(2)		Ch 2		Ch 2	P1 37	P1B 7	CP20 6
$\overline{\text{IDX(2)}}$					P1 35	P1B 23	CP20 7

Signal	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on …		
	Related RTI Block(s)	Ch/Bit (RTI)	Related RTLib Functions	Ch/Bit (RTLib)	DS1104	Sub-D Conn.	CP/CLP
Serial Interface (RS232 mode) • RS232 voltage range • DCD (data carrier detect), CTS (clear to send), RTS (ready to send), DSR (data set ready), DTR (data terminal ready), RXD (receive), TXD (transmit) • I/O circuit and further electrical characteristics: see *Serial Interface* on page 136							
DCD *	*DS1104SER_SETUP / DS1104SER_STAT / DS1104SER_TX / DS1104SER_RX / DS1104SER_INT_Ix / DS1104SER_INT_REC_LEV*		See *Serial Interface* in the *DS1104 RTLib Reference*		P1 3	P1B 34	CP21 1
CTS *					P1 5	P1B 18	CP21 8
RTS *					P1 6	P1A 18	CP21 7
DSR *					P1 7	P1B 2	CP21 6
DTR *					P1 8	P1A 2	CP21 4
RXD *					P1 9	P1B 35	CP21 2
TXD *					P1 10	P1A 35	CP21 3
Serial Interface (RS422/RS485 mode) • RS422/RS485 voltage range • CTS, $\overline{\text{CTS}}$ (clear to send and inverted signal), RTS, $\overline{\text{RTS}}$ (ready to send and inverted signal), RXD, $\overline{\text{RXD}}$ (receive and inverted signal), TXD, $\overline{\text{TXD}}$ (transmit and inverted signal) • I/O circuit and further electrical characteristics: see *Serial Interface* on page 136							
CTS *	*DS1104SER_SETUP / DS1104SER_STAT / DS1104SER_TX / DS1104SER_RX / DS1104SER_INT_Ix / DS1104SER_INT_REC_LEV*		See *Serial Interface* in the *DS1104 RTLib Reference*		P1 3	P1B 34	CP22 8
RTS *					P1 4	P1A 34	CP22 7
$\overline{\text{CTS}}$ *					P1 5	P1B 18	CP22 9
$\overline{\text{RTS}}$ *					P1 6	P1A 18	CP22 6
RXD *					P1 7	P1B 2	CP22 3
TXD *					P1 8	P1A 2	CP22 2
$\overline{\text{RXD}}$ *					P1 9	P1B 35	CP22 4
$\overline{\text{TXD}}$ *					P1 10	P1A 35	CP22 1

Signal	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on ...		
	Related RTI Block(s)	Ch/Bit (RTI)	Related RTLib Functions	Ch/Bit (RTLib)	DS1104	Sub-D Conn.	CP/CLP
Slave DSP Bit I/O Unit • TTL voltage range • Output current range: ±13 mA • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
SPWM7 *	*DS1104SL_DSP_BIT_IN_Cx/ DS1104SL_DSP_BIT_OUT_Cx*	Bit 0	See *Slave DSP Bit I/O Unit* in the *DS1104 RTLib Reference*	Group 2 bit 0	P1 31	P1B 6	CP18 10
SPWM8 *		Bit 1		Group 2 bit 1	P1 29	P1B 22	CP18 29
SPWM9 *		Bit 2		Group 2 bit 2	P1 27	P1B 38	CP18 11
ST1PWM *		Bit 3		Group 2 bit 3	P1 25	P1B 5	CP18 23
ST2PWM *		Bit 4		Group 2 bit 4	P1 23	P1B 21	CP18 5
ST3PWM		Bit 5		Group 2 bit 5	P1 21	P1B 37	CP18 24
SCAP1 *		Bit 6		Group 3 bit 4	P1 18	P1A 20	CP18 2
SCAP2 *		Bit 7		Group 3 bit 5	P1 16	P1A 36	CP18 21
SCAP3 *		Bit 8		Group 3 bit 6	P1 14	P1A 3	CP18 3
SCAP4 *		Bit 9		Group 3 bit 7	P1 12	P1A 19	CP18 22
SCLK *		Bit 10		Group 4 bit 0	P1 17	P1B 20	CP18 17
SSTE *		Bit 11		Group 4 bit 1	P1 15	P1B 36	CP18 35
SSIMO *		Bit 12		Group 4 bit 2	P1 13	P1B 3	CP18 16
SSOMI *		Bit 13		Group 4 bit 3	P1 11	P1B 19	CP18 34

Signal	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on ...		
	Related RTI Block(s)	Ch/Bit (RTI)	Related RTLib Functions	Ch/Bit (RTLib)	DS1104	Sub-D Conn.	CP/CLP
Slave DSP PWM Signal Generation (PWM, PWM3, PWMSV) • TTL output voltage range • Output current range: ±13 mA • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
ST2PWM *	*DS1104SL_DSP_PWM*	Ch 1	See *Slave DSP PWM Generation* in the *DS1104 RTLib Reference*	Ch 1	P1 23	P1B 21	CP18 5
SPWM7 *		Ch 2		Ch 2	P1 31	P1B 6	CP18 10
SPWM8 *		Ch 3		Ch 3	P1 29	P1B 22	CP18 29
SPWM9 *		Ch 4		Ch 4	P1 27	P1B 38	CP18 11
SPWM1 *	*DS1104SL_DSP_PWM3 / DS1104SL_DSP_PWMSV*	Phase 1	See *Slave DSP PWM3 Generation / Slave DSP PWMSV Generation* in the *DS1104 RTLib Reference*	Phase 1	P1 32	P1A 6	CP18 7
SPWM3 *		Phase 2		Phase 2	P1 28	P1A 38	CP18 8
SPWM5 *		Phase 3		Phase 3	P1 24	P1A 21	CP18 9
SPWM2		Phase 1 (inverted)		Phase 1 (inverted)	P1 30	P1A 22	CP18 26
SPWM4		Phase 2 (inverted)		Phase 2 (inverted)	P1 26	P1A 5	CP18 27
SPWM6		Phase 3 (inverted)		Phase 3 (inverted)	P1 22	P1A 37	CP18 28
Slave DSP Square-Wave Signal Generation (D2F) • TTL output voltage range • Output current range: ±13 mA • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
SPWM1 *	*DS1104SL_DSP_D2F*	Ch 1	See *Square Wave Signal Generation (D2F)* in the *DS1104 RTLib Reference*	Ch 1	P1 32	P1A 6	CP18 7
SPWM3 *		Ch 2		Ch 2	P1 28	P1A 38	CP18 8
SPWM5 *		Ch 3		Ch 3	P1 24	P1A 21	CP18 9
ST2PWM *		Ch 4		Ch 4	P1 23	P1B 21	CP18 5
Slave DSP PWM Signal Measurement (PWM2D) • TTL input voltage range • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
SCAP1 *	*DS1104SL_DSP_PWM2D*	Ch 1	See *Slave DSP PWM Measurement (PWM2D)* in the *DS1104 RTLib Reference*	Ch 1	P1 18	P1A 20	CP18 2
SCAP2 *		Ch 2		Ch 2	P1 16	P1A 36	CP18 21
SCAP3 *		Ch 3		Ch 3	P1 14	P1A 3	CP18 3
SCAP4 *		Ch 4		Ch 4	P1 12	P1A 19	CP18 22
Slave DSP Square-Wave Signal Measurement (F2D) • TTL input voltage range • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
SCAP1 *	*DS1104SL_DSP_F2D*	Ch 1	See *Square Wave Signal Measurement (F2D)* in the *DS1104 RTLib Reference*	Ch 1	P1 18	P1A 20	CP18 2
SCAP2 *		Ch 2		Ch 2	P1 16	P1A 36	CP18 21
SCAP3 *		Ch 3		Ch 3	P1 14	P1A 3	CP18 3
SCAP4 *		Ch 4		Ch 4	P1 12	P1A 19	CP18 22

Signal	Channel/Bit Numbers of Related RTI Blocks/RTLib Functions				I/O Pin on ...		
	Related RTI Block(s)	Ch/Bit (RTI)	Related RTLib Functions	Ch/Bit (RTLib)	DS1104	Sub-D Conn.	CP/CLP
Slave DSP Serial Peripheral Interface (SPI) • TTL voltage range • Output current range: ±13 mA • SSOMI: SPI slave out, master in • SSIMO: SPI slave in, master out • SSTE: SPI slave transmit enable • SSCLK: SPI clock • I/O circuit and further electrical characteristics: see *Slave DSP Digital I/O* on page 142							
SSOMI *	–		See *Slave DSP Serial Peripheral Interface* in the *DS1104 RTLib Reference*		P1 11	P1B 19	CP18 34
SSIMO *	–				P1 13	P1B 3	CP18 16
SSTE *	–				P1 15	P1B 36	CP18 35
SSCLK *	–				P1 17	P1B 20	CP18 17
User Interrupts • TTL input voltage range • I/O circuit and further electrical characteristics: see *Bit I/O* on page 125							
IO16 *	*DS1104MASTER_HWINT_Ix*	User int 1	See *Interrupt Handling* in the *DS1104 RTLib Reference*	Ext int 0	P1 52	P1A 42	CP17 32
IO17 *		User int 2		Ext int 1	P1 51	P1B 42	CP17 14
IO18 *		User int 3		Ext int 2	P1 50	P1A 9	CP17 33
IO19 *		User int 4		Ext int 3	P1 49	P1B 9	CP17 15

GND pins The following I/O pins provide GND potential:

Connector		Pin
DS1104		
I/O Connector	P1	1, 2, 33, 34, 47, 48, 69, 70, 73, 74, 77, 78, 81, 82, 85, 86, 89, 90, 93, 94, 97, 98
Sub-D Connector	P1A	1, 13, 15, 17, 25, 30, 32, 39, 45, 47, 49
	P1B	1, 13, 15, 17, 25, 30, 32, 39, 45, 47, 49
CP1104/CLP1104 Connector Panel		
BNC	CP1 ... CP16	Shell
Digital I/O	CP17	1, 4, 7, 10, 13, 16 ... 19, 22, 25, 28, 31, 34, 35
Slave I/O	CP18	1, 4, 6, 12 ... 15, 20, 25, 30 ... 33, 36, 37
Incremental Encoder Interface	CP19, CP20	8, 10 ... 15
UART RS232 and RS485/422	CP21 , CP22	5

GND of the DS1104 is internally connected to PC ground.

