DELGEN

X-Graph XG4000 Family Rabbit Single Board Computer with Graphic LCD Interface

Users Manual
Version 1.0 Release – 14th August 2007

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1 Welcome

1.1 Introduction

The X-Graph XG4000 and XG4100 modules are low-cost Rabbit 4000 Single Board Computers. They are available as stand-alone, self-powered single board computers or as operating consoles with a large choice of user configurable character and graphic LCD's.

The XG4000/XG4100 include a Rabbit 4000 processor running at its max. speed (60MHz) with all the required support logic and up to 1.5Mbyte of local memory. The SBC uses a small pcb with components installed on a single side to increase reliability.

Several 0.1" expansion headers are available. These headers are used for Rabbit I/O expansion signals, analog inputs, LCD expansion, special XG4000 extensions and buffered I/O signals.
The SBC has on-board connectors for Ethernet, xgBus, power input, RS232C and a Rabbit programming interface (USB optional).

Three (5Volt, 3.3Volt, 1.8Volt) on-board linear power supplies are standard. Depending on the LCD backlight configuration the XG4000 can be powered from a DC input ranging from 6.5Volt up to 9Volt.

The XG4100 uses a larger pcb to add extra features. I.e. a SDCard socket, a RS485 driver, a CCFL convertor, more LCD interfaces, a d-sub9 connector, a 34-pin expansion header and a fully XG5000 compatible slave processor with all its advanced features.

Have a look at the impressive feature list of the X-Graph XG4000 (Max. configuration):
- Universal TFT LCD interface supports QVGA TFT LCD's
- STN B/W or CSTN Color ¼ VGA LCD interface
- White-led backlight LCD support (no CCFL backlight)
- Industry standard 16-pin character LCD interface for low cost applications
- optional MMC and SD slot
- Three 10-pin Industry standard 0.1" male headers
- Optional USB interface (can be used for programming at 1MBaud, no programming cable required)
- 10Mbit Ethernet interface
- DC input plug
- 2-channel 10-bit ADC
- RS232C driver included (4 lines, 2 serial ports supported)
- Secured 64 byte eeprom array

The XG4100 adds to that list:
- CCFL convertor
- 8-channel 10-bit ADC
- MMC/SD Slot
- RS485 driver
- High-voltage white-led backlight power supply
- 34-pin IDC 0.1" expansion connector
- d-Sub9 RS232C connector
- XG5000 compatible slave processor
- Keypad interface
- 1-Wire interface
- Extra async or sync serial port
- RC-5 receiver
- Hardware I2C interface

- PC/AT compatible keyboard interface
- Secured 512 byte eeprom array and 1024 byte flash array

Several sub-versions are available (standard DELGEN MOQ applies):
- XG4x10: 1MByte Fast-SRAM installed
- XG4x01: 60MHz cpu clock (required for TFT LCD)
- XG4x02: Low-cost version: No Ethernet interface, RS485 and SDCard socket installed

If you are unfamiliar with the Rabbit microcontroller, visit the Rabbit Semiconductor website (www.rabbitsemiconductor.com).

1.1.1 The Next Generation Low-Cost Rabbit SBC with LCD

The XG4000 family is a new generation Rabbit Single Board Computer and Operating Console incorporating features you cannot find in any competitive Rabbit based product.

On top of all standard Rabbit 4000 features the XG4000/XG4100 modules include a universal LCD interface which supports QVGA B/W STN, color CSTN and TFT displays. The standard Dynamic C graphic libraries are compatible with the B/W LCD. DELGEN adds to this an advanced xgGUI graphic library supporting all types of LCD's. This library adds graphic widgets and faster and better text and bitmap control. The TFT LCD interface supports a 8-bit (256 color) color depth.

The unique direct display hardware offers faster drawing speed and faster response to user interactions. The displays are available with or without an analog touchscreen.

The Rabbit 4000 runs at its maximum allowed speed of 60MHz, something RCM modules do not offer. All X-Graph modules have standard 512 kByte program memory. More memory then ever can be added because the XG4000/XG4100 support a MMC/SD slot for memory upgrades up to 4GByte and higher. DELGEN offers a FAT library to read/write files on a FAT formatted SD Card.

Interfaces? The XG4000 has standard a 4-channel RS232C driver, a 10Mbit Ethernet and optional Full-Speed USB interface. The XG4100 adds a RS485 driver, 1-Wire, I2C, PC/AT interface.
Forget about the slow download speeds of Dynamic C with the XG4000/XG4100 modules. The USB interface supports a 1MBaud download speed, reducing the wait time for large programs to a minimum.

Two (XG4000) or eight (XG4100) analog inputs are available (two used for optional touchscreen interface).

The XG4000/XG4100 modules can be delivered as pcb-modules or with several attractive plastic cases some with IP65 water/dustproof capability. Custom made keyboard panels can also be supplied.

Expansion modules can be easily added because many I/O ports and decoded I/O chip selects are available on standard 0.1" headers.

DELGEN offers a special custom made X-Graph service. This service includes X-Graph modules with selected interfaces, the design and manufacturing of expansion modules, cases and keyboards, and a full software service to implement the user interfaces for your product.

1.1.2 XG4000/XG4100 Features
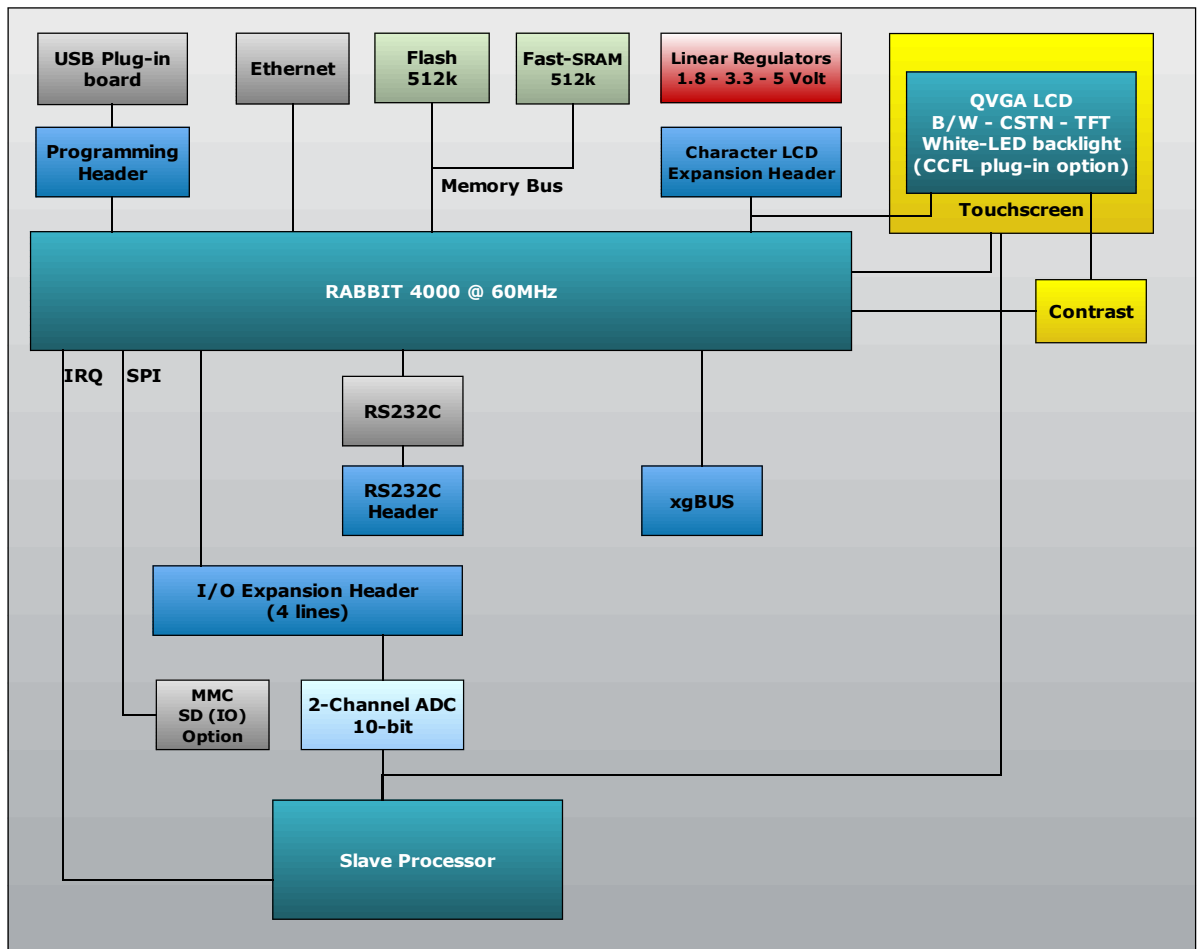
Figure 1: XG4000 features

- Rabbit 4000 running at speeds up to 60MHz
- TFT LCD interface
  - 5.6" 320x234 or 5.7" QVGA 320x240 TFT
  - Bright white-led backlight
  - Optional CCFL backlight (XG4100)
  - PWM brightness control
  - Analog touchscreen (XG4100)
  - Direct video page memory access
  - 256 color (8-bit) support uses a one byte/pixel system for very fast drawing speed
- STN 320x240 graphic screen with or without analog touchscreen
  - Color, B/W or Blue/White versions
  - LCD's can be used vertical or horizontal with a selectable viewing angle (3, 6, 9 or 12 o'clock)
  - Bright white-led backlight
  - Optional CCFL backlight (XG4100)
  - PWM brightness control
  - Analog touchscreen (XG4100)
  - Direct video page memory access
- 16-pin industry standard character LCD interface for cost-effective LCD applications.
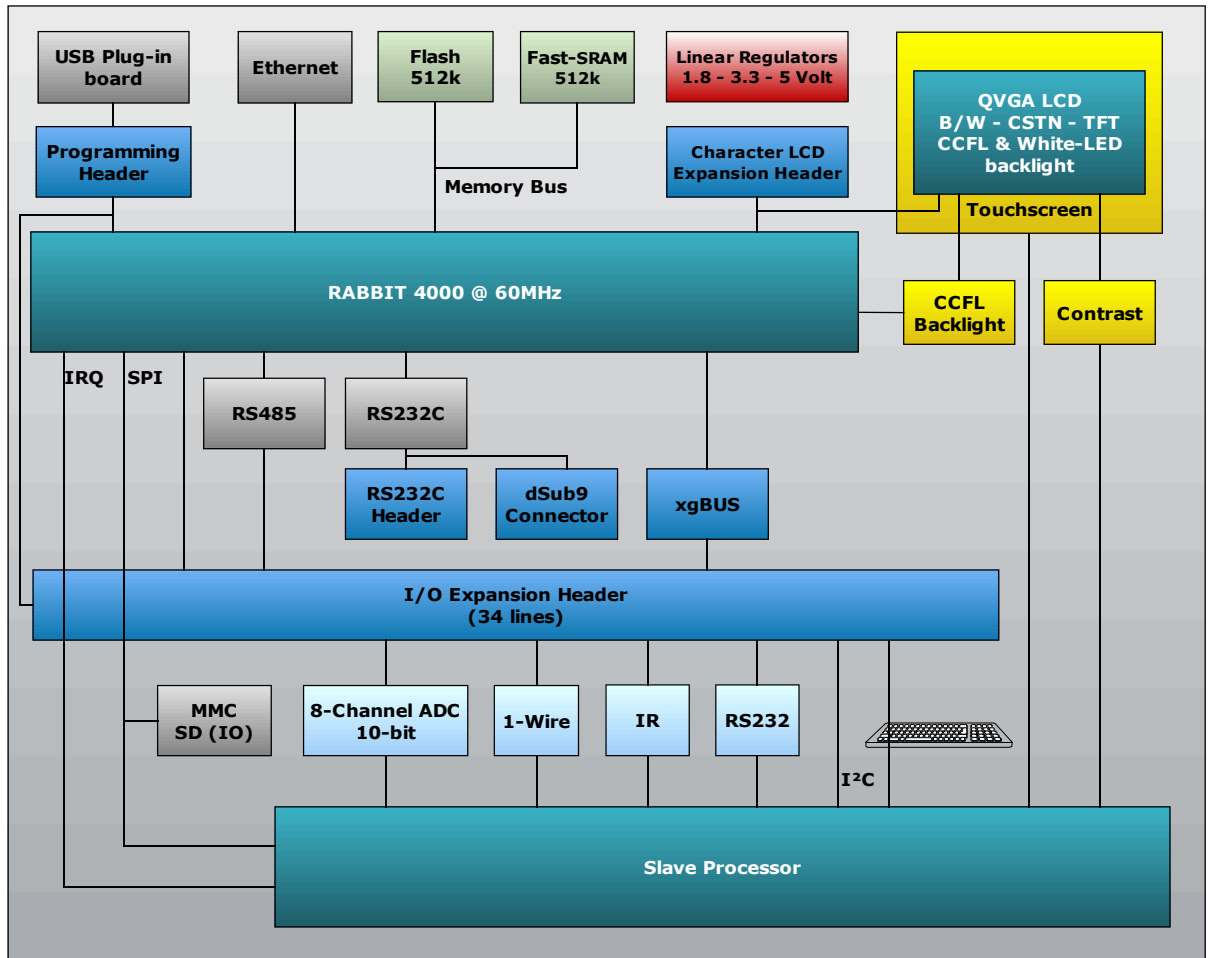
Figure 2: XG4100 features

- Expanded Memory Interfaces
    - 512 kByte program Flash
    - 512 kByte or 1MByte Fast-SRAM: program, data and video memory with zero-waitstate operation
    - 64 Bytes (XG4000) or 512 Bytes (XG4100) of secured EEPROM storage
    - 1024 Bytes of secured Flash storage (XG4100)
    - MMC/SD card interface in SPI mode with support for memory cards up to 4 GByte
    - The SD card slot also supports IO cards as WLAN, Bluetooth, ... (no drivers included)
- Serial Ports
    - Rabbit programming port header (non USB version)
    - RS232C port (RXD/TXD, RTS/CTS or 2xRXD/2xTXD)
    - All Rabbit serial ports including 2 free async/sync and HDLC compatible serial channels are available unbuffered on the expansion connectors
    - All buffered serial ports signals are also available on an expansion connector
- Extra Serial Ports on XG4100
    - RS485 driver
    - Extra serial port on slave processor
    - 1-Wire interface
    - Hardware I2C interface
    - PC/AT keyboard interface
    - RC-5 Remote control receiver

- 2 (XG4000) or 8 (XG4100) single ended 10-bit ADC channels (2 channels used for analog touchscreen)
- 4x4 keypad header (XG4100)
- Power
    - Power-saving 1.8/3.3/5 Volt design (NOT 5Volt compatible I/O)
    - DC power input
    - Linear regulators
    - Input voltage range from 6.5 Volt up to 9 Volt
- Different types of enclosures available
    - board-only version (no enclosure)
    - Different enclosures available matching the selected LCD type (most are available with an IP65 dust/waterproof option)
- Custom-made keyboards available
    - Very short turnaround
    - Perfectly matching the X-Graph enclosures
- 10 MBit Ethernet port
- Optional USB (!!) Rabbit download port (Port A) with speeds up to 1MBaud
- Optional d-Sub9 RS232C connector on XG4100
- Expandable
    - Rabbit I/O ports available on 0.1" expansion connectors
    - Male or Angled-Male headers available
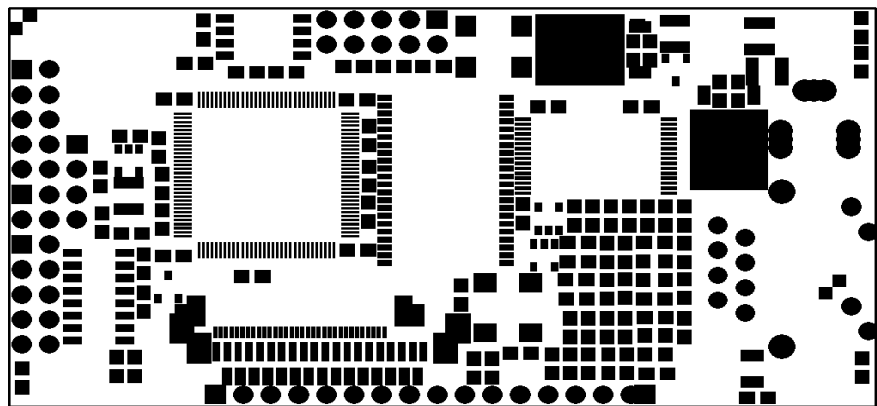
Figure 3: XG4000 PCB layout (not on scale)
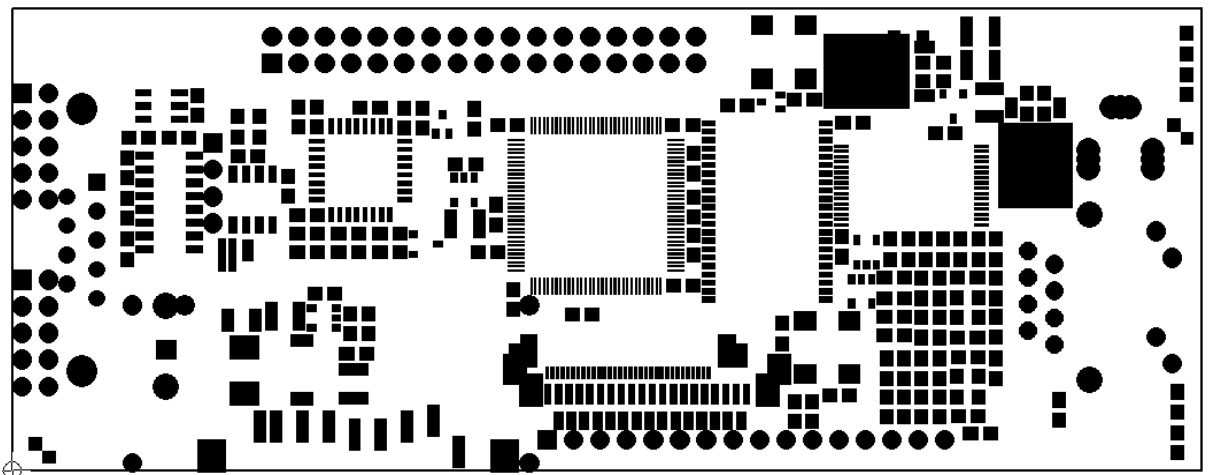
Figure 4: XG4100 PCB layout (not on scale)

1.2 How This Book Is Organized

You can find following chapters in it:

Chapter 1 contains a view on all the information in this book.

Chapter 2 gives helps on getting started with your new X-Graph module.

Chapter 3 describes the features of the XG4000 standard module, the development kit contents and the XG4000/XG4100 custom design possibilities.

The different LCD and enclosure options are listed in **Chapter 4**.

In **chapter 5** you receive a detailed description of all hardware features including information on custom-made expansion modules.

Chapter 6 gives information on installing and mounting the X-Graph module.

In **chapter 7** we add all available technical information.

Chapter is dedicated to custom-made design products DELGEN is offering.

Several other X-Graph Users Manuals are available. They include information on using the X-Graph modules with a C Compiler, the X-Graph software modules and X-Graph expansion cards.

1.3 More Questions

If you have questions while using your X-Graph module, check first if the information is available in this book. If you cannot find the answer check the information and forum on the X-graph website (www.x-graph.be). Finally you can also contact your local distributor or the X-Graph technical support by e-mail (techsup@x-graph.be).

This manual includes all available documentation on the X-Graph module. It is strongly advised to download and read documentation on the Rabbit processor, and the OP7200 operating console (for X-Graph modules with a B/W LCD installed) available from the Rabbit Semiconductor (www.rabbitsemiconductor.com) website. This manual is complimentary to the documentation found on these websites.

2 Getting Started

Get quickly started by connecting the power supply and installing and running the demo software and development tools.

2.1 Power Supply

2.1.1 Power Input

Different power inputs are available. Warning: only use one single input. Connecting several DC inputs will result in damage to the power supplies and/or the module.

The available power inputs are:
- DC Input connector J8
- The XG4100 expansion connector has a power input/output pin
- USB bus powered (option, 500mAmp max.)

2.1.2 Power Supply Design Concept

The XG4000/XG4100 module electronics have been designed to operate with a single 3.3 Volt power supply. The Rabbit 4000 requires a small 1.8 Volt regulator to power its core. A 5 Volt power supply is installed to power the backlight of the LCD modules.
On custom modules one (5Volt) or both (5Volt and 3.3Volt) regulators can be removed if external stabilized power supplies are available.

This linear regulators allow a non-regulated voltage input range from 6.5 up to 9 Volt and can supply each about 800mAmps of total power to the module and expansion modules. Note that the heat build-up with higher input voltages and supply currents might be considerable. For each design (enclosure, pcb position), the heat dissipation of the regulators should be checked. Generally a low-voltage input voltage adapter should be used.

Warning: All the XG4000/XG4100 I/O lines on the I/O expansion headers are 3.3Volt tolerant. Higher input voltages will damage the module and void warranty. This module has NO 5Volt tolerant I/O pins. You can consider the XG5000 if you need this.

2.1.3 Voltage Selection

On most systems the modules DC input will be used to power the system. It requires a 2.1mm matching connector.

IMPORTANT: Make sure the polarity of the AC/DC adaptor is correct. The inner contact should be the + input, the outer contact the ground.

There is NO reverse polarity protection included on the module. Note that reversing the polarity can destroy the external power supply, and will destroy the X-Graph module and void your warranty.

Carefully measure the power dissipation (temperature) when using the on-board linear regulators to power your expansion boards. The maximum power output of the regulators is 800mAmp and a current limiter is build in the system.

The XG4100 expansion connector has a pin directly connected to the power input rail. If the DC input plug is not used, this pin can be used as a power input. All other pins,

including the DC input plug, will carry the input voltage connected to the selected power input pin.
Check the expansion connector pin table in chapter 3 for correct pin numbers.

WARNING: Connecting a voltage higher then 3.3Volt on any other pin will destroy your module and void your warranty. Observe carefully the pin number and location of the power pins before applying power.

Most expansion connectors also include a 3.3Volt pin. On a standard module these are output pins available to power electronics an expansion boards.
But, the module can also be powered via one of these 3.3Volt pins. The selected pin is then acting as a voltage input pin but only if the module is custom designed for this. The standard module has the linear regulators installed and does NOT accept an external 3.3Volt input.