VCC pins

The following I/O pins provide access to the PC power supply VCC (+5 V):

Connector		Pin
DS1104		
I/O Connector	P1	19, 20
Sub-D Connector	P1A	4
	P1B	4
CP1104/CLP1104 Connector Panel		
Digital I/O	CP17	36, 37
Slave I/O	CP18	18, 19
Incremental Encoder Interface	CP19, CP20	1, 9

- For the DS1104, the total load of the connector pins P1 19 and P1 20 (pins P1B 4 and P1A 4 on the Sub-D connector) must not exceed 500 mA.
- For the connector panels CP1104 and CLP1104, the total load of all connector pins that provide access to the PC power supply must not exceed 500 mA (CP1104) or 400 mA (CLP1104).

Conflicting I/O Features

Conflicts

There are I/O features that share the same board resources.

Conflicts concerning single I/O channels There are conflicts that concern single channels of an I/O feature. The dSPACE board provides only a limited number of I/O pins. The same pins may be shared by different I/O features. However, one pin can serve as the I/O channel for only one feature at a time.

Conflicts concerning an I/O feature as a whole There are conflicts that concern the use of an I/O feature as a whole. Suppose two I/O features of the dSPACE board use the same on-board timer device. In this case, only one of the two I/O features can be used at a time. The other feature is completely blocked.

Conflicts for the DS1104

The following I/O features of the DS1104 conflict with other I/O features:

- Bit I/O Unit: see page 110
- Serial Interface: see page 110
- Slave DSP Bit I/O Unit: see page 111
- Slave DSP 1-Phase PWM Signal Generation (PWM): see page 112
- Slave DSP 3-Phase PWM Signal Generation (PWM3): see page 112
- Slave DSP Space Vector PWM Signal Generation (PWMSV): see page 113
- Slave DSP Square-Wave Signal Generation (D2F): see page 114
- Slave DSP PWM Signal Measurement (PWM2D): see page 115
- Slave DSP Square-Wave Signal Measurement: see page 116
- Slave DSP Serial Peripheral Interface (SPI): see page 117

Conflicts for the Bit I/O Unit

The following I/O features of the DS1104 conflict with the Bit I/O unit:

Bit I/O Unit *)			Conflicting I/O Feature **)		
Bit (RTI)	Bit (RTLib)	Signal		Ch (RTI)	Ch (RTLib)
Conflicts Concerning Single Bits					
Bit 16	Bit 16	IO16	User interrupt	User Int 1	Ext Int 0
Bit 17	Bit 17	IO17	User interrupt	User Int 2	Ext Int 1
Bit 18	Bit 18	IO18	User interrupt	User Int 3	Ext Int 2
Bit 19	Bit 19	IO19	User interrupt	User Int 4	Ext Int 3
*) Related RTI blocks and RTLib functions: • *DS1104BIT_IN_Cx/DS1104BIT_OUT_Cx* • See *Bit I/O Unit* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: • *DS1104MASTER_HWINT_Ix* • See *Interrupt Handling* in the DS1104 RTLib Reference		

Conflicts for the Serial Interface

The master PPC of the DS1104 supports only one serial interface. It can be configured as either RS232 or RS422/RS485 transceiver.

Conflicts for External Triggering

Enabling the external trigger conflicts with the slave DSP bit I/O unit. You cannot use the following bits for digital I/O purposes at the same time:

External Trigger Signal			Conflicting I/O Feature **)		
Bit (RTI)	Bit (RTLib)	Signal		Ch (RTI)	Ch (RTLib)
Conflicts Concerning External Triggering					
External Trigger			SPWM7	Bit 0	Group 2 bit 0
			SPWM8	Bit 1	Group 2 bit 1
			SPWM9	Bit 2	Group 2 bit 2
			ST1PWM (used for triggering)	Bit 3	Group 2 bit 3
			ST2PWM	Bit 4	Group 2 bit 4
			ST3PWM	Bit 5	Group 2 bit 5
*) Related RTI blocks and RTLib functions: • *DS1104SYNC_IO_SETUP* • See *Synchronous I/O Trigger* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_BIT_IN_Cx*, *DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference		

Conflicts for the Slave DSP Bit I/O Unit

The following I/O features of the DS1104 conflict with the Slave DSP Bit I/O unit:

Slave DSP Bit I/O Unit *)			Conflicting I/O Feature **)		
Bit (RTI)	**Bit (RTLib)**	**Signal**		**Ch (RTI)**	**Ch (RTLib)**
Conflicts Concerning Single Bits					
Bit 0	Group 2, bit 0	SPWM7	• PWM • External Trigger	Ch 2	Ch 2
Bit 1	Group 2, bit 1	SPWM8	• PWM • External Trigger	Ch 3	Ch 3
Bit 2	Group 2, bit 2	SPWM9	• PWM • External Trigger	Ch 4	Ch 4
Bit 3	Group 2, bit 3	ST1PWM	• Slave DSP PWM int • External Trigger		
Bit 4	Group 2, bit 4	ST2PWM	• PWM • D2F • External Trigger	• Ch 1 • Ch 4	• Ch 1 • Ch 4
Bit 5	Group 2, bit 5	ST3PWM	External Trigger		
Bit 6	Group 3, bit 4	SCAP1	PWM2D/F2D	Ch 1	Ch 1
Bit 7	Group 3, bit 5	SCAP2	PWM2D/F2D	Ch 2	Ch 2
Bit 8	Group 3, bit 6	SCAP3	PWM2D/F2D	Ch 3	Ch 3
Bit 9	Group 3, bit 7	SCAP4	PWM2D/F2D	Ch 4	Ch 4
Bit 10	Group 4, bit 0	SCLK	SPI	–	
Bit 11	Group 4, bit 1	SSTE	SPI	–	
Bit 12	Group 4, bit 2	SSIMO	SPI	–	
Bit 13	Group 4, bit 3	SSOMI	SPI	–	
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_BIT_IN_Cx/ DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: PWM: • *DS1104SL_DSP_PWM* • See *Slave DSP PWM Generation* in the DS1104 RTLib Reference Slave DSP PWM int • *DS1104SLAVE_PWMINT* • See *ds1104_slave_dsp_pwm3_int_init* in the DS1104 RTLib Reference D2F: • *DS1104SL_DSP_D2F* • See *Square Wave Signal Generation (D2F)* in the DS1104 RTLib Reference PWM2D/F2D: • *DS1104SL_DSP_PWM2D/DS1104SL_DSP_F2D* • See *Slave DSP PWM Measurement (PWM2D)/Square Wave Signal Measurement (F2D)* in the DS1104 RTLib Reference SPI: • See *Slave DSP Serial Peripheral Interface* in the DS1104 RTLib Reference		

Conflicts for Slave DSP 1-Phase PWM Signal Generation (PWM)

The following I/O features of the DS1104 conflict with Slave DSP 1-Phase PWM Signal Generation:

Slave DSP 1-Phase PWM Signal Generation (PWM) *)			Conflicting I/O Feature **)		
Ch (RTI)	Ch (RTLib)	Signal		Ch (RTI)	Ch (RTLib)
Conflicts Concerning Slave DSP 1-Phase PWM Signal Generation as a Whole					
• If you use channel 4 of D2F, you cannot generate 1-phase PWM signals at the same time.					
Conflicts Concerning Single Channels					
Ch 1	Ch 1	ST2PWM	Slave DSP Bit I/O unit	Bit 4	Group 2, bit 4
Ch 2	Ch 2	SPWM7	Slave DSP Bit I/O unit	Bit 0	Group 2, bit 0
Ch 3	Ch 3	SPWM8	Slave DSP Bit I/O unit	Bit 1	Group 2, bit 1
Ch 4	Ch 4	SPWM9	Slave DSP Bit I/O unit	Bit 2	Group 2, bit 2
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_PWM* • See *Slave DSP PWM Generation* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: D2F: • *DS1104SL_DSP_D2F* • See *Square Wave Signal Generation (D2F)* in the DS1104 RTLib Reference Slave DSP Bit I/O Unit: • *DS1104SL_DSP_BIT_IN_Cx/ DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference		

Conflicts for Slave DSP 3-Phase PWM Signal Generation (PWM3)

The following I/O features of the DS1104 conflict with Slave DSP 3-Phase PWM Signal Generation:

Slave DSP 3-Phase PWM Signal Generation (PWM3) *)			Conflicting I/O Feature **)		
Ch (RTI)	Ch (RTLib)	Signal		Ch (RTI)	Ch (RTLib)
Conflicts Concerning Slave DSP 3-Phase PWM Signal Generation as a Whole					
• If you perform space vector PWM signal generation (PWMSV) or square-wave signal generation (D2F), you cannot generate 3-phase PWM signals at the same time.					
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_PWM3* • See *Slave DSP PWM3 Generation* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: PWMSV: • *DS1104SL_DSP_PWMSV* • See *Slave DSP PWMSV Generation* in the DS1104 RTLib Reference D2F: • *DS1104SL_DSP_D2F* • See *Square Wave Signal Generation (D2F)* in the DS1104 RTLib Reference		

Conflicts for Slave DSP Space Vector PWM Signal Generation (PWMSV)

The following I/O features of the DS1104 conflict with Slave DSP Space Vector PWM Signal Generation:

<table>
<tr><th colspan="2">Slave DSP Space Vector PWM Signal Generation (PWMSV) *)</th><th rowspan="2">Signal</th><th colspan="3">Conflicting I/O Feature **)</th></tr>
<tr><th>Ch (RTI)</th><th>Ch (RTLib)</th><th></th><th>Ch (RTI)</th><th>Ch (RTLib)</th></tr>
<tr><td colspan="6">Conflicts Concerning Slave DSP 3-Phase PWM Signal Generation as a Whole
• If you perform 3-phase PWM signal generation (PWM3) or square-wave signal generation (D2F), you cannot generate space vector PWM signals at the same time.</td></tr>
<tr><td colspan="2">*) Related RTI blocks and RTLib functions:
• DS1104SL_DSP_PWMSV
• See Slave DSP PWMSV Generation in the DS1104 RTLib Reference</td><td></td><td colspan="3">**) Related RTI blocks and RTLib functions:
3-phase PWM signal generation (PWM3):
• DS1104SL_DSP_PWM3
• See Slave DSP PWM3 Generation in the DS1104 RTLib Reference
D2F:
• DS1104SL_DSP_D2F
• See Square Wave Signal Generation (D2F) in the DS1104 RTLib Reference</td></tr>
</table>

Conflicts for Slave DSP Square-Wave Signal Generation (D2F)

The following I/O features of the DS1104 conflict with Slave DSP Square-Wave Signal Generation:

Slave DSP Square-Wave Signal Generation (D2F) *)			Conflicting I/O Feature **)		
Ch (RTI)	Ch (RTLib)	Signal		Ch (RTI)	Ch (RTLib)
Conflicts Concerning Slave DSP Square-Wave Signal Generation as a Whole					
• If you perform 3-phase or space vector PWM signal generation (PWM3 or PWMSV), you cannot generate square-wave signals at the same time.					
Conflicts Concerning Single Channels					
Ch 4	Ch 4	ST2PWM	• Slave DSP Bit I/O unit • PWM	• Bit 4 • Ch 1	• Group 2, bit 4 • Ch 1
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_D2F* • See *Square Wave Signal Generation (D2F)* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: PWM3/PWMSV: • *DS1104SL_DSP_PWM3*/*DS1104SL_DSP_PWMSV* • See *Slave DSP PWM3 Generation*/*Slave DSP PWMSV Generation* in the DS1104 RTLib Reference Slave DSP Bit I/O Unit: • *DS1104SL_DSP_BIT_IN_Cx*/ *DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference PWM: • *DS1104SL_DSP_PWM* • See *Slave DSP PWM Generation* in the DS1104 RTLib Reference		

Conflicts for Slave DSP PWM Signal Measurement (PWM2D)

The following I/O features of the DS1104 conflict with Slave DSP PWM Signal Measurement:

Slave DSP PWM Signal Measurement (PWM2D) *)			Conflicting I/O Feature **)		
Ch (RTI)	**Ch (RTLib)**	**Signal**		**Ch (RTI)**	**Ch (RTLib)**
Conflicts Concerning Slave DSP PWM Signal Measurement as a Whole					
• If you perform square-wave signal measurement (F2D), you cannot measure PWM signals at the same time.					
Conflicts Concerning Single Channels					
Ch 1	Ch 1	SCAP1	Slave DSP Bit I/O unit	Bit 6	Group 3, bit 4
Ch 2	Ch 2	SCAP2	Slave DSP Bit I/O unit	Bit 7	Group 3, bit 5
Ch 3	Ch 3	SCAP3	Slave DSP Bit I/O unit	Bit 8	Group 3, bit 6
Ch 4	Ch 4	SCAP4	Slave DSP Bit I/O unit	Bit 9	Group 3, bit 7
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_PWM2D* • See *Slave DSP PWM Measurement (PWM2D)* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: F2D: • *DS1104SL_DSP_F2D* • See *Square Wave Signal Measurement (F2D)* in the DS1104 RTLib Reference Slave DSP Bit I/O Unit: • *DS1104SL_DSP_BIT_IN_Cx*/ *DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference		

Conflicts for Slave DSP Square-Wave Signal Measurement (F2D)

The following I/O features of the DS1104 conflict with Slave DSP Square-Wave Signal Measurement:

Slave DSP Square-Wave Signal Measurement (F2D) *)			Conflicting I/O Feature **)		
Ch (RTI)	**Ch (RTLib)**	**Signal**		**Ch (RTI)**	**Ch (RTLib)**
Conflicts Concerning Slave DSP Square-Wave Signal Measurement as a Whole					
• If you perform PWM signal measurement (PWM2D), you cannot measure square-wave signals at the same time.					
Conflicts Concerning Single Channels					
Ch 1	Ch 1	SCAP1	Slave DSP Bit I/O unit	Bit 6	Group 3, bit 4
Ch 2	Ch 2	SCAP2	Slave DSP Bit I/O unit	Bit 7	Group 3, bit 5
Ch 3	Ch 3	SCAP3	Slave DSP Bit I/O unit	Bit 8	Group 3, bit 6
Ch 4	Ch 4	SCAP4	Slave DSP Bit I/O unit	Bit 9	Group 3, bit 7
*) Related RTI blocks and RTLib functions: • *DS1104SL_DSP_F2D* • See *Square Wave Signal Measurement (F2D)* in the DS1104 RTLib Reference			**) Related RTI blocks and RTLib functions: PWM2D: • *DS1104SL_DSP_PWM2D* • See *Slave DSP PWM Measurement (PWM2D)* in the DS1104 RTLib Reference Slave DSP Bit I/O Unit: • *DS1104SL_DSP_BIT_IN_Cx*/ *DS1104SL_DSP_BIT_OUT_Cx* • See *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference		

Conflicts for the Slave DSP Serial Peripheral Interface (SPI)

The following I/O features of the DS1104 conflict with the Slave DSP Serial Peripheral Interface (SPI):

Slave DSP Serial Peripheral Interface *)	Signal	Conflicting I/O Feature **)	Bit (RTI)	Bit (RTLib)
Conflicts Concerning the Slave DSP Serial Peripheral Interface (SPI) as a Whole				
• If you use the following bits of the Slave DSP Bit I/O Unit you cannot use the SPI.				
	SCLK	Slave DSP Bit I/O unit	Bit 10	Group 4, bit 0
	SSTE	Slave DSP Bit I/O unit	Bit 11	Group 4, bit 1
	SSIMO	Slave DSP Bit I/O unit	Bit 12	Group 4, bit 2
	SSOMI	Slave DSP Bit I/O unit	Bit 13	Group 4, bit 3
*) Related RTLib functions: • See *Slave DSP Serial Peripheral Interface* in the DS1104 RTLib Reference		**) Related RTI blocks and RTLib functions: • Related RTI blocks: *DS1104SL_DSP_BIT_IN_Cx/ DS1104SL_DSP_BIT_OUT_Cx* • Related RTLib functions: see *Slave DSP Bit I/O Unit* in the DS1104 RTLib Reference		

Signal Connection to External Devices

This chapter provides descriptions of the on-board I/O circuits, lists important electrical characteristics and gives notes and tips on signal conditioning and signal connection to external devices.

The information given is sorted according to the I/O units of the DS1104:

User interrupts must be connected to the pins of the bit I/O unit. For details, see *Recognizing User Interrupts* on page 128.

Analog Inputs

The DS1104 contains two different types of analog/digital converters (ADCs) for the analog input channels:

- One 16-bit ADC with four multiplexed input signals: **ADCH1** ... **ADCH4**
- Four 12-bit parallel ADCs with one input signal each: **ADCH5** ... **ADCH8**

For a feature description of the ADCs refer to *ADC Unit* in the *DS1104 Features* document.

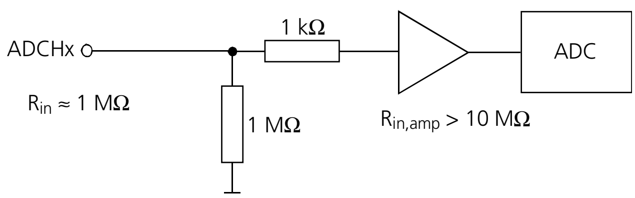
For detailed information on connecting external devices to the analog inputs, refer to:

- *Input Circuit and Electrical Characteristics* on page 121
- *Notes and Tips on Signal Conditioning* on page 121

Input Circuit and Electrical Characteristics

Input circuit

The following illustration is a simplified diagram of the input circuitry of the ADCs.



Electrical characteristics

The analog inputs are single-ended bipolar inputs with the following characteristics.

<table>
<tr><th colspan="2">Parameter</th><th colspan="2">Value</th></tr>
<tr><td colspan="2">Input voltage</td><td>Min.
–10 V</td><td>Max.
+10 V</td></tr>
<tr><td colspan="2">Input resistance</td><td colspan="2">Approx. 1 MΩ</td></tr>
<tr><td>SNR (signal-to-noise ratio)</td><td>• 16-bit muxed ADCs
• 12-bit parallel ADCs</td><td colspan="2">• > 80 dB
• > 65 dB</td></tr>
</table>

Notes and Tips on Signal Conditioning

The following notes and tips are intended to help you achieve optimum results using the ADCs.

Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if you do not perform the following correctly:

- *Grounding and Shielding* on page 147
- *Avoiding Crosstalk* on page 151
- *Wiring Up External Devices* on page 152

Analog Outputs

The DS1104 provides a digital/analog converter (DAC) with 8 parallel DAC channels. The analog output channels are called **DACH1** ... **DACH8**.

For a feature description of the DACs refer to *DAC Unit* in the *DS1104 Features* document.

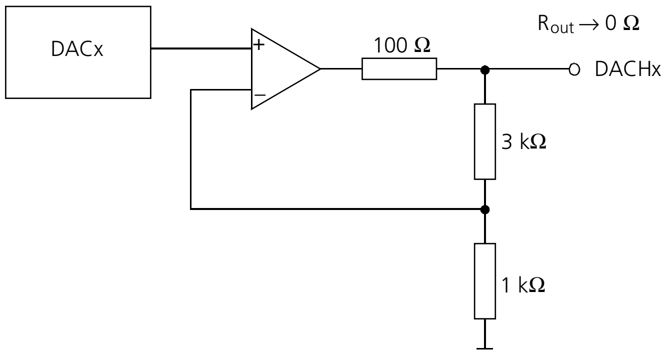
For detailed information on connecting external devices to the analog outputs, refer to:

- *Output Circuit and Electrical Characteristics* on page 123
- *Notes and Tips on Signal Conditioning* on page 124

Output Circuit and Electrical Characteristics

Output circuit

The following illustration is a simplified diagram of the output circuitry of the DACs.