2.1.4 Current Calculation

Total typical current: 100 mA (7 Volt input, no expansion cards, no LCD)

2.1.5 USB Bus Powered

The XG4000/XG4100 modules can be powered directly from a USB bus. Configured like this, the module can be used as a slave USB device. Only one cable is required for power and communication with a PC.

The USB standard limits the maximum current used by each USB device to 500mA which is well within the power requirements of the XG4000/XG4100 modules. If you connect a USB device to a passive hub, the limit is 100mA in which case the X-Graph module will not operate.

Note that some LCD's, some MMC/SD cards and additional I/O cards might result in a total power consumption larger than the maximum 500mA. Carefully check your design before operating the module on a USB connection.

WARNING: the USB Bus powered modules are available as a factory option. The standard modules can not be used in this mode. Contact DELGEN for test samples or instructions how to convert a standard module to a USB Bus powered module.

2.2 Demonstration Program on Power-Up

A demo program is installed on delivery. Check the DC samples directory for the source code. See the 'X-Graph and Dynamic C' manual for information on how to install the included samples and libraries.

This program demonstrates the GUI features of the XG4000/XG4100 and start the xgConsole. Just connect a terminal emulator to a serial port (RS232C, USB, Ethernet) to get connected and start entering X-Graph console commands. Refer to the 'xgConsole Users Manual' for more information on the xgConsole mode.

The 'X-Graph Ethernet Firmware Upgrade' utility is also installed. You can load your custom firmware via the Ethernet port to the Flash memory. No need to connect any development tools or interfaces.

2.3 Using Dynamic C or WinIDE with the X-Graph Module

Refer to the 'X-Graph and DynamicC' and 'X-Graph and Softools Rabbit WinIDE' manuals for a description on how to use Dynamic C or Softools WinIDE with the X-Graph module.

3 XG4x00 Standard Module / Custom Module

Learn about the different XG4000/XG4100 configurations, the X-Graph custom design service and the development kit.

3.1 Development Kit

The XG4000 development kits (XG4000DK)

What's included in the development kit:
- XG4000 Standard Module
- Your choice of LCD
- A quality plastic X-Graph enclosure fitting the selected LCD
- An AC/DC adapter with europlug (only for EC deliveries)
- An RS232C cable with matching male dSub-9 connector
- Two xgBus expansion modules (8-outputs, 8-inputs) with matching cables
- USB expansion board with 2 pin male jumper (programming mod)
- USB cable
- The latest libraries and documentation can be downloaded from our website (www.x-graph.be)

Possible LCD options (no touchscreen installed):
- XG4000DK: no LCD included
- XG4000DKH4X16: 4x16 character LCD
- XG4000DKL57: Blue/White 5.7" QVGA LCD
- XG4000DKT56: 5.6" QVGA TFT LCD

Refer to chapter 4 to get more information on the available LCD options.

The XG4100 development kits (XG4100DK)

What's included in the development kit:
- XG4100 Standard Module
- Your choice of LCD
- A quality plastic X-Graph enclosure fitting the selected LCD
- An AC/DC adapter with europlug (only for EC deliveries)
- An RS232C cable with matching male dSub-9 connector (can be used for programming the module)
- A 128MByte SDCard to start exploring the unlimited memory expansion capabilities of the XG4100
- Two xgBus expansion modules (8-outputs, 8-inputs) with matching cables
- The latest libraries and documentation can be downloaded from our website (www.x-graph.be)

Possible LCD options (no touchscreen installed):
- XG4100DK: no LCD included
- XG4100DKH4X16: 4x16 character LCD
- XG4100DKL57A: Blue/White 5.7" QVGA LCD with touchscreen
- XG4100DKC57A: Color STN 5.7" QVGA LCD with touchscreen
- XG4100DKT56A: 5.6" QVGA TFT LCD with touchscreen

Refer to chapter 4 to get more information on the available LCD options.

The module can be operated without purchasing any development software by using it's standard xgConsole control firmware. Refer to 'xgConsole Users Manual' for more information.

But, to develop user programs for your new X-Graph development kit, you will need to purchase some development software.

If you don't own it yet, you will need a copy of the DynamicC compiler. It's available online from the Rabbit Semiconductor website (www.rabbitsemiconductor.com). Different versions are available, but the standard compiler (DynamicC Individual License) will do fine. There is no need to buy any of the available options to operate the XG4000/XG4100. Rabbit Semiconductor regularly offers a 'DynamicC Promotional Bundle' including libraries for SSL, FAT, RabbitWeb, PPP, SNMP and AES. Unless you need one of these functions, you don't need to purchase the bundle (don't mind FAT, it's included free-of charge with all X-Graph products).

Refer the 'X-Graph and DynamicC' and the X-Graph software library manuals to get more info on the free libraries included with the X-Graph modules.

DELGEN also supports the Softools WinIDE (www.softools.com) ANSI C compiler on its X-Graph modules. Refer to the 'X-Graph and Softools Rabbit WinIDE' manual for more information on the Softools compiler.

For fast and intuitive GUI development DELGEN advises to use the xgGUI (X-Graph GUI) development package (refer to chapter 'xgGUI Users Manual').
With the Softools compiler an alternative GUI development environment can be used. The easyGUI (www.easygui.com) pc program integrates with minimal changes with the Softools compiler. Note that to use the easyGUI generated C code with DynamicC several changes are need to be made in this code.

3.2 Standard Module

The XG4000/XG4100 modules can be manufactured in almost an unlimited number of versions. To reduce production costs and increase stock availability DELGEN offers a single XG4000 and XG4100 'Standard' module. For any purchase of up to 100pcs, we advise to use this standard module. Custom designs can be made for any quantity, but price increases will apply for lower then 100pcs quantities.

3.2.1 What's included

Refer to chapter 5 to get a complete detailed overview of all the possible hardware options of the XG4000/XG4100. Below is a list of the features included in the XG4000 and XG4100 Standard Module. Also refer to the table in 3.3 for a complete overview.

- Rabbit 4000 running at 40MHz (Epson precision oscillator)
  The TFT LCD version uses a 60MHz oscillator
- 512kByte Flash program memory
- 512kByte Fast-SRAM program, video & data memory
- 10Mbit Ethernet interface with RJ connector and indicator leds
- 4-line RS232C driver
- 2-channel 10-bit ADC
- 10-pin 0.1" header for RS232C
- 10-pin 0.1" header for xgBus
- 10-pin 0.1" header for programming interface
- 5Volt & 3.3Volt Linear Regulators with 2.1mm DC input plug (up to 9V input)
- XG4000 Standard enclosure (only without LCD)
- Depending on your order an LCD with or without touchscreen is included and the matching connectors and backlight options are installed on the XG4000/XG4100.

XG4100 extras:
- SDCard socket
- RS485 driver
- RC-5 receiver input
- Alternate UART or PS/2 keyboard interface inputs

- 1-Wire input/output
- 8-channel 10-bit ADC
- CCFL convertor (for CCFL backlight LCD's)

A matching AC/DC adapter and SDCards are available as options.

3.2.2 What's not included

Note that the following features are NOT included in the standard module. This is a limited list, refer to section 3.3 for a complete overview.

- 1Mbyte Fast-SRAM
- Touchscreen interface for non-touchscreen LCD's
- SDCard socket (XG4000)
- USB option

3.3 Custom Designs

The XG4000/XG4100 can be delivered with any user selection of interfaces installed. DELGEN will consider any purchase of 100pcs or more as a custom design without additional costs.

For lower quantities we advise to use the standard module. On request additional interfaces can be added to the standard module for a reasonable extra cost. A full custom design for small quantities (1 to 99pcs) is possible, but will cost extra.

Below is a complete list of all XG4000/XG4100 features. Refer to chapter 5 for a complete detailed description of all hardware features.

To get a quote on a custom form you can send a copy of below list with the items you require indicated to DELGEN.

Column 1 has * indicators if the feature is installed on the standard module.
Column 2 contains a short description of the feature.
Column 3 contains an indication of the features size or configuration in the standard module version.
Column 4 can be used to fill in the required size or configuration for custom designs.

XG4000 Hardware Features

	Description	Default	Custom value
	Processor		
*	Rabbit 4000		
*	Epson precision oscillator (any clock possible up to 60MHz)	40MHz	
	60MHz clock (standard for TFT LCD versions)		
*	Flash program memory (512kByte)		
*	Fast SRAM program memory (512kByte or 1MByte)	512kByte	
*	Rabbit programming header (XG4000)		
	XG4100 Expansion header with programming pins (XG4100)		
	Ethernet		
*	10 Mbit Ethernet Port		
*	Ethernet RJ connector with indicator leds		
	Memory & I/O Expansion		
	XG4000 SDCard socket (can not be combined with xgBus or RS232C connector)		
*	XG4100 SDCard socket		
	Serial Port Buffers		
	USB Port (plug-in board on programming header)		
	USB powered system (max. 500mAmp)		
*	RS232C buffer (4 lines)		
*	2x5 male header to connect dSub-9 cable		
*	xgBus 2x5 male header		
	d-Sub 9 connector (XG4100) (can not be combined with xgBus or RS232C header)		
	RS485 (XG4100)		
*	RS485 driver (XG4100)		
	110 Ohm end resistor		
	680 Ohm polarizing resistors		
	ADC		
*	2-channel (XG4000) or 8-channel (XG4100) ADC (2 channels used for touchscreen if this is installed)		
	Slave processor options (XG4100) (Note: 8-channel ADC, RC-5 receiver, 1-Wire interface, extra serial port or PS/2 keyboard interface, I2C interface, configurable I/O ports, eeprom, flash area are standard on the XG4100 module)		
	1-Wire protection diode		
	4 pin 0.1" angled touchscreen header		
	4 pin 1mm FFC touchscreen header horizontal		
	4 pin 1mm FFC touchscreen header vertical		
	Power supply		
*	3.3Volt linear regulator 800mAmp		
*	5.0Volt linear regulator 800mAmp (LCD backlight)		

*	2.1mm DC input plug (7-9 Volt input range)		
	LCD Interface		
*	Universal character LCD interface		
	B/W LCD FFC Connector		
	CSTN LCD FFC Connector		
	TFT LCD FFC Connector		
	White-Led backlight connector (CSTN & TFT)		
	CCFL backlght plug-in pcb (CSTN & TFT)		
	CCFL backlight on-board (XG4100) (CSTN & TFT)		
	XG4000/XG4100 Plug-in Cards		
	8 Opto-Isolated inputs xgBus module (can be expanded to any size: 16, 24, ….)		
	8 Opto-Isolated outputs zgBus module (can be expanded to any size: 16, 24, ….)		

Table 1: XG4000/XG4100 Hardware Features

4 LCD Versions & XG4000/XG4100 Enclosures

In this chapter you will find all technical information on the LCD displays available with the XG4000/XG4100. A number of LCD's are considered standard and are usually available from stock for sample quantities. Also several non-standard and custom design LCD's can be interfaced with the XG4000/XG4100.
Each standard LCD fits an X-Graph enclosure. Technical information on these is also available in this chapter.

LCD's with a LED backlight can be used with both the XG4000 and XG4100.

LCD's with a CCFL backlight should only be used with the XG4100. This module has an on-board CCFL convertor. The XG4000 requires an external CCFL convertor for these LCD's. DELGEN does not advise the use of the XG4000 for CCFL backlight LCD's.

4.1 Standard Graphic LCD Versions

The XG4000 has 3 different connectors to allow connection of three QVGA 5.6/5.7" LCDs. It is perfectly possible to design a low-cost version of your project with a B/W LCD, or even no LCD. More expensive version(s) can be offered to your customer with a more expensive CSTN or TFT LCD without the need of complicated application software changes.

4.1.1 5.7" QVGA B/W & Blue/White LCD
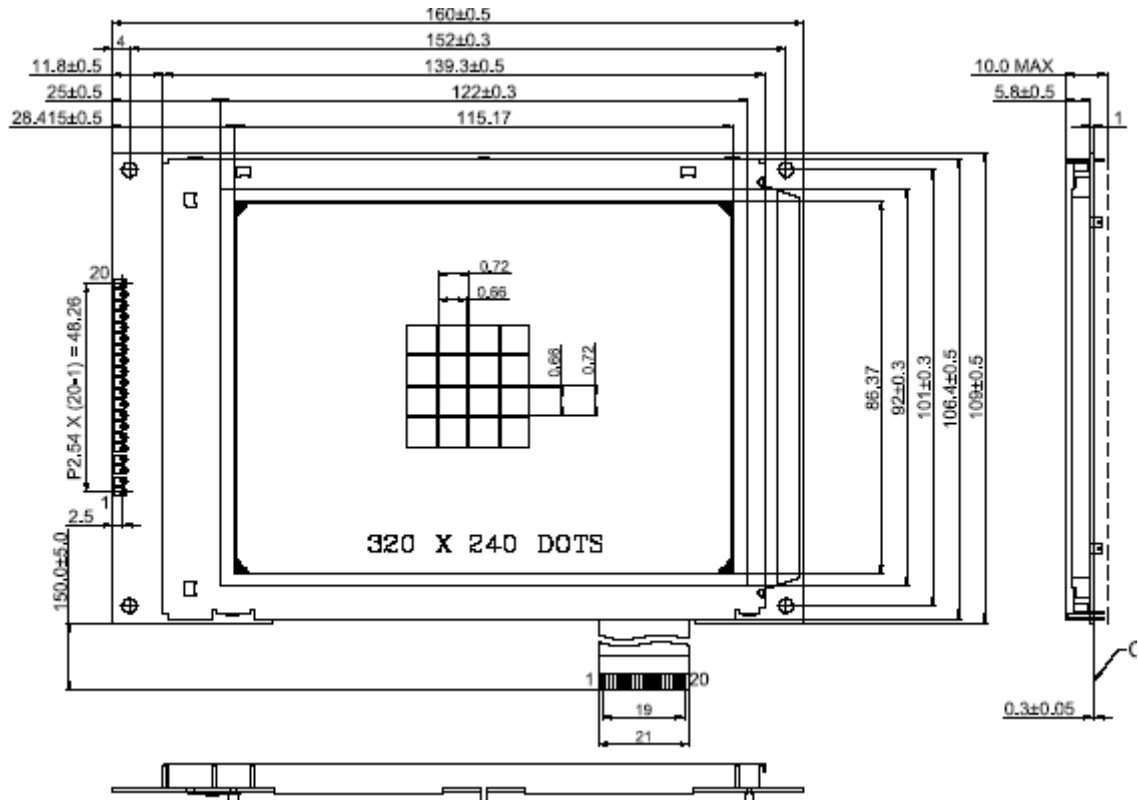
Figure 5: Mechanical Drawing of 5.7" B/W LCD

Backlight: white leds (10000 hours lifetime to 50% brightness)
Typical Brightness B/W: 150 cd/m2 (130 cd/m2 with touchscreen)
Typical Brightness Blue/White: 140 cd/m2 (120 cd/m2 with touchscreen)
Typical power consumption LCD: 50mA @ 3.3 Volt
Typical power cons. backlight: 140mA @ 5 Volt (7 leds), 180mA @ 5Volt (10 leds)
Uses XG4000/XG4100 connector: J4 = 20-pin 1mm FFC
Touchscreen: available
Enclosure: All

Available versions (call DELGEN for more info):
- B/W or Blue/White
- Any viewing angle
- Transmissive, Reflective, Negative
- 7 leds or 10 leds backlight

Standard: Blue/White 6 o'clock negative with or without touchscreen and 7 leds backlight

4.1.2 5.7" QVGA CSTN Color LCD
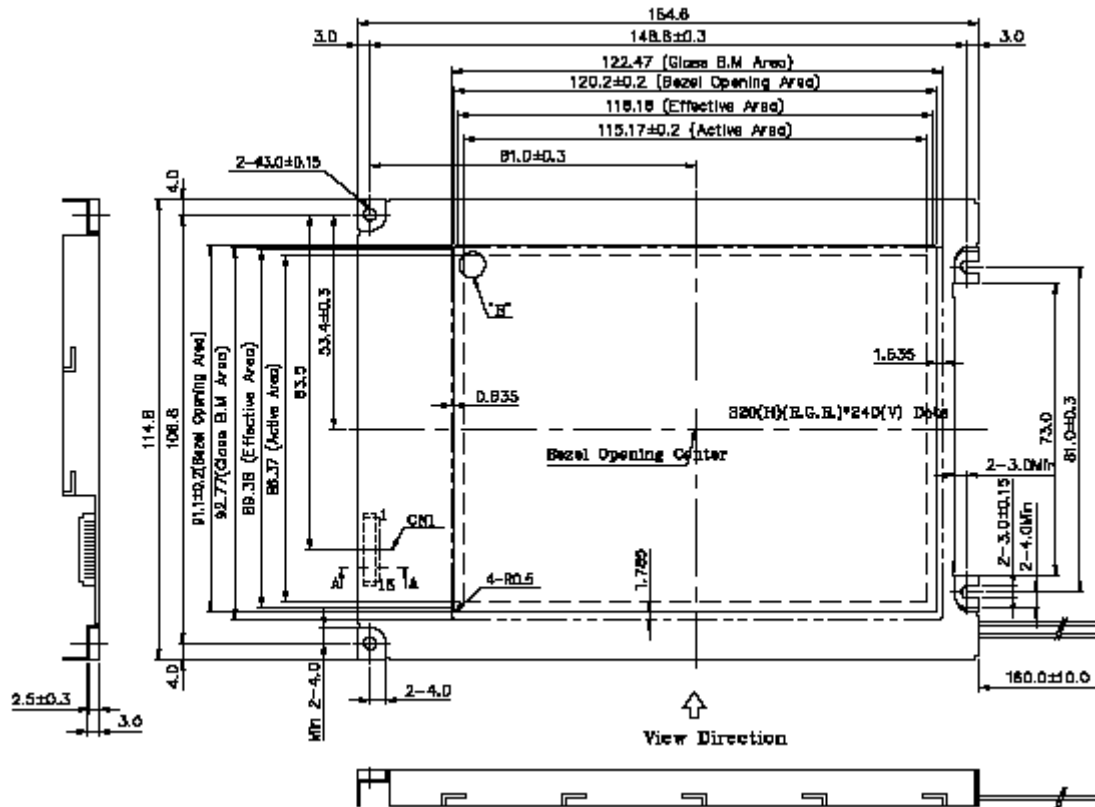
Figure 6: Mechanical Drawing of 5.7" CSTN LCD

Backlight: CCFL (40000 hour lifetime to 50% brightness)
Backlight: LED (10000 hour lifetime to 50% brightness)
Typical Brightness CCFL: 180 cd/ m2 (140 cd/m2 with touchscreen)
Typical Brightness LED: 70 cd/ m2 (60 cd/m2 with touchscreen)
Typical power consumption LCD: 50mA @ 3.3 Volt
Typical power consumption backlight: 510mA @ 5 Volt (CCFL) / 200mA (LED)
Uses XG4000/XG4100 connector: J2 = 15-pin 1.25mm X-Graph cable
Touchscreen: available
Enclosure: All

Available versions (call DELGEN for more info):
- with or without touchscreen
- CCFL or LED backlight

Standard: CSTN 6 o'clock with or without touchscreen and CCFL backlight (LED backlight version available on demand)

4.1.3 5.6" 320x232 TFT Color LCD

Backlight: CCFL (30000 hour lifetime to 50% brightness)
Backlight: LED (25000 hour lifetime to 50% brightness)
Typical CCFL Brightness: 500 cd/m2 (400 cd/m2 with touchscreen)
Typical LED Brightness: 320 cd/m2 (250 cd/m2 with touchscreen)
Typical power consumption LCD: 150 mA @ 3.3 Volt
Typical power consumption backlight: 510 mA @ 5 Volt (CCFL) / 420 mA (LED)
Uses XG4000 connector: J1 = 32 pin 0.5mm FFC cable
Touchscreen: available
Enclosure: All
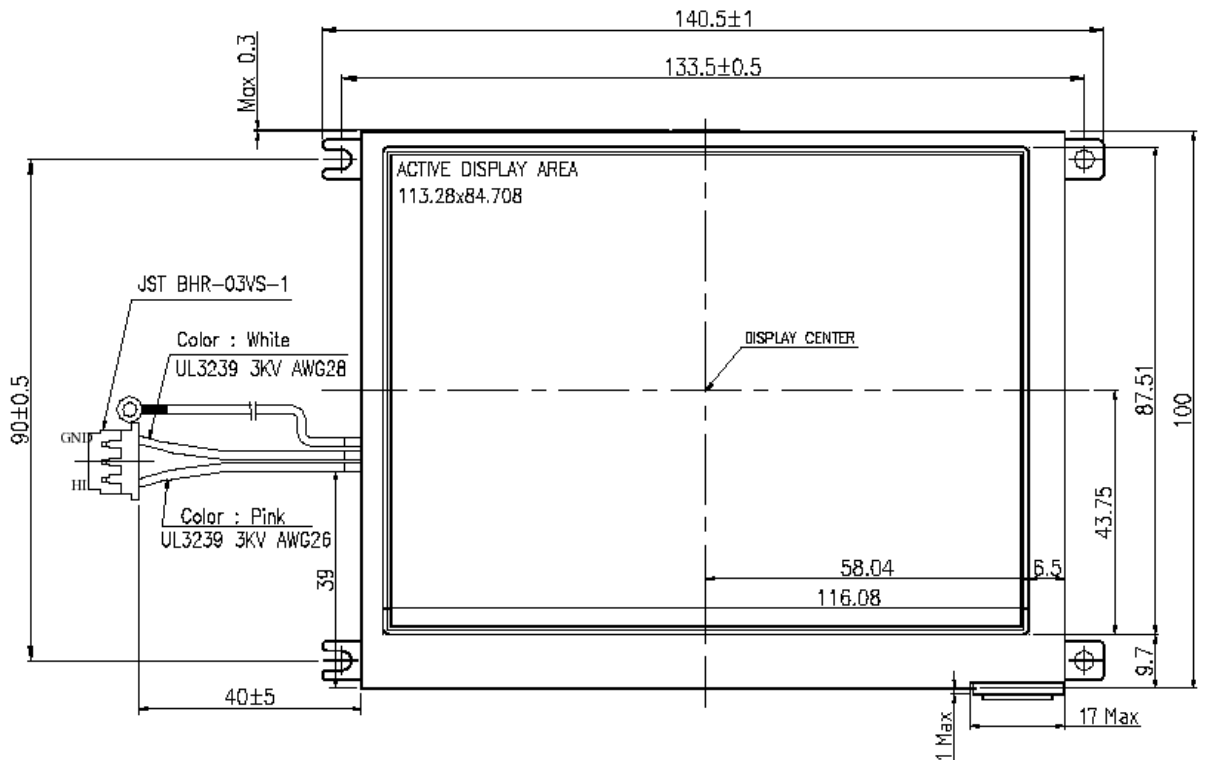
Figure 7: Mechanical Drawing of 5.6" TFT LCD

Available versions (call DELGEN for more info):
- with or without touchscreen
- with or without 4 screw connections

Standard:
- with touchscreen and with screw connections, CCFL
- without touchscreen and withhout screw connections, CCFL
- available soon: with touchscreen, with screw connections and LED backlight

This LCD is a very cost effective TFT solution matching the XG4000/XG4100 perfectly.