Electrical characteristics

The analog outputs are single-ended bipolar outputs with the following characteristics.

Parameter	Value	
	Min.	Max.
Output voltage	–10 V	+10 V
Output current	–5 mA	+5 mA
Output resistance	→ 0 Ω	
Power-up default	0 V	
SNR (signal-to-noise ratio)	> 80 dB	

DAC outputs are low-impedance outputs.

Notes and Tips on Signal Conditioning

The following notes and tips are intended to help you achieve optimum results when using the DACs.

Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if you do not perform the following correctly:

- *Grounding and Shielding* on page 147
- *Avoiding Crosstalk* on page 151
- *Wiring Up External Devices* on page 152

Bit I/O

The DS1104 contains a bit I/O unit with 20 digital I/O pins called **IO0** ... **IO19.**

You can select the direction for each bit individually by software. For a feature description of the bit I/O unit refer to *Bit I/O Unit* in the *DS1104 Features* document.

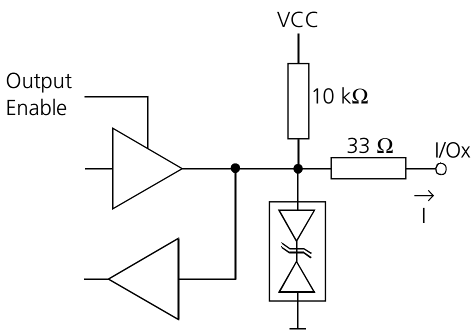
For detailed information on connecting external devices to the bit I/O, refer to:

- *I/O Circuit and Electrical Characteristics* on page 126
- *Notes and Tips on Signal Conditioning* on page 127

I/O Circuit and Electrical Characteristics

I/O circuit

The following illustration is a simplified diagram of the input/output circuitry of the bit I/O.



Electrical characteristics

The bit I/O has TTL output/input levels with the following characteristics.

Parameter		Value	
		Min.	Max.
Input voltage	High Low	2.0 V 0 V	5.0 V 0.8 V
Output voltage	High Low	2.4 V 0 V	5.0 V 0.4 V
Output current		–5 mA	+5 mA
Input current (The current direction is shown in the circuit diagram above.)			500 µA
Power-up default		All bit I/O output circuits are disabled and driven to VCC by the built-in 10 kΩ pull-up resistors.	

Notes and Tips on Signal Conditioning

The following notes and tips are intended to help you achieve optimum results when using the bit I/O:

- *Changing Power-up Default* on page 128
- *Recognizing User Interrupts* on page 128
- Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if you do not perform the following correctly:
  - *Grounding and Shielding* on page 147
  - *Avoiding Crosstalk* on page 151
  - *Wiring Up External Devices* on page 152

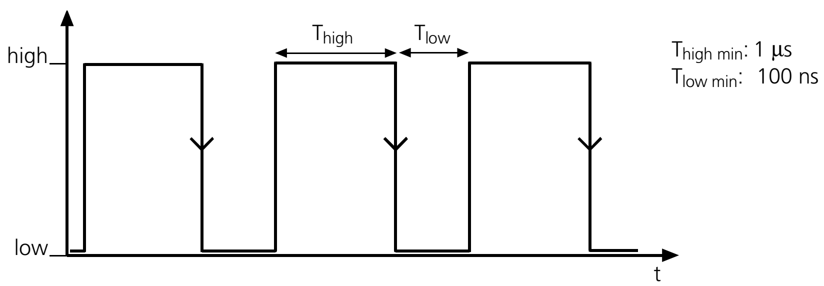
Changing Power-up Default

After power-up the bit I/O unit is configured to input mode. In this case, the I/O pins have a defined logical high level because of the built-in pull-up resistors.

If you want to change the power-up default, you can set the I/O pins to a defined logical low level by connecting a 1 kΩ pull-down resistor from ground to each I/O pin.

Recognizing User Interrupts

IO16 ... **IO19** can be used as external interrupt inputs. To allow the interrupt controller to recognize incoming user interrupts, the input of the interrupts must be kept high for at least 1 µs. The interrupt is activated by the high to low transition of the signal. The signal must remain low for at least 100 ns after the transition.



Incremental Encoder Interface

The DS1104 provides a digital incremental encoder interface with input channels for two incremental encoders. The pins which make up the inputs are called:

- **IDX(1), $\overline{\textbf{IDX(1)}}$, PHI90(1), $\overline{\textbf{PHI90(1)}}$, PHI0(1), $\overline{\textbf{PHI0(1)}}$**
- **IDX(2), $\overline{\textbf{IDX(2)}}$, PHI90(2), $\overline{\textbf{PHI90(2)}}$, PHI0(2), $\overline{\textbf{PHI0(2)}}$**

The incremental encoder interface supports single-ended TTL and differential RS422 signals (selectable by software). For a feature description of the encoder interface refer to *Incremental Encoder Interface* in the *DS1104 Features* document.

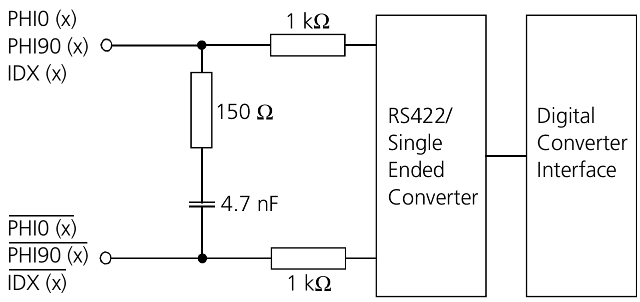
For detailed information on connecting external devices to the incremental encoder interface, refer to:

- *Input Circuit and Electrical Characteristics* on page 130
- *Notes and Tips on Signal Conditioning* on page 132

Input Circuit and Electrical Characteristics

Input circuit

The following illustration is a simplified diagram of the input circuitry of the digital incremental encoders.



Electrical characteristics

The encoder interface supports single-ended TTL and differential RS422 signals with the following characteristics.

Parameter		Value	
		Min.	Max.
TTL input voltage	High Low	2.0 V 0 V	5.0 V 0.8 V
TTL input resistance		12 kΩ	
RS422 input voltage	High Low	Diff > +0.2 V Diff < -0.2 V • Diff = Voltage difference between non-inverted and inverted signal • The input signal, together with the corresponding inverted signal, must be in the range 0 ... 5 V.	
RS422 input resistance		The input resistance gradually drops from 8.5 kΩ at the corner frequency of 28 kHz to 210 Ω at the corner frequency of 225 kHz.	

Encoder power supply lines

The DS1104 offers a 5 V supply voltage for the incremental encoders. These voltage outputs (**VCC**) are connected to the PC's 5 V power supply via a multifuse.

If a supply output is overloaded or shorted, the multifuse is heated by the overcurrent and abruptly increases its resistance. To reset the multifuse to its initial low resistance, remove the power for some minutes to allow the multifuse to cool down.

You should use the **VCC** supply voltages for all connected incremental sensors.

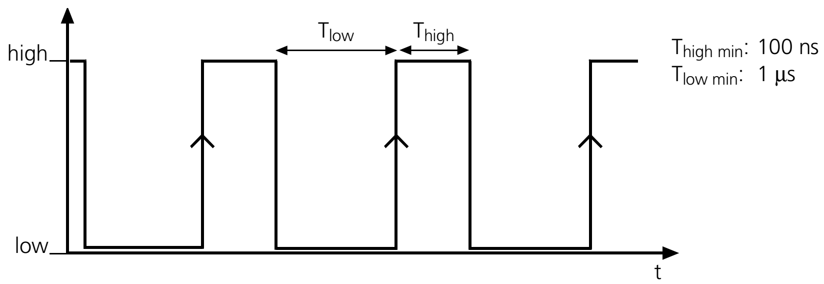
Notes and Tips on Signal Conditioning

The following notes and tips are intended to help you achieve optimum results using the incremental encoder interface:

- *Recognizing Encoder Index Interrupts*: see below
- *Connecting Encoders* on page 133
- *Supplying Power to Encoders* on page 135
- Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if you do not provide correct shielding. For details refer to *Shielding* on page 150.

Recognizing Encoder Index Interrupts

To allow the interrupt controller to recognize incoming index interrupts (IDX1, IDX2), the input of the index interrupts must be kept low for at least 1 µs. The interrupt is activated by the low to high transition of the signal. The signal must remain high for at least 100 ns after the transition from low to high.



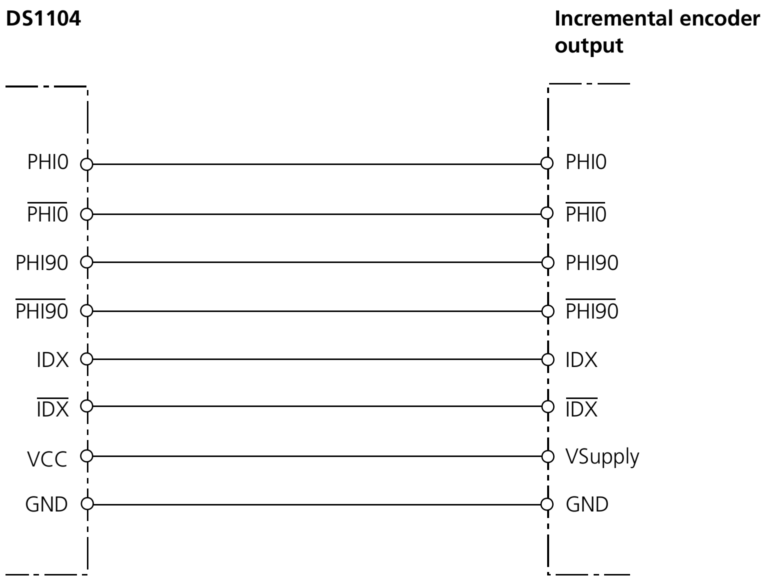
Connecting Encoders

General

To allow proper operation, do not connect the outputs of your encoder to an AC-coupling network. The input signals must be DC signals.