4.2 Character LCD Versions

Several industry-standard 3.3Volt compatible character LCD modules can be connected to J7.

A non-limited list of available CLCD's (contact DELGEN about availability):
- 1 line x 16 characters @ 60x6.5mm (40 or 120mA backlight)
- 1 line x 16 characters @ 95x9.6mm (190 mA backlight)
- 2 lines x 16 characters @ 56x11.5mm (20 or 90mA backlight)
- 4 lines x 16 characters @ 56x20.8mm (220 mA backlight)
- 2 lines x 20 characters @ 119x19mm (270 mA backlight)
- 4 lines x 20 characters @ 55x17.5mm (150 mA backlight)
- 4 lines x 20 characters @ 70x20.8mm (260 mA backlight)
- 4 lines x 20 characters @ 119x38mm (770 mA backlight)

 (dimensions are character size, glass size is larger)

Available versions:
- Negative or positive
- Green, white or blue backlight

Enclosures: all

Standard: depends on stock, contact DELGEN for availability.

4.3 Enclosures

All XG4000/XG4100 modules are available with matching high quality modern plastic enclosures. Several standard enclosures are available and custom designed enclosures can be manufactured.

4.3.1 Basic Enclosure

Figure 8: Basic Enclosures

For applications which dont require an LCD the XG4000/XG4100 perfectly fit a small X-Graph basic enclosure. Each module has a matching enclosure available in two heights.

Part numbers are:
- XG4000 low: G403
- XG4000 high: G404
- XG4100 low: G407
- XG4100 high: G410

4.3.2 Desktop Enclosure
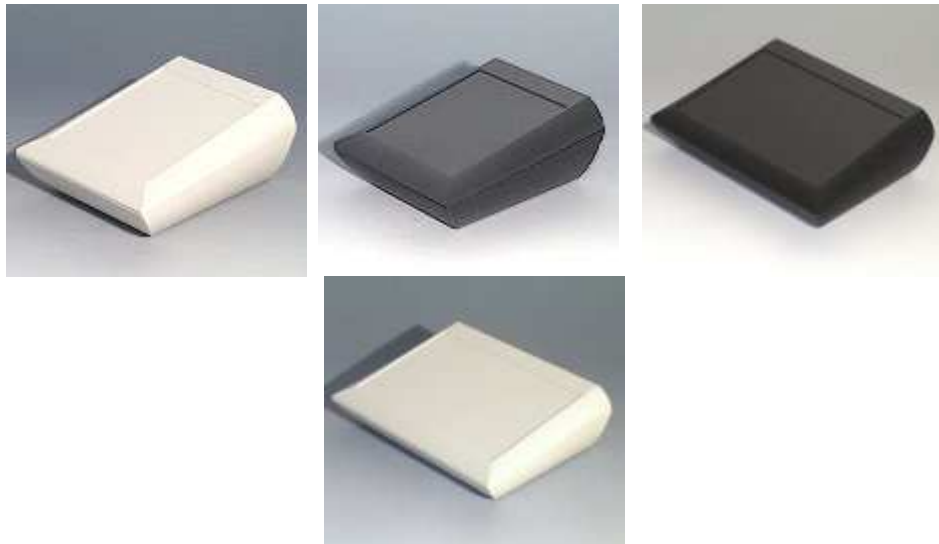
Figure 9: Desktop Enclosure

This is a three part enclosure for table top and wall-mounted applications. The operating area is ergonomically sloped by 10° and the top area has a recessed area for optional membrane keyboards. There is a version with or without a battery compartment (9Volt or 4x1.5Volt). And the enclosure is available in white (RAL9002) or black (RAL9005)

There are two orientation versions: vertical or horizontal. Thus an LCD can be fitted in landscape or portrait mode.

The XG4000/XG4100 is installed either on the rear side of the LCD or on the bottom of the enclosure. All I/O connectors are available via milled openings on the rear side (if desk mounted).

There is a wall bracket available and several battery options. Either 4 AA batteries, or 1 or 2 9Volt batteries can be installed to power the XG4000/XG4100 (limited power, depends on LCD type used).
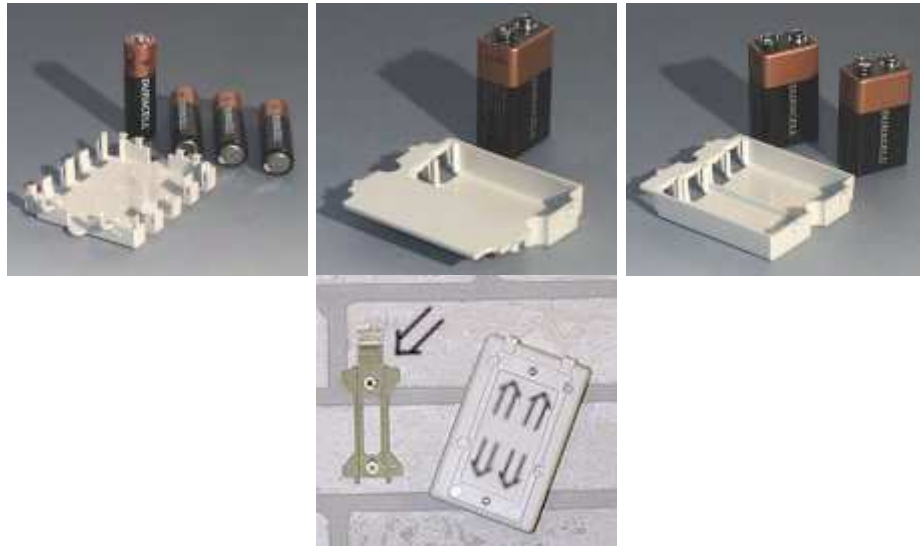
Figure 10: Standard Enclosure Options

This enclosure fits all XG4000/XG4100 LCD's. There is enough space for expansion cards and an optional keypad

Part numbers are:
- Horizontal white version: A0620107
- Idem with battery compartment: A0620117
- Horizontal black version: A0620109
- Idem with battery compartment: A0620119
- Vertical white version: A0612107
- Vertical black version: A0612109
- Wall suspension element: B1350048
- Battery holder for 2x 9Volt batteries: A9174002
- Battery holder for 1x 9Volt battery: A9174003
- Battery holder for 4x AA batteries: A9174004
- Set of battery clips for 4xAA batteries: A9161001
- Set of battery clips for 1x9Volt battery: A9174006

4.3.3 Smart Enclosure

The modern design Smart enclosure (white RAL9002) is intended to be used with all XG4000 LCDs. There is enough space to add custom keyboard designs.

Figure 11: Smart Enclosure

It's available with two different types of optional covers, foot stickers and a 9 Volt battery compartment.
The white cover covers the complete LCD, the plexi cover can be used to cover the LCD while keeping it readable.
This enclosure is intended to be wall mounted but it could be installed on a desktop surface with the foot stickers.

Figure 12: Smart Enclosure Options

Two types of batteries can be installed in the battery compartment. Two AAA batteries can be used for backup or a single 9Volt battery can be used for full XG4000/XG4100 operation (limited power, depends on LCD type used).

Figure 13: Smart Enclosure Batteries / Mounting

Space is available in this enclosure to add plug-in and/or expansion boards. Both side panels can be easily removed to access connectors and they can be locked.
Connectors can be installed on the wall-side or on the top and bottom sides. A special I/O board needs to be designed for this.

The XG4000/XG4100 board can be installed on any side of this enclosure. This gives you the option to have all cables on the top, bottom or read side. The easily removable side panels can be used to access optional connectors on I/O boards.

Part numbers are:
- White case: A9094107
- White cover: A9194127
- Transparent cover: A9194121
- 4 pcs of feet: A921233

4.3.4 Other Enclosures

If your application requires a custom enclosure or a different style of standard enclosure, contact DELGEN for help.
A custom enclosure can be made with other 'standard' available enclosures, or a real custom designed enclosure can be designed for your application.

All enclosures can be painted per your request. Any color or combination of colors is available.

Below are some pictures of other 'standard' enclosures which can fit the XG4000/XG4100. Options like batteries, card readers, keypads, are possible.

Figure 14: Examples of other enclosures

Custom enclosures can also be designed by DELGEN. Any form factor or material, on your request, can be used.

5 Hardware Specification

Learn more about all hardware features of the X-Graph module. Discover all special functions and find out how to build expansion boards.

5.1 Clock Speed

5.1.1 RTC

The Rabbit processor requires a 32.768kHz oscillator for its RTC and for the initial communication protocol with Dynamic C. To prevent the known problems with this oscillator, see Tech Notes on the Rabbit Semiconductor website, the X-Graph module is equipped with an external oscillator module.

This prevents any oscillation startup problems, removes all influence of external contamination, and reduces standby current.

The XG4000/XG4100 does not have a battery backup for the RTC (time and date are lost on power loss).

5.1.2 Rabbit Processor Clock

On the XG4000/XG4100 standard module the Rabbit is clocked at 40MHz. Other clock speeds are available on request, and the max. possible clock speed is 60MHz. A lower clock speed will result in a reduced performance, but also in a lower current consumption. A clock of 40MHz reduces cost (same clock as Ethernet interface).
Note that the TFT system requires a minimum clock of 60MHz.

The XG4000/XG4100 use a high precision Epson clock oscillator. This reduces all contamination, accuracy and drift problems known from the RCM modules. The Rabbit 4000 internal oscillator is not used on the XG4000/XG4100 standard modules.
Note that (only for custom designs) the Epson clock oscillator is one-time programmable to any required frequency.

To reduce clock instabilities the Rabbit 4000 clock doubler and clock spreader are not used unless on customer request for low cost custom designs. Both systems tighten the requirements on the external memory bus. Using both the doubler and spreader in combination with the internal oscillator would limit the maximum operation frequency.

For custom designs different clock speeds can be considered, some examples:
- With the 60MHz oscillator you get maximum performance. This clock is needed for the TFT system.
- The standard oscillator runs at 40MHz. This is the most cost-effective clock speed as the same oscillator can be used for the Ethernet interface.
- A 14.112MHz or 56.448MHz oscillator could be used to get perfect matching audio frequencies (44100Hz, 22050Hz).
- Any lower frequency oscillator can be installed for low-power applications. For proper B/W LCD operation the clock speed should not be lower then 15MHz.

Selected clock speeds should be multiples of 115200 to allow exact timing of the high-speed serial channels.

5.2 Memory

The XG4000/XG4100 module has a unique memory organization to get the maximum possible performance and remain compatible with DynamicC. Several enhancements have been made compared to RCM modules.

5.2.1 Memory Organization

5.2.1.1 Memory Devices

The XG4000/XG4100 allows zero waitstate program memory operation for speeds up to 60MHz.

- o Flash: 512 kByte, 45 nsec access time. The flash memory is used to store the application program during power off. Programs are never executed from Flash. Once the module is booted, the flash memory is not used anymore unless your application needs it to store data in it (flash file system or user ID block).
- o Fast SRAM: 512 kByte, 15 nsec access time min. (modules might have 10 or 8 nsec devices installed). After booting the program runs with zero-waitstates from this memory. Also all user data and the video buffer is stored in this memory.

As the Fast SRAM is used to store the user data and the video buffer, the available program memory is limited to 512kByte minus the required data/video memory. When this is not sufficient the XG4000/XG4100 offers two options.

Either the program can be executed directly from Flash. But at a 60MHz clock speed, two wait-states are added and this will slow down the cpu execution speed.
Or a 1MByte Fast SRAM can be installed. This results in 512kByte program space and 512kByte user data/video memory.

5.2.1.2 Rabbit Memory Quadrants Allocation

A Rabbit 4000 can control 6MByte of physical memory, but only 1MByte is indirectly accessible. The MMU divides this 1Mbyte of memory space in four 256kByte quadrants. On the XG4000/XG4100 the following quadrant configuration is used. This list includes the memory mapping used by DynamicC and the X-Graph libraries.

- CS0/OE0/WE0: 512kByte Flash: this memory is never mapped during normal program execution. During booting the BIOS maps this memory temporarily to Q0/Q1, and makes a copy to the 512kByte fast-sram. Then the program restarts from the fast-sram. This is a system supported by DynamicC to allow zero-wait state program execution on fast Rabbit 4000 systems.
- CS1/OE1/WE1: 512kByte of fast-sram. This memory is used for program execution, data storage and video memory. Mapped to Q0/Q1.
- CS1/OE1/WE1 (XG4x10): 1MByte of fast-sram. This memory is used for program execution, data storage and video memory. Mapped to all 4 quadrants.

5.2.1.3 Root memory, MMU and Physical Memory

The Rabbit processor can only access 64kByte of memory directly. It does have an on-board MMU to access 1Mbyte of memory indirectly. The physical memory interface has enough I/O lines reserved to connect a maximum of 6MByte memory. How to manage this in software?
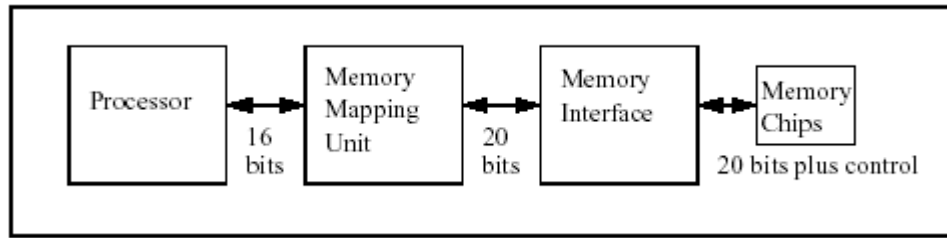
Figure 15: Rabbit MMU

The 64kByte of directly accessible memory is divided in 4kByte chunks. The top 8kByte is always used as a window in the full 1MByte physical memory map. The Rabbit proccessor has some easy and fast instructions to handle this window. The C Compiler uses this 'xmem' window to access the program memory automatically. A programmer does not need to worry about program size because the full 512kByte of program memory can be accessed almost directly and the compiler handles all overhead. If a program needs to use this window to access the physical memory, the program itself can not be running in this window. This type of program is called a 'root' memory program.
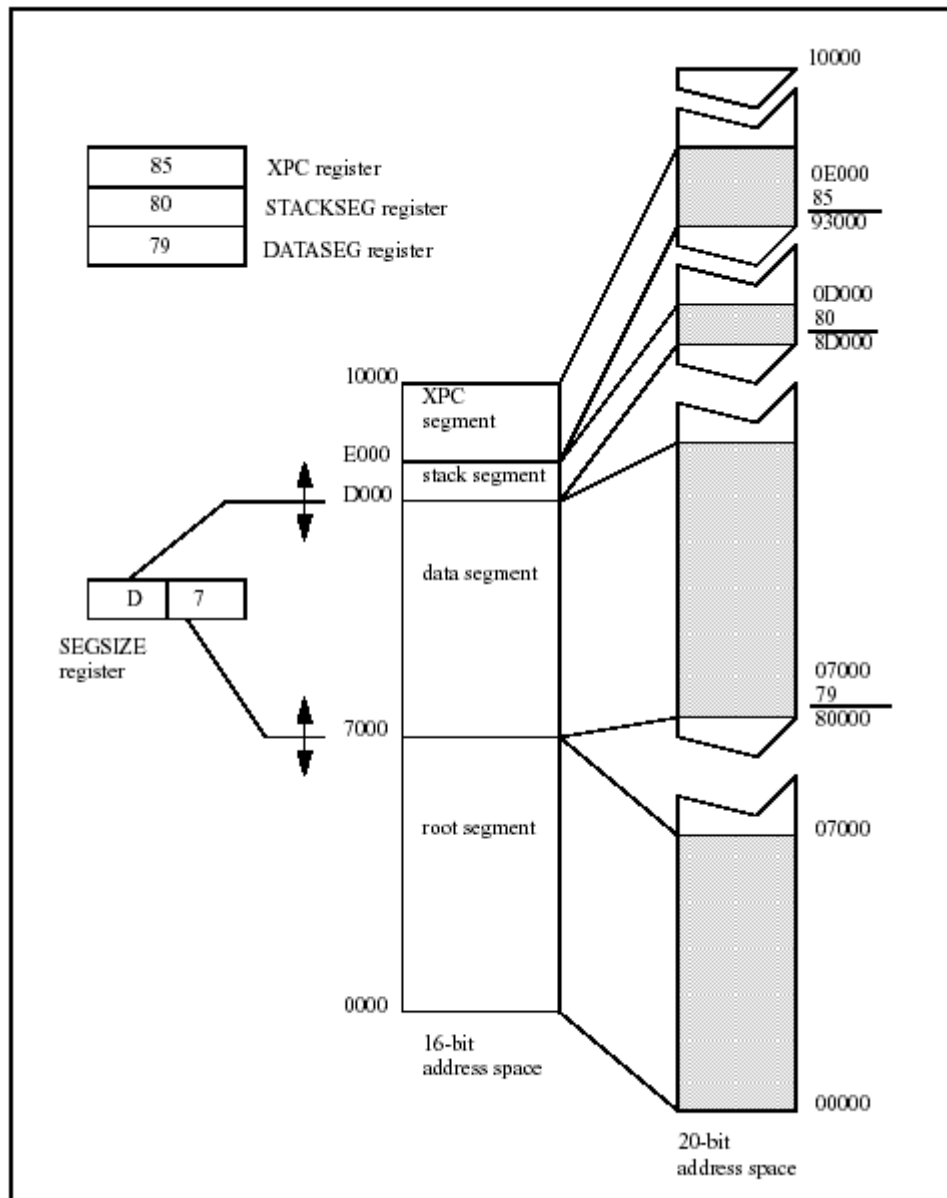
Figure 16: Rabbit MMU Example Configuration

The remaining 56kByte of directly accessible memory is divided in 3 regions by controlling some Rabbit I/O registers. Each region is another window mapped in the physical memory. But these windows don't have an easy system to change the mapping on-the-fly, as the top 8Kbyte window has. The DynamicC BIOS uses the easy approach, and does not support any window remapping. The windows are mapped to physical hardware based on the available hardware.

For the X-Graph modules the root window starts at address 0 and its size is standard 44kByte. This window is used to store root memory programs and root data. How much memory is assigned to root memory and root data can be defined in the BIOS with a macro. The Rabbit processor also can use a trick called 'separate instruction and data spaces' to almost double the amount of root memory/data space. But we don't encourage you to use I&D unless you really run out of root memory space.

The second window is normally not used by DynamicC in the X-Graph hardware configuration. DELGEN has implement an innovative feature with this 'not-used' window, i.e. far variables, far pointers and far arithmetic. This windows size is 8kByte. The xgRAM library uses it to give full C style access to all available RAM without the need for far pointers or far arithmetic. This is a new amazing system which gives the programmer full access to all the available ram memory without the need for xmem2root and root2xmem functions. C style type checking works with xgRAM and it is compatible with almost all Dynamic C library functions. Check the 'xgRAM Users Manual' to learn more.

The third window with (4kByte size) is the DynamicC stack window. This size normally fits most DynamicC programs and only needs to be enlarged in very special cases.

This describes how DynamicC uses the 4 available windows, a root program may reconfigure the window mapping I/O registers and use the windows as needed. DELGEN does only encourage users with a very good knowledge of the Rabbit memory system to try window remapping.

5.2.1.4 Accessing more then 20kByte Data Memory

Most users think the Rabbit processor memory model is complicated. Actually, for most applications it's not.

A programmer can just write an application of up to 512kByte program memory size without special actions. To put code in the root memory, a special keyword needs to be used. Because root memory is a limited, you should have a very good reason to use it. Note that many low-level DynamicC libraries use root memory. You might run out of root code memory due to the inclusion of too many DynamicC libraries.

The root code memory is also used to store all users constants !! Try to limit the use of constants and replace them by either xmem constants or use the xgRAM library to access far constants.

Normally 20kByte of root data space is available. This is used to store all global variables of the program. By default DynamicC stores all local variables (of functions) on the stack. The number of local variables is only limited by the stack size (standard is 4kByte). For global variables, global structs and global data arrays, one can use the available root data space. If the 20Kbyte of available space is not sufficient there are several solutions.

The first solution would be increasing the root data space (setting in the BIOS). This will decrease the root program space. Interrupt routines and many DynamicC libraries require root program space. Thus the amount of data space which can be 'stolen' here is limited.

The second solution would be using 'separate instruction & data space'. This will open an extra +/- 16kByte of root data space, but it comes at a speed penalty, an increase of

program memory (application dependant) and a decrease of available program memory on fast-sram systems (X-Graph modules).

The third solution is just using the remaining available SRAM memory to store data. On an X-Graph module there is a lot of free available SRAM memory. There is all the memory not used for program execution and root programs in the program fast-sram. Also all the memory in the video memory chip which is not used for the video memory map can be used as data memory.

The main problem many first-time DynamicC users encounter, is how to access all this extra ram memory. It can NOT be accessed with standard C style commands. DynamicC includes a set of library functions to read/write 'extended' data memory. It generally involves copying a chunk of extended data memory to a root memory data buffer before using it. For example one can store an array of 512 elements of a 123 byte struct (62976 bytes) easily in extended memory. To do this you should allocated the amount of needed extended memory, then create a single struct variable in root memory, fill this element with data and copy it to the correct array element in extended memory. To read a struct you'll need to copy the correct element first to a root struct. Got it…., if not check the examples included with DynamicC (the examples on extended memory access).

But the easiest ans most ANSI-C compatible solution is using the DELGEN xgRAM library. This library uses a Rabbit hardware window to access all the available SRAM with the standard C style variables (see previous section). No need for xallocs or xmem calculations. Check the 'xgRAM Users Manual' for more info and start writing DynamicC programs without complicated and buggy xmem2root/root2xmem logic.

5.2.2 MMC/SD(IO) Slot

The XG4000 can be equipped with a Secure Digital card socket (not compatible with xgBus and RS232C expansion headers). The XG4100 has a SD socket standard. This slot is compatible with MMC (Multimedia card) and SD (Secure Digital) memory and I/O cards. These cards are accessed with an SPI interface. Examples are GPS, GPRS, Bluetooth, WLAN, … cards. Of course suitable SD(IO) drivers have to be written. DELGEN organizes a forum for exchanging these drivers.