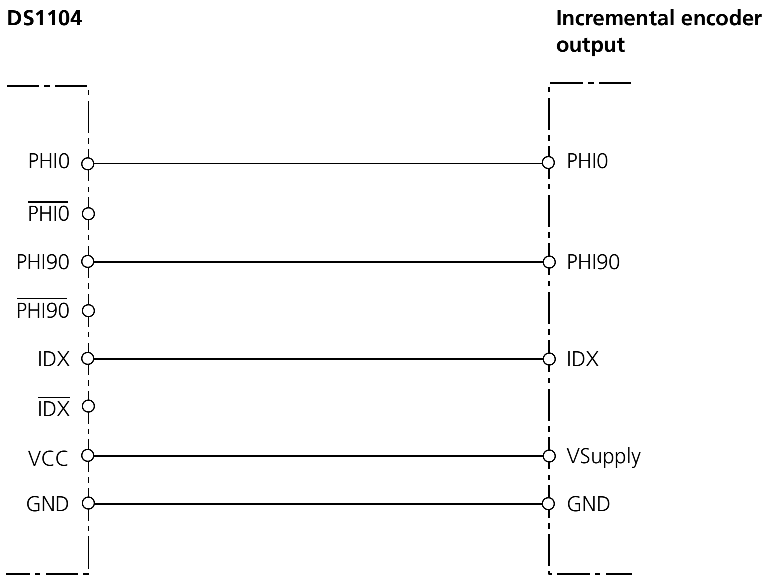
Encoder providing differential RS422 signals

Connect encoders that provide differential RS422 signals to the DS1104 as shown in the illustration below.



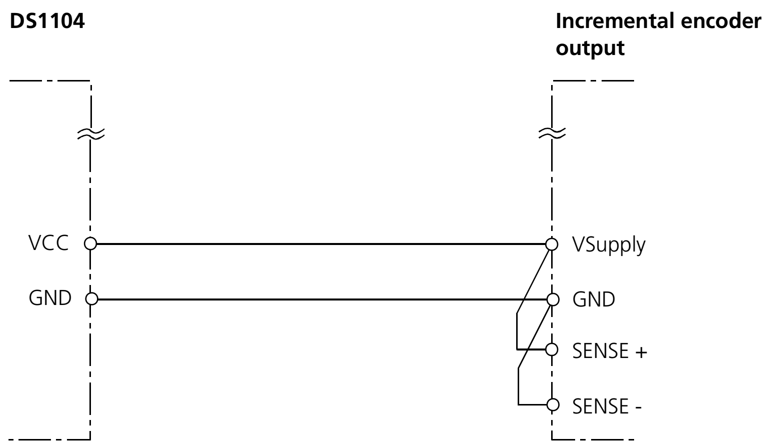
Encoder providing single-ended TTL mode

If the single ended TTL mode is used, the inverted pins $\overline{\text{PHI90}}$, $\overline{\text{PHI0}}$ and $\overline{\text{IDX}}$ must be left unconnected (see below).



Encoder providing SENSE lines

If your encoder has sense lines, connect SENSE+ to Vsupply and SENSE– to GND. Connect the sense lines directly within the connector of the encoder (see below).



Encoder without index signal

You can leave the IDX and $\overline{\text{IDX}}$ pins unconnected if your encoder does not provide an index signal. In this case, you cannot use RTLib functions or RTI blocks that require an index signal.

Supplying Power to Encoders

Using VCC pins

The DS1104 offers two VCC pins. You should use these supply voltages for all connected incremental encoders.

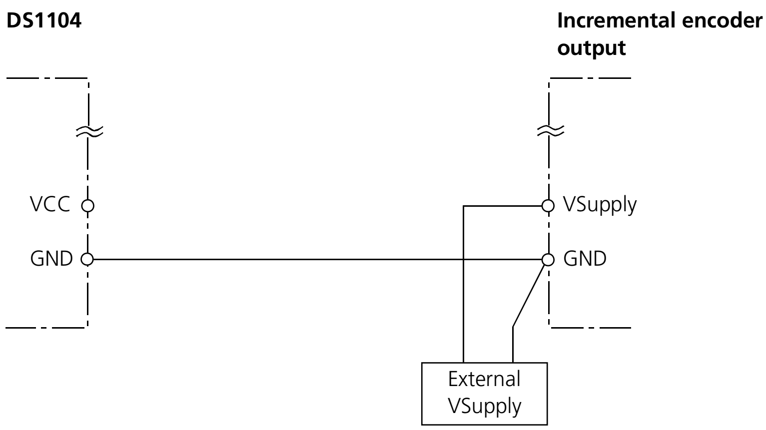
Connect both pins so that the current is shared evenly by both pins. Use wires of sufficient diameter to avoid voltage drops.

The total load of **all** connector pins that provide access to the PC power supply must not exceed 500 mA (DS1104 or via CP1104) or 400 mA (CLP1104).

Using an external power supply

If you use an external supply voltage, you have:

- To guarantee that no input voltages are fed to the DS1104 while it is switched off
- To connect the encoder's ground line to a ground pin of the board (see example below)



Serial Interface

The DS1104 contains a Universal Asynchronous Receiver and Transmitter (UART) to perform communication with external devices. The UART can be configured as a RS232, RS422 or RS485 transceiver.

The pins of the UART are called:

- **RXD, $\overline{\text{RXD}}$**
- **TXD, $\overline{\text{TXD}}$**
- **RTS, $\overline{\text{RTS}}$**
- **CTS, $\overline{\text{CTS}}$**
- **DCD, DTR, DSR**

For a feature description refer to *Serial Interface* in the *DS1104 Features* document.

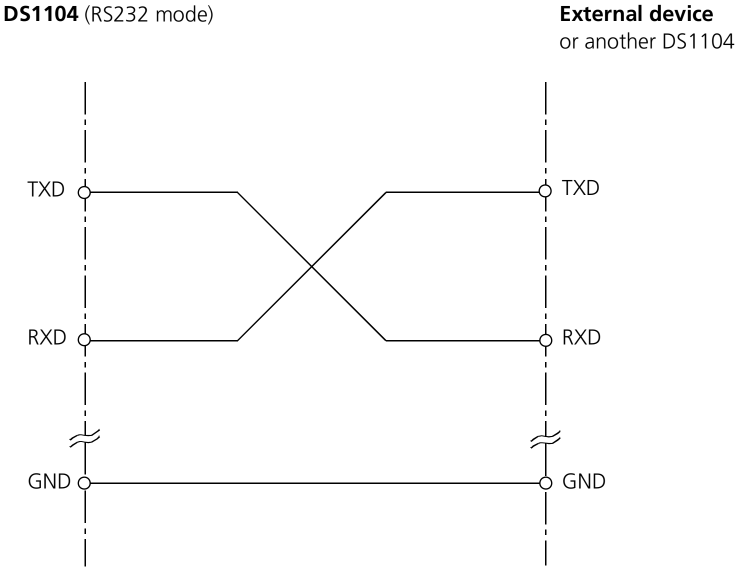
For notes and tips of connecting the UART, refer to:

- *Connecting RS232 Devices* on page 137
- *Connecting RS422/RS485 Devices* on page 138

Connecting RS232 Devices

If you use the UART interface as an RS232 transceiver, you have to cross-connect the TXD and RXD signals for connecting external devices.

To do this, connect the pin of the TXD (output) signal to the pin of the RXD (input) signal as shown below.



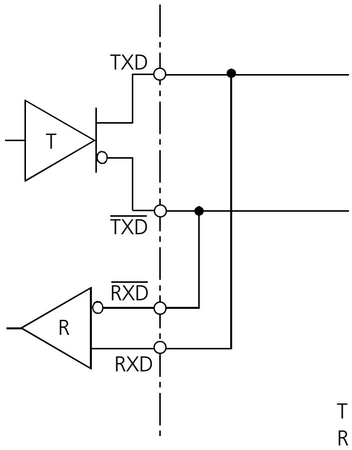
For some devices (e.g., modems), you should not cross-connect the TXD and RXD signals. For the correct connection refer to the manual of the device you want to connect to the DS1104.

Connecting RS422/RS485 Devices

By default, the UART interface of the DS1104 is configured as an RS422 transceiver. To use the UART as an RS485 transceiver you have to connect the following pins (see below):

- TXD signal to RXD signal
- $\overline{\text{TXD}}$ signal to $\overline{\text{RXD}}$ signal

DS1104 (RS485 mode)



T = Transmitter
R = Receiver

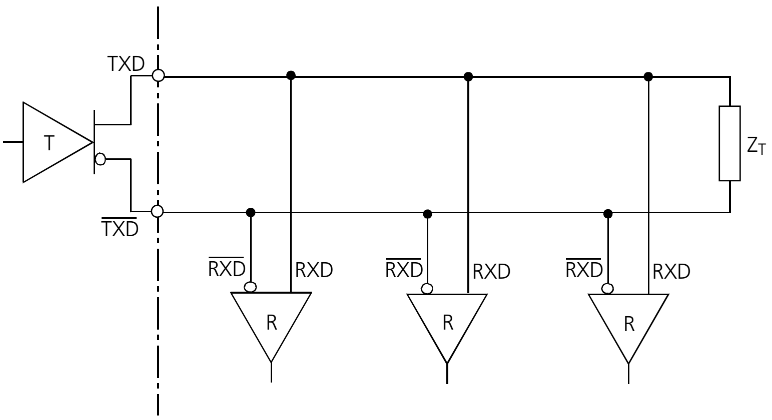
For proper operation of the UART interface you have to pay attention to **line termination** and **grounding**.

Line termination

The UART chip of the DS1104 does not provide line termination. If you use the UART as an RS422 or RS485 transceiver, line termination is essential, especially for faster data transfer rates and long cables. The main reasons for correct termination are reflections at the ends of the line, and the minimum transmitter load requirement.

Because RS422 allows only one transmitter in the bus, the termination resistor is placed only at the end of the cable near the last receiver (see figure below).