Cards should use a polling system for card and write-protect detection. The slots card detection and write-protect switches are not connected, because they tend to be unreliable on most cards.

SD Cards do not have a reset line and rely on a power on detection for reset. Practical tests indicate that in some situations with some brands of cards a software reset is needed. A mosfet is installed on the XG4000/XG4100 to allow the cards to be reset.

NOTE: High Power level cards (up to 250 mA) should preferable not be used. Most MMC/SD cards do not use this power level.

DELGEN provides a basic driver to access SD memory cards.

5.2.3 EEPROM

The X-Graph module has a 64 byte (XG4000) or 512 byte (XG4100) EEPROM area available in the Atmel slave processor. It can be read or written on byte level and can be used to store configuration information.

Dynamic C and Rabbit modules do offer a user data area in the ID-Block stored in Flash. The X-Graph module also offers this. But the EEPROM area is much faster and easier to access.

5.2.4 Secure Flash (XG4100)

The X-Graph module has a 1024 byte secure Flash area available in the Atmel slave processor. This area uses 64 byte blocks, but the software supports byte level read/writes. It can be used to store configuration or ID information which does not change often. The flash supports 10.000 rewrites for each 64 byte block.

Dynamic C and Rabbit modules do offer an ID-Block stored in Flash. The X-Graph module also offers this. But the XG4100 secure flash area is impossible to erase by simple DynamicC commands and it's impossible to erase during Rabbit firmware upgrades or DynamicC bugs, making it much more secure.

DELGEN provides support to remove the ID-Block feature from the Flash and store all ID-Block data in this secure flash area. This makes available an extra 32kByte of Flash and removes any occasional erasure problems of the ID blocks due to bugs in some DynamicC versions.
The xgBIOS library includes support for this feature.

5.3 I/O Expansion

The standard Rabbit RCM modules are very small modules offering I/O expansion on 2 mm pitch headers.

The XG4000 module is about the same size as RCM modules and has I/O expansion capabilities on industry standard IDC 2.54 mm (0.1") headers. Of course the XG4000 also has LCD I/O functions.

The XG4100 adds a single 34-pin IDC 0.1" header on a slightly larger pcb.

If your project needs more I/O then have a look at the XG5000 module.

5.3.1 Available I/O pins

Many Rabbit I/O ports, buffered I/O ports, LCD and ADC lines are available on the I/O expansion headers. Cheap through-hole I/O boards can be designed to offer custom-made I/O functions. These boards can be easily installed on the 2.54 mm headers of the X-Graph module.

DELGEN offers a design service for such I/O cards. Contact us if you need more information. Several I/O boards are already available (X-Graph Expansion Modules Users Manual) and several more are being designed.

For a list of available I/O port pins see the description of the I/O expansion headers in the next sections. Several installation options are available for the I/O expansion headers. They can be installed on the component or solder side of the pcb. Either female or male connectors are available in straight, raised or angled versions. The XG4000/XG4100 development kit is delivered with a set of matching headers. Users can solder the proper connectors for their applications.

For more info of the signals mentioned in below tables and marked 'Rabbit 4000 xxxxx', refer to the Rabbit 4000 datasheet (www.rabbitsemiconductor.com).

5.3.1.1 J9: xgBus Slave header

This header is used to connect the XG4000/XG4100 to xgBus modules. Or, the I/O lines can be used for any other I/O function.

All I/O lines are directly connected to Rabbit 4000 I/O pins. Some pins are multiplexed with other XG4000/XG4100 functions. These alternate functions are indicated in the table after th ' / mark.

Pin	Signal name	Function
1	OE	PE0
2	LD	PD1
3	CLK	PB0 (= SCLKB)
4	GP0	PD6 (= TXE) / RS485 TXD
5	STR	PD3 (= RXF)
6	GP1	PD7 (= RXE) / RS485 RXD / J12.2
7	TXD	PC4 (= TXB)
8	RXD	PC5 (= RXB)
9	+3.3V	+3.3V Power Supply
10	GND	Ground

Table 2: J9 xgBUS Expansion Header

5.3.1.2 J10: RS232C and Modem

J10 is a 2x5 pin male header, which can be connected to a standard RS232C cable and male dSub-9 connector (included with development kit). The port can be used to directly interface any general-purpose serial device, which normally connects to a pc.
To use this port for connecting the XG4000/XG4100 to a PC, a null-modem cable is required. This is for example needed for the xgConsole mode.

Pin	Signal Name	Function
1	Not connected	
2	Not connected	
3	RXD	Received Data
4	RTS	Ready To Send
5	TXD	Transmitted Data
6	CTS	Clear To Send
7	DTR (XG4100)	Reset input (do not connect unless in programming mode)
8	Not connected	
9	GND	Ground
10	+3.3V	+3.3Volt Power Supply (not connected on d-Sub9 connector)

Table 3: J10 RS232 Header

The XG4100 can have a d-Sub9 male connector (J16) installed on the board. This connector replaces both J9 and J10 (mutual exclusive).

5.3.1.3 J5: Programming header (XG4000)

The XG4000 programming header is used to switch the Rabbit 4000 in programming mode and to flash the slave processor.

DELGEN offers a matching USB programming plug-in board. This USB board can also be used to power the XG4000 from the USB bus (using pin 1 as an input).

The XG4000 can also be set to programming mode by using a custom programming interface. Note that ALL signals are 3.3 Volt tolerant only. Using 5 Volt signals will destroy the Rabbit 4000 and void your warranty.
To set the Rabbit 4000 in programming mode, both SMODE pins must be pulled to 3.3 Volt. The PROG TXD and PROG RXD are the communication lines and normally the RS232C DTR pin should be connected to RESETIN.

Pin	Signal Name	Function
1	+V	Power input/output
2	GND	Ground
3	SMODE0	Rabbit 4000 SMODE0 pin
4	SMODE1	Rabbit 4000 SMODE1 pin
5	PROG TXD	Programming output
6	PROG RXD	Programming input
7	RESETIN	Reset input
8	SMOSI/CLK32KHZ	Slave programming input / 32kHz output
9	SSCK/ADC0	Slave programming clock / ADC0 input
10	SMISO/SLAVE	Slave programming output / Rabbit-Slave communication bus

Table 4: J5 Programming Header (XG4000)

Three lines are reserved to flash the slave processor. Contact DELGEN for the correct procedure. Once the slave processor is programmed the pins change function. Pin 9 can be used as an alternate ADC0 input pin. Pin 10 can be used a single line communication bus to other devices. Contact DELGEN if you need more information on this.

5.3.1.4 J11: ADC header (XG4000)

J11 is an optional header on the XG4000. It adds the ADC input pins and two Rabbit 4000 I/O pins.

Pin	Signal Name	Function
1	PD2	Free Rabbit 4000 pin
2	ADC0	Analog input 0
3	CLK	Free Rabbit 4000 pin
4	ADC1	Analog input 1

Table 5: J11 ADC Header (XG4000)

5.3.1.5 J5: I/O Expansion header (XG4100)

The XG4100 adds a 34-pin I/O expansion header.

Pin	Signal name	Function
1	AIN7	Slave I/O or SCL or ADC-7
2	AIN6	Slave I/O or SDA or ADC-6
3	AIN5	Slave I/O or ADC-5
4	AIN4	Slave I/O or ADC-4
5	AIN3	Slave I/O or Touchscreen or ADC-3
6	AIN2	Slave I/O or Touchscreen or ADC-2
7	AIN1	ADC-1
8	AIN0	ADC-0
9	GND	Analog and digital ground
10	GND	Analog and digital ground
11	RS485 B	RS485 B line
12	RS485 A	RS485 A line
13	ATM RXD	Slave I/O or RS RXD or PS2 keyboard Data
14	ATM TXD	Slave I/O or RS TXD or PS2 keyboard CLK
15	RC5 Receive	Slave I/O or RC-5 Receive
16	1WIRE	Slave I/O or 1-Wire
17	SPI MOSI	On-board SPI Txd (Serial Port D)
18	SPI MISO	On-board SPI Rxd (Serial Port D)
19	SPI SCK	Serial Port D SPI Clock
20	SLAVEIRQ / PE4	Slave handshake / Alternate INT0
21	XGBUS_STR / PD3	xgBus Strobe / RXF
22	DE1 / PD2	RS485 DE / PD2 I/O pin
23	XGBUS_GP0 / PD6	xgBus GP0 / RS485 Txd / TXE
24	XGBUS_GP1 / PD7	XgBus GP1 / RS485_Rxd / RXE
25	USB_DTR	
26	DRS_DTR	
27	PROG_TXD	TXA / TXE
28	RS232_TXD	TXC / TXF
29	PROG_RXD	RXA / RXE
30	RS232_RXD	RXC / RXF
31	SMODE	Rabbit 4000 SMODE pin
32	+3.3V	+3.3Volt power supply
33	+V	+V input Power Supply
34	+V	+V input Power Supply

Table 6: J19 XG41000 I/O Expansion Header

Pin description:
- Several pins are reserved for the ADC input pins and the slave I/O pins.
- Ground and power pins
- RS485 driver pins
- The on-board SPI bus to connect external SPI devices (3.3Volt only !!!).
- PE4 is a Rabbit 4000 interrupt pin, used by the slave processor. Contact DELGEN for info on how to use this pin for external interrupts.
- The xgBus strobe pin is not needed on all xgBus devices. If not used, it's available as a general purpose I/O pin or as Serial Port F receive.
- PD2, PD6 and PD7 are general purpose I/O pins, reconfigurable as serial port E. They are used by the on-board RS485 (custom version can have the chip not installed) and as GPx pins on the xgBus (option pins).
- IMPORTANT: the following feature is NOT available on the R1 pcb.
  Pins 25-26, 27-28, 29-30, 31-32 should be jumpered in programming mode. Else these pins are the Rabbit 4000 programming serial port pins and the general I/O

pins used for the RS232C driver. On custom boards without the RS232C driver chip these pins are available for general use.
For XG4100-R1 boards the XG4000 USB programming board can be used or a custom programming cable needs to be manufactured (contact DELGEN).

5.3.1.6 J12/J11/J20: Touchscreen headers

The XG4000 includes a single touchscreen header (J12) matching the B/W LCD touchscreen. The other LCD's require a touchscreen interface pcb to connect their touchscreens to the XG4000. Note that touchscreen functionality is not standard on the XG4000, it's only available for custom designs.

The XG4100 has two additional FFC touchscreen headers (J11 and J20) which match the CSTN and TFT LCD touchscreen connectors.

5.3.1.7 J7: Character LCD or I/O Expansion header

J23 uses the industry standard 16-pin connection of character LCD's. Many character LCD's of different manufacturers fit this connector.

Note that only 3.3V compatible character LCD's can be used.
Also mind the contrast voltage and backlight voltage required for a character LCD. These might require adjustments on the contrast resistor divider and/or secondary SMPS output voltage.