DS1104 (RS422 mode)

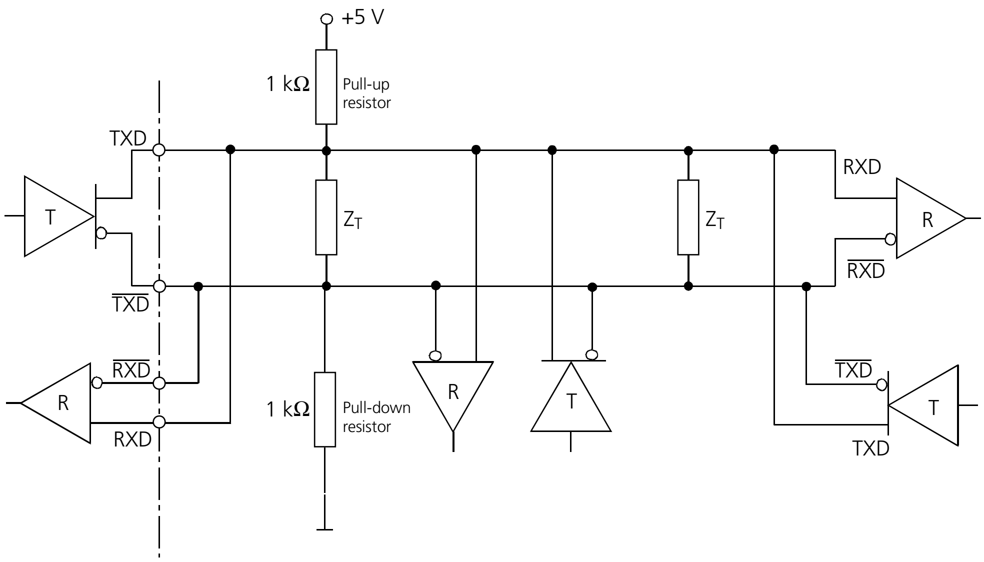


T = Transmitter
R = Receiver

The termination resistor Z_T, must be within 20% of the characteristic impedance of the cable (Z_0) and can vary from 90 Ω to 120 Ω.

The figure below shows a typical 485-compliant network, with a transceiver at both ends of the cable and transmitters/receivers placed along the length of the cable. Since each device communicates bidirectionally, it is impossible to determine where the transmitter is and to which device the transmitter is currently transmitting at the moment. Moreover, it is also possible for the transmitter to be in the middle of the line. So, both ends of the line have to be terminated with a terminator.

DS1104 (RS485 mode)



T = Transmitter
R = Receiver

The termination resistor Z_T, must be within 20 % of the characteristic impedance of the cable (Z_0) and can vary from 90 Ω to 120 Ω.

Avoiding undefined conditions (RS485)

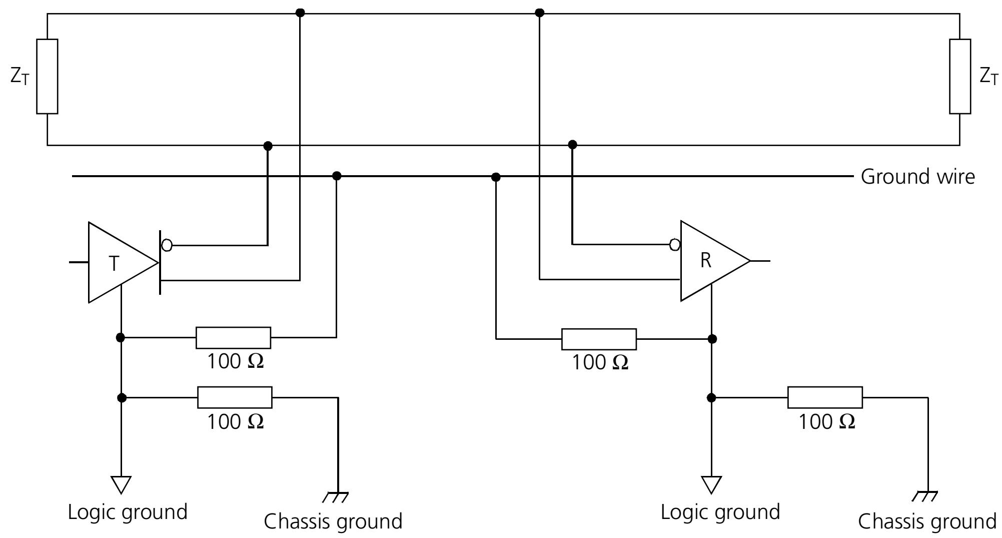
If no transmitter is currently active in an RS485 network, undefined conditions may occur. To avoid these conditions, you must provide a pull-up and a pull-down resistor (each 1 kΩ) as shown above.

Ground connection

For correct operation of the transmitter and the receiver, a return signal path between the grounding of the individual devices is required.

This has to be realized by a third wire. Here a resistor can be connected in series to limit unwanted high currents resulting from ground potential differences.

The figure below shows the grounding arrangement in an RS485 network.



T = Transmitter
R = Receiver

Slave DSP Digital I/O

The slave DSP of the DS1104 provides the following I/O:

- Slave DSP Bit I/O Unit
- Slave DSP Timing I/O Unit
- Slave DSP Serial Peripheral Interface

The pins of the slave DSP digital I/O are called:

- **SPWM1** ... **SPWM9**
- **ST1PWM** ... **ST3PWM**
- **SCAP1** ... **SCAP4**
- **SSOMI**
- **SSIMO**
- **SSTE**
- **SSCLK**

For a feature description of the slave DSP digital I/O refer to *Features Provided by the Slave DSP* in the *DS1104 Features* document.

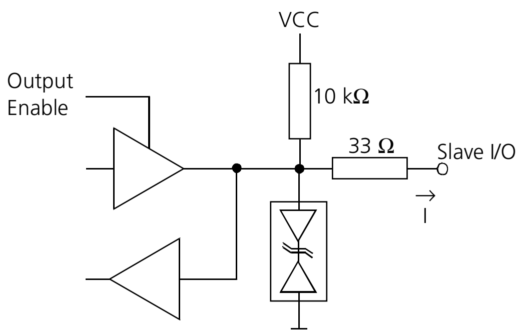
For detailed information on connecting external devices to the slave DSP digital I/O, refer to:

- *I/O Circuit and Electrical Characteristics* on page 143
- *Notes and Tips on Signal Conditioning* on page 144

I/O Circuit and Electrical Characteristics

I/O circuit

The following illustration is a simplified diagram of the input/output circuitry of the slave DSP digital I/O.



Electrical characteristics

The slave DSP digital I/O have TTL output/input levels with the following characteristics.

Parameter		Value	
		Min.	Max.
Input voltage	High Low	2.0 V 0 V	5.0 V 0.8 V
Output voltage	High Low	2.4 V 0 V	5.0 V 0.4 V
Output current		–13 mA	+13 mA
Input current (The current direction is shown in the circuit diagram above.)			500 µA
Power-up default		All digital I/O output circuits are disabled and driven to VCC by the built-in 10 kΩ pull-up resistors.	

Notes and Tips on Signal Conditioning

The following notes and tips are intended to help you achieve optimum results using the slave DSP digital I/O:

- *Changing Power-up Default* on page 144
- *Using the ST1PWM Pin* on page 145
- Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if you do not perform the following correctly:
  - *Grounding and Shielding* on page 147
  - *Avoiding Crosstalk* on page 151
  - *Wiring Up External Devices* on page 152

Changing Power-up Default

After power-up the digital I/O are configured to input mode. In this case, the I/O pins have a defined logical high level because of the built-in pull-up resistors.

If you want to change the power-up default, you can set the I/O pins to a defined logical low level by connecting a 1 kΩ pull-down resistor from ground to each I/O pin.

Using the ST1PWM Pin

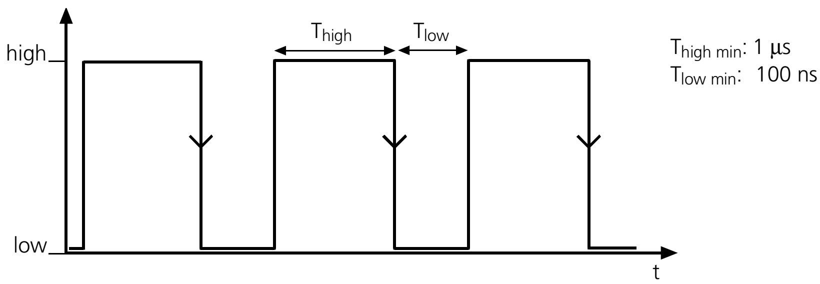
The ST1PWM pin is lead to the interrupt controller of the DS1104, so it is possible to generate interrupts that are synchronous to PWM signal generation. You can also use the pin as a further external interrupt input (user interrupt). In this case the ST1PWM pin has to be configured as an input (using RTLib1104).

Strobing I/O

In addition, you can use the ST1PWM pin for strobing the I/O (ADCs, DACs and incremental encoder signals). The required trigger signal can be either generated by the slave DSP or driven externally. In the second case the ST1PWM pin has to be configured as an input or the slave DSP must be in reset mode.

Recognizing signals at the ST1PWM pin

To allow the interrupt controller to recognize an incoming signal at the ST1PWM pin (PWM interrupt, external interrupt or trigger for strobing), the interrupt signal must be kept high for at least 1 µs. The interrupt is activated by the high to low transition of the signal. The signal must remain low for at least 100 ns after the transition.



General Notes and Tips on Signal Conditioning

In addition to this section (= general notes) you will find specific notes and tips on signal conditioning according to the I/O units of the board. You should also refer to these.

Noise, crosstalk and inductive effects can degrade the signal and lead to incorrect results if the following are not performed correctly:

- *Grounding and Shielding* on page 147
- *Avoiding Crosstalk* on page 151
- *Wiring Up External Devices* on page 152

ADC performance of dSPACE boards

When you are sampling an unconnected A/D input, you are looking at a noisy signal traced in ControlDesk. This may give the impression that the performance of the A/D sections of dSPACE boards is poor.

For an explanation of this incorrect impression and further background information (definition of SNR, measuring noise), refer to *ADC Performance of dSPACE Boards* on page 153.

Grounding and Shielding

Proper grounding and shielding reduces noise and inductive effects.

The advice given here also applies to the cabling of the devices inside your test bench. It is better to eliminate the cause, than to reduce the effects.

Grounding

- There are different terms for ground signals which are often mixed up. For their definitions, refer to *Definitions of Different Ground Signals* on page 148.
- For notes on cabling and connecting ground lines as well as further background information, refer to *Grounding Signals* on page 149.

Shielding

- For notes on cabling and connecting the shield as well as further background information, refer to *Shielding* on page 150.

Definitions of Different Ground Signals

There are three classes of signals often referred to as ground signals, i.e. signal return, power ground and shield. To achieve the best results regarding signal quality, noise rejection and EMC behavior, these different ground signals must not be mixed.

- A **signal return line** is the reference potential of a signal. It should carry the same current as the corresponding signal line, and this current should be kept small.
- **Power supply ground** is the return path for the supply voltage. It carries large and varying currents resulting in significant (AC) voltage drops along the cable. Never use the same wire for signal return and power supply ground.
- **Shield** is a barrier to keep in everything inside and keep out everything outside. It is usually connected to the device enclosures at both ends to form a closed cage around all signals and cards. It is not necessarily connected to power ground.

Grounding Signals

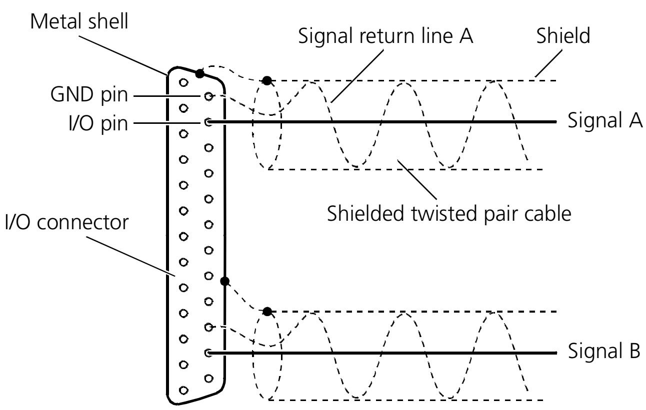
Do not use a ground line for more than one purpose. A grounding scheme has to be evaluated based on its AC current flow and not on its DC behavior. The DC resistance of a cable has only minor impact. Cable inductance plays a major role.

Avoiding ground loops and ground bounces

To avoid ground loops and ground bounces, use separate signal return (ground) lines for all connected sensors and actuators.

Each signal should have its own return line. The best results can be achieved with a shielded twisted pair cable. A twisted pair cable has the lowest inductance.

On the sensor/actuator side, connect one of the twisted wires to the signal and the other one to ground. On the board side, connect the first wire to the input/output and the second one to ground. The shield should be connected to the housing of the sensor/actuator and to the metal shell of the board connector. Do not connect the shield to ground anywhere.



If not enough ground pins are available at the connector, several return lines can be attached to a common ground pin. However, this common ground lead should be kept as short as possible to reduce ground line inductance.

If a cable contains unused leads, connect them to signal return (ground) lines at both ends to lower the inductance of the ground path between the dSPACE system and the sensor/actuator.

Star ground configuration

In a star ground configuration, ground loops are of no concern, if the signal return (ground) lines within the external devices are not connected to protective ground.

Always connect all signal return (ground) lines at both ends of a cable, i.e. board connector and sensor/actuator.

Shielding

The best shield is a low-inductance conductive barrier surrounding the complete setup of the device, cable and system, keeping in everything inside and keeping out everything outside (faraday cage). Low resistance, and most especially low inductance, are the key to a good shield.

EMC radiation and immunity are mostly affected by the outer cable shield. Individual lead shielding has only a minor effect if a common outer shield is present. Individual shielding is only necessary to reduce crosstalk.

Cabling

For cabling you should use shielded, twisted pair cables. The inner twisted-pair leads are used for the signal line and the return line (ground line). The return line should be connected to the ground pins of the respective board connector.

Ideally, each signal should be twisted with its return line so that any electromagnetic fields cancel one another.

Using the encoder interface with differential signals, the PHI90 line should be twisted with $\overline{\text{PHI90}}$, PHI0 with $\overline{\text{PHI0}}$ et cetera.

Connecting shield to the dSPACE system

Use a metal shell connector to the dSPACE board connector and connect the shield to the connector shell so that shield, connector shell and system enclosure form a closed shield surrounding all electronics. Use a large area connection and avoid pigtails.

Do not connect the shield to the GND pins of the dSPACE system.

Connecting shield to the external device

At the other end, the shield should be connected directly to the sensor/actuator housing. Sometimes sensors and actuators have dedicated shield pins available at their connector. The idea is to form one closed shielding cage consisting of the cable shield and sensor/actuator enclosure, which is ideally nowhere connected to signal ground. Use a large area connection and avoid pigtails.

Avoiding Crosstalk

Crosstalk occurs if a signal with steep edges runs close to a high impedance analog signal. The main reason for crosstalk is inductive coupling. It can be reduced by the following measures:

- Twist each signal line with its return line (ground).
- Never twist two signal lines.
- Separate digital and analog signal lines. Keep fast-changing signals far away from analog inputs.
- Avoid connecting high-impedance sources to the inputs of the dSPACE boards.
- If you use multiconductor cables, the individual twisted pairs should be shielded.
- You should also note the advice in *Wiring Up External Devices* on page 152.

Wiring Up External Devices

Noise and/or crosstalk can be reduced and maybe avoided by the following measures:

Using connector panels

- Do not use a connector panel in areas of strong electromagnetic radiation. Note that a ribbon cable may pick up some of this radiation.
- If optimum signal quality is a must, avoid using connector panels. Connect your external devices to the board connectors directly.

Using BNC cables

- If your dSPACE hardware offers BNC cables: If noise is a problem, avoid the use of BNC connectors. BNC connectors use the outside of the connector for ground. They do not permit shielding.
- To avoid poor signal performance, do not create ground loops within the BNC wiring.

Cabling

- Use connections as short as possible between your test bench and the dSPACE board.
- Keep cabling away from noise sources.
- Separate signal lines from high-current or high-voltage lines. These lines are capable of inducing currents on the signal lines if they run parallel and close to them. To reduce the magnetic coupling between lines, separate them by a reasonable distance if they run in parallel, or run the lines at right angles to each other.
- Do not route signal lines through conduits that also contain power lines.
- Protect signal lines from magnetic fields caused by devices such as monitors, electric motors, welding equipment, transformers, and so on, by running these through special metal conduits.

ADC Performance of dSPACE Boards

We are frequently contacted because of the “poor” performance of the A/D sections of our boards. This is usually derived from looking at the noisy signal traced in ControlDesk when sampling an unconnected A/D input or an A/D input shorted to ground. However, this has nothing to do with the definition of the SNR (signal-to-noise-ratio) we publish in the data sheets of our boards.

A common misunderstanding is that theoretical maximum values of ideal ADCs are expected from real-world components in real-world board designs, even inside PC environments. This is impossible. A 16-bit ADC, for example, never has an effective number of bits equal to 16.

The A/D section of every dSPACE board is FFT (Fast Fourier Transform) tested during production so that we can guarantee the published data sheet values for every board. For 16-bit ADCs we typically achieve an SNR of 78 … 82 dB depending on the board type. This corresponds to an effective number of bits of about 12.5 … 13. This is the best that can be achieved in typical PC environments.

For background information, refer to:

- *Definition of SNR* on page 154
- *Measuring Noise* on page 155
- “Noise Reduction Techniques in Electronic Systems” by Henry W. Ott, John Wiley & Sons, Inc.

Definition of SNR

SNR (signal-to-noise-ratio) is defined as a true rms (root mean square) ratio between the input signal and the noise. SNR is usually expressed in dB.

The SNR for a sinusoidal input signal can be described as:

$$SNR = 20 \cdot \log \frac{signal(rms)}{noise(rms)} dB$$

An application note from the well-known ADC manufacturer MAXIM describes the formula used and explains how the SNR parameter correlates with ADC performance: *Defining and Testing Dynamic Parameters in High-Speed ADCs, Part 1.* It is available at http://www.maxim-ic.com/appnotes.cfm/appnote_number/728.

Notes on calculation of SNR

Often the peak-to-peak values of the signal and the noise are mistakenly taken to calculate the SNR with the formula shown above. However, this results in much lower performance than the A/D converter really obtains. While the rms value of a sine wave can be obtained by dividing its peak-to-peak value by 2.828, the peak-to-peak value of a noise signal must be divided by approximately 6 … 8 to obtain its rms value (occasional extreme peaks must be ignored using this equation). Furthermore, the peak-to peak noise theoretically might be ±10 V (even if the inputs are shorted) without decreasing the SNR, assuming that such high peaks appear rarely enough.

Measuring Noise

It is often claimed that the noisy signal measured with the dSPACE board looks much better when measured with an oscilloscope. The reason is that you are using the wrong "voltage range" for the dSPACE system!

dSPACE boards have an input range of ±10 V and you are looking at signals with a voltage range of a few mV. That is similar to using a ruler to measure 1/1,000 inches. When you use your oscilloscope, you select an appropriate voltage range for the signal you are watching. You should do the same with the dSPACE system: You should adapt your input signal to the ±10 V scale of the dSPACE board before converting it. Use external amplifiers to ensure that the maximum amplitude range of the signal to be measured is mapped to the full scale range of the ADC, which is usually ±10 V.

Data Sheets

For the technical data of the DS1104 and the optional connector panels CP1104/CLP1104, see:

- *DS1104 Data Sheet* on page 158
- *CP1104 Data Sheet* on page 161
- *CLP1104 Data Sheet* on page 161

DS1104 Data Sheet

The following table shows the data sheet of the DS1104 R&D Controller Board.

Parameter	Characteristics
Processor	• MPC8240 processor with PPC603e core and on-chip peripherals • 64-bit floating-point processor • 250 MHz CPU • 2 x 16 KB cache; on-chip • On-chip PCI bridge (33 MHz)
Memory	• Global memory: 32 MB SDRAM • Flash memory: 8 MB
Timer	• 1 sample rate timer (decrementer): 32-bit down counter, reload by software, 40 ns resolution • 4 general purpose timer: 32-bit down counter, reload by hardware, 80 ns resolution • 1 time base counter: 64-bit up counter, 40 ns resolution, range 23400 years
Interrupt controller	• 5 timer interrupts • 2 incremental encoder index line interrupts • 1 UART interrupt • 1 slave DSP interrupt • 1 slave DSP PWM interrupt • 5 ADC end of conversion interrupts • 1 host interrupt • 4 user interrupts from the I/O connector
ADC 1 x 16-bit ADC with mux	• 4 muxed channels equipped with one 16-bit sample & hold ADC Note: 5 ADC channels (1 x 16-bit + 4 x 12-bit) can be sampled simultaneous • 16-bit resolution • ±10 V input voltage range • 2 µs conversion time • ±5 mV offset error • ±0.25 % gain error • 4 ppm/K offset drift • 25 ppm/K gain drift • >80 dB signal-to-noise ratio (SNR)

Parameter	Characteristics
ADC 4 x 12-bit ADC	• 4 channels each equipped with one 12-bit sample & hold ADC Note: 5 ADC channels (1 x 16-bit + 4 x 12-bit) can be sampled simultaneous • 12-bit resolution • ±10 V input voltage range • 800 ns conversion time • ±5 mV offset error • ±0.5 % gain error • 4 ppm/K offset drift • 25 ppm/K gain drift • >65 dB signal-to-noise ratio (SNR)
DACs 8 x 16-bit DAC	• 16-bit resolution • ±10 V output voltage range • ±5 mA maximum output current • Max. 10 µs settling time (full scale, accuracy 1/2 LSB) • ±1 mV offset error • ±0.1 % gain error • 13 ppm/K offset drift • 25 ppm/K gain drift • >80 dB signal-to-noise ratio (SNR)
Digital I/O	• 20-bit parallel I/O • Single bit selectable for input or output • ±5 mA maximum output current • TTL output/input levels
Digital Incremental Encoder Interface (2 x 24 bit)	• 2 channels • Selectable single-ended (TTL) or differential (RS422) input • Fourfold line subdivision • Max. 1.65 MHz input frequency, i.e. fourfold pulse counts up to 6.6 MHz • 24-bit loadable position counter • Reset on index • 5 V/0.5 A sensor supply voltage
Serial interface	• 1 serial UART (universal asynchronous receiver and transmitter) • Selectable transceiver mode: RS232/RS422/RS485 • Max. baudrate RS232: 115.2 kBaud • Max. baudrate RS422/RS485: 1 MBaud

Parameter	Characteristics
Slave DSP subsystem	• Texas Instruments TMS320F240 DSP • 16-bit fixed-point processor • 20 MHz clock frequency • 64 K x 16 external program memory • 28 K x 16 external data memory • 4 K x 16 dual-port memory for communication • 16 K x 16 flash memory • 1 x 3-phase PWM output • 4 x 1-phase PWM output • 4 capture inputs • SPI (serial peripheral interface) • Max. 14-bit digital I/O • TTL output/input levels for all digital I/O pins • ±13 mA maximum output current
Host interface	• 32-bit PCI host interface • 5 V PCI slot • 33 MHz ±5 %
Physical size	PCI 185 x 106.68 mm (7.28 x 4.2 in)
Ambient temperature	0 … 55 °C (32 ... 131 °F)
Cooling	Active cooling by fan
Power supply	• +5 V ±5 %, 2.5 A • +12 V ±5 %, 0.3 A • –12 V ±5 %, 0.2 A
Power consumption	18.5 W

CP1104 Data Sheet

The following table shows the data sheet of the CP1104 Connector Panel.

Parameter	Characteristics
Grounding	The enclosure and the front panel are not grounded.
Cable length	2 m (6.6 ft) standard
Physical size (with desktop enclosure) (length x depth x height)	281 x 142.5 x 70 mm (11.06 x 5.61 x 2.75 in)
Space needed for 19” rack mount	Height 3 U; width 10.8“
Weight	Approx. 2.2 kg (4.8 lbs); incl. enclosure and shielded ribbon cables

CLP1104 Data Sheet

The following table shows the data sheet of the CLP1104 Connector/LED Combi Panel.

Parameter	Characteristics
Power consumption	5 V; max. 100 mA (via DS1104 board)
Grounding	The enclosure and the front panel are not grounded.
Cable length	2 m (6.6 ft) standard
Physical size (with desktop enclosure) (length x depth x height)	433.5 x 142.5 x 70 mm (17.07 x 5.61 x 2.75 in)
Space needed for 19” rack mount	Height 3 U; width 16.8“
Weight	Approx. 2.5 kg (5.5 lbs); incl. enclosure and shielded ribbon cables

Troubleshooting

If any problem related to the hardware and software of your system occurs, refer to the following information:

- *Checking the DS1104* on page 164
- *Problems with Multiple Plug & Play Boards* on page 165
- *Checking the Host PC* on page 168
- *Problems Related to the Firmware* on page 168

If this information does not help you solve the problem, you should check the support section of our Web site http://www.dspace.de/goto?support. This might help you solve the problem on your own. The support's FAQ section especially might be of help.

If you cannot solve the problem, contact dSPACE Support via dSPACE Support Wizard. It is available:

- On your dSPACE CD at `\Diag\Tools\dSPACESupportWizard.exe`
- Via **Start – Programs – dSPACE Tools** (after installation of the dSPACE software)
- At http://www.dspace.de/goto?supportwizard

  You can always find the latest version of dSPACE Support Wizard here.

Checking the DS1104

Perform the following checks if the DS1104 does not operate correctly:

➤ Check whether the host PC is running correctly.

➤ Use ControlDesk's Platform Manager to check the board properties (see *How to Run ControlDesk* on page 32).

➤ Check the PCI interface clock rate by the status of the red LED on the board.

If the LED is lit, the host PC's PCI bus for the DS1104 is over- or underclocked. The LED is lit whenever the clock rate is lower than 5 MHz or higher than 35 MHz.

For the location of the status LED, see *Board Overview* on page 78.

For PCI interfaces, 33 MHz is the standard frequency. The host interface of the DS1104 is therefore designed to handle frequencies in the range 33 MHz ±5%.

Problems with Multiple Plug & Play Boards

Working with more than one dSPACE board in plug & play configuration presents us with two problems. The first is that the logical name of a board as assigned by the software must be associated with a physical board. The second is that under certain conditions, assignment of the names to the boards may change unexpectedly. It is vital to detect this situation, because otherwise an application to be loaded to a certain board might be loaded to another board of the same type by mistake.

For example, assume you have one board connected to the engine ECU and another connected to the ESP system of a vehicle. In order to avoid severe damage to the car, you must avoid loading the program intended for the ECU-related board to the ESP-related board, and vice versa.

Affected boards

The problem described always applies to **DS1104** boards (and **MicroAutoBox** via DS815 or DS817) because plug & play mode cannot be disabled.

It also applies to **DS1103** and **DS1005** boards if they are configured to plug & play mode. For these boards, plug & play mode can be used only if they are installed in a PC directly. This might be the case with an industrial PC with many ISA slots and a built-in PC.

The problem can be avoided for **DS1103** and **DS1005** boards installed in a PC simply by disabling the plug & play mode. This means, however, that you must set up a configuration free of I/O address conflicts by setting the I/O address switches of the boards manually.

Plug & play boards in an expansion box

The problem never applies to **DS1103**, **DS1005** and **DS1006** boards installed in a dSPACE expansion box independently of the type of interface used to connect the box to the PC, because when they are installed in expansion boxes, the plug & play mode must be disabled.

Handling plug & play boards in ControlDesk

ControlDesk's Platform Manager handles the boards by detecting their type (DS1005, DS1103, DS1104, MicroAutoBox via DS815 or DS817) and their actual I/O address. For plug & play boards, the actual I/O address is dynamically assigned by the PC BIOS or the plug & play components of the operating system. If you add hardware components to your host PC or remove them from it, or enable or disable motherboard components, the PC's BIOS and/or the operating system's plug & play components assign new resources such as I/O addresses to all plug & play components, including dSPACE boards in plug & play mode.

This may result in different I/O addresses being assigned to the same board without even touching any of the dSPACE boards! This situation cannot be automatically corrected by the Platform Manager. It does, however, detect a change in the configuration, that is a change in the names assigned to the boards and the particular board. Detection is based on the board serial numbers.

The Platform Manager detects such a change if at least one board was allocated a different name by the device driver. The affected board is removed from the dSPACE configuration and cannot be accessed by the Platform Manager to avoid confusion when loading applications and to prevent damage to external devices connected to the board. The Platform Manager displays an error message and requires the user to reregister all the hardware before all boards can be used again.

To restore a consistent dSPACE board configuration

1. From ControlDesk's menu bar, choose **Platform** – **Initialization** – **Clear System**.

   Boards setup in plug & play mode are then reregistered automatically.

2. In the Platform Navigator, double-click the corresponding board icon to open the Platform Properties dialog.
3. Compare the serial number of each dSPACE board (label on each board's bracket) with the one shown in the board's property page of the Platform Manager to make sure that your applications are still loaded to the correct dSPACE boards.

The following table displays the affected dSPACE boards and the property pages showing the boards' serial numbers:

dSPACE Board	Property Page
DS1005	DS1005 Properties page
DS1103	DS1103 Properties page
DS1104	Board Properties page
DS1401 (MicroAutoBox)	DS1401 Properties page

For details, see *Platform Properties* in the *ControlDesk Reference*.

- After using the Clear System command, you must reregister all installed dSPACE boards that do not support plug & play or where plug & play mode is disabled by means of the address switches.
- It is your responsibility to check and ensure that all applications are still loaded to the correct board. Since this is not under complete control of the dSPACE software it might even be necessary to change external connections to the boards! In a subsequent release of the Platform Manager it will be possible to assign board names to the particular boards as needed.

Checking the Host PC

If the host PC does not operate correctly after installation of the DS1104, check that the board is installed firmly.

Problems Related to the Firmware

If you are prompted to update your firmware when downloading an application to your real-time processor(s), see *Updating the Firmware* on page 38 for further information.

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