Pin	Signal name	Function
1	GND	Ground
2	+3.3V	+3.3V Power Supply
3	Contrast +V	Contrast voltage (fixed resistor divider used)
4	PB2	RS
5	PB3	R/W
6	PF0	E
7	PA0	DB0
8	PA1	DB1
9	PA2	DB2
10	PA3	DB3
11	PA4	DB4
12	PA5	DB5
13	PA6	DB6
14	PA7	DB7
15	Backlight +V	Anode
16	Ground	Cathode

Table 7: J23 Character LCD Header

5.4 Interrupts & DMA

In a real time system it is very important to understand which interrupts occur when and how long it takes to execute the interrupt routines.

5.4.1 Periodic Interrupt

This level 1 interrupt is enforced by Dynamic C. It reenables interrupts very fast thus allowing level 1, 2 and 3 interrupt to occur. But it does interrupt the main program every 488 µsec. Generally this interrupt requires about 2% of the CPU time (@ 20 MHz), about 1% @ 60MHz.

5.4.2 LCD DMA

The XG4000 LCD control system uses the Rabbit 4000 DMA module which uses cpu cycle stealing. For a QVGA TFT interface about 50% of the cpu time is needed. The B/W QVGA LCD only requires 20% of the cpu time (on 60MHz systems)
If this is not acceptable for your application, refer to the XG5000 module which uses a 0% cpu time LCD interface.

5.4.3 Serial Bus Interrupts

Most serial busses will require an interrupt for receiving data. Otherwise bytes might be lost at higher communication speeds. Preferable use level 1 and for very critical serial busses level 2 interrupts. Each level 2 interrupt will prevent the periodic interrupt from occurring. This can lock up Dynamic C and make the RTC run slower.

An example of a serial bus library with level 2 interrupts can be found in the DMX512.lib library.

5.5 Integrated I/O

The XG4000/XG4100 modules are very compact, but still include several interesting interfaces on their expansion headers. The standard Dynamic C libraries support most interfaces. DELGEN delivers some extra libraries for the X-Graph specific functions.

5.5.1 Network

The Ethernet connector has two build-in led indicators. They are connected to the LINK and ACT led outputs of the Rabbit 4000 ethernet interface.

Yellow led: will be active for 0.1 seconds following each packet transmission

Green led: on = link detected, off = no link.

The Rabbit 4000 internal network controller is used (identically to the RCM4000 module). It is 100% compatible with the Dynamic C version 9.50 and higher network libraries.

5.5.2 Touchscreen & LCD

Refer to chapter 4 for learning about the different available XG4000/XG4100 LCD's. A short description of the hardware/software interface of the 4 standard LCD controllers is given below.

5.5.2.1 Character LCD (CLCD)

A 16-pin character LCD connector is available (J7).

Character LCD's use a simple 8-bit interface. The Rabbit PortA is connected to the CLCD databus. Further 3 Rabbit I/O pins (PB2, PB3, PB4) are used. Note that to control a CLCD the Rabbit Secondary I/O bus must be disabled.

A small CLCD library is included with the XG4000/XG4100, which handles all this and offers a few functions to control the CLCD.

5.5.2.2 B/W QVGA Display

The STN LCD interface uses the Rabbit 4000 DMA to generate all LCD signals automatically. This requires about 20% of the available CPU time to refresh the LCD (at 60MHz clock speed). A linear video memory map is stored in the Fast-SRAM and is continuously read by the DMA controller. The Rabbit 4000 has continuously access to the video sram = 100% of the available bandwith. This results in the fastest possible drawing and refresh speed.

DELGEN includes with the XG4000/XG41000 libraries a low level driver for this display. This driver integrates perfectly in the GRAPHIC.LIB library included with Dynamic C. No changes to this Dynamic C library are required.

The LCD uses a 9600 byte chunk of RAM as display buffer.
The LCD interfaces also uses the Rabbit 4000 external I/O bus (PortA, PortB and PE2).

5.5.2.3 CSTN QVGA Color Display

On the standard module the CSTN LCD interface uses the Rabbit 4000 DMA to generate all LCD signals automatically. This requires about 30% of the available CPU time to refresh the LCD (at 60MHz clock speed). A linear video memory map is stored in the Fast-SRAM and is continuously read by the DMA controller. The Rabbit 4000 has continuously access to the video sram = 100% of the available bandwith. This results in the fastest possible drawing and refresh speed.

DELGEN includes with the XG4000/XG4100 libraries a low level driver for this display. The GRAPHIC.LIB library included with Dynamic C cannot be used because it does not support color. A complete set of X-Graph GUI (xgGUI) libraries is included with the XG4000/XG4100.

The driver uses a 32kByte chunk of RAM as display buffer.
The LCD interfaces also uses the Rabbit 4000 external I/O bus (PortA, PortB and PE2).

5.5.2.4 TFT LCD

The TFT LCD interface uses the Rabbit 4000 DMA to generate all TFT signals automatically. This requires about 50% of the available CPU time to refresh the LCD (at 60MHz clock speed). A linear video memory map is stored in the Fast-SRAM and is continuously read by the DMA Controller. The Rabbit 4000 has continuously access to the video sram = 100% of the available bandwith. This results in the fastest possible drawing and refresh speed.

The XG4000 graphic system can handle a QVGA TFT LCD in 8-bit color mode (256 colors). DELGEN includes with all XG4000/XG4100 modules its enhanced xgGUI set of libraries. The drawing speed of these libs is considerable faster compared to the GRAPHIC.LIB functions because no bit manipulations are needed. Correct BMP files (8-

bit) can be directly imported without conversion. Even GIF or JPG files could be used, given a proper decoder is used.

Check the 'xgGUI Users Manual' to get more information on the xgGUI libs.

The driver uses a 128kByte chunk of RAM as display buffer.
The LCD interfaces also uses the Rabbit 4000 external I/O bus (PortA, PortB and PE2).

5.5.2.5 Analog Touchscreen

The slave processor manages the analog touchscreen by using two channels of the on-board ADC. Touchscreen actions are pushed in an event buffer, which is read by the Rabbit-Slave interface software driver.

5.5.3 Serial Interfaces

The Rabbit microcontroller includes six serial channels. Four or five channels are pre-assigned on the XG4000/XG4100 module and the required hardware interfaces are integrated on the module.

One channel (PortD) is configured as a SPI bus and used for the SDCard interface and the slave processor.

5.5.3.1 Programming port / USB

The Rabbit 4000 programming port is fixed to PortA. The required pins are available on the XG4000 programming header and on the XG4100 expansion header.

For the XG4000 a USB plug-in board (programming header) is available.
The FTDI FT232R chip on this board is used to interface a USB1.1 compliant connector to serial port A on the Rabbit. This connection is required for debugging but it can also be used for applications.
The DTR line is connected to the Reset line of the board, a debugging requirement.

The standard Dynamic C libraries, RS232.LIB and MODEM.LIB, can be used with this port. The necessary macro's are available in XGRAPH.LIB.

If the USB hardware is not installed, header J5 can be used to connect a Rabbit programming cable (custom design).

The XG4100 programming interface can also be used with a plug-in USB board or custom programming cable.
IMPORTANT: the following feature is not available on the R1 pcb's.
But the XG4100 can also be used in programming mode with the on-board serial port. Either J10 (d-Sub9 adaptor cable needed) or J16 (if installed on the board, this needs a null-modem cable) can be used. Four jumpers need to be installed on J19 to activate this mode (pins 31-32, 29-30, 27-28, 25-26).

5.5.3.2 RS232C and Modem

A RS232C communication interface with RTS/CTS handshaking is connected to Rabbit serial port C or serial port F (software configurable). The module includes a RS232C 4-channel level shifter with ESD protection. The 4 level shifted RS lines are available on the RS232C header J10 or on the d-Sub9 connector J16 (option on XG4100).
This port is fully compatible with the DC libraries RS232.LIB and MODEM.LIB.

When the RTS/CTS handshake lines are not used, they offer a secondary level shifted serial channel. Both lines can double as a RXD/TXD pair connected to the Rabbit 4000 serial port B pins (alternate pins, serial port B is also used for the xgBus interface).

Note that the xgBus connector can not be installed on the XG4000 combined with the SDCard connector.

J9 is a 2x5 pin boxed header, which can be connected to a standard RS232C cable and male dSub-9 connector (included with development kit). The port can be used to directly interface any general-purpose serial device, which normally connects to a pc.
To use this port for connecting the XG4000/XG4100 to a PC, a null-modem cable is required. This is for example needed for the xgConsole mode.

See the previous section for a pinning table of this connector.

5.5.3.3 RS485 (XG4100)

A RS485 driver is installed on the XG4100. It's connected to either the Rabbit 4000 serial port A or serial port E (software configurable). PD2 is used as a data enable line for RS485 transmissions.

Note that the RXD/TXD lines are multiplexed with the xgBUS GP0/GP1 lines.

5.5.3.4 xgBUS

An X-Graph xgBUS connector is installed on the XG4000/XG4100. Refer to the 'xgBUS Users Manual' for information on the xgBUS.

When the xgBUS is not used this connector carries 8 I/O lines which can be used as needed. The xgBUS pins include pins connected to two Rabbit 4000 serial ports (B and E).

See the previous section for a pinning table of this connector.

Note that the xgBus connector can not be installed on the XG4000 combined with the SDCard connector.

5.5.4 XG4000 Slave Processor

The X-Graph module includes a slave processor for internal hardware management. The XG4000 compact slave processor only handles the touchscreen and eeprom array.

It uses a one-line communication protocol with the Rabbit processor. A driver is included in the XGRAPH.LIB to handle the low-level communication protocol. Several functions are available to easily control the slave processor features without worrying about this protocol.

The slave processor firmware is user upgradeable. Either new firmware to solve bugs or patches can be installed by the user. Or specific application dependant firmware can be developed by DELGEN or the user. For example the slave processor communication protocol could be changed to allow fast control of one single feature.
Note: the XG4000 slaved processor firmware can only be updated with a special programming cable.

Two slave processor I/O pins are directly available on J12. Both of these pins are by default configured as general purpose I/O pins. They can be individually configured input

or output. Each pin has a programmable pull-up resistor (on or off). Both pins can be reconfigured as analog input pins with a 10-bit resolution.
Once a touchscreen is installed, both pins are reserved for this on J11.

5.5.5 XG4100 Slave Processor

The X-Graph module includes a slave processor for internal hardware management.
The XG4100 includes the full featured XG5000 slave processor. It offers some of the most interesting hardware interfaces of the X-Graph module without putting a software load on the Rabbit microcontroller.

The slave processor is connected to the Rabbit processor with the on-board SPI bus and a single handshake line. A driver is included in the XGRAPH.LIB to handle the low-level communication protocol. Several functions are available to easily control the slave processor features without worrying about this protocol.

The slave processor firmware is user upgradeable. Either new firmware to solve bugs or patches can be installed by the user. Or specific application dependent firmware can be developed by DELGEN or the user. For example the slave processor communication protocol could be changed to allow fast control of one single feature.

12 slave processor I/O pins are directly available on J19. All of these pins are by default configured as general purpose I/O pins. They can be individually configured input or output. Each pin has a programmable pull-up resistor (on or off). All pins also have special functions, which can be enabled individually.

On overview of the pin configurations:

J19 Pin	Signal name	Default	Function 1	Function 2	Function 3
16	1WIRE	I/O pin	1-Wire		Keypad 1
14	ATM TXD	I/O pin	RS232 Txd	PS2 keyboard Data	Keypad 2
13	ATM RXD	I/O pin	RS232 Rxd	PS2 keyboard Clk	Keypad 3
15	RC5 Receive	I/O pin	RC-5 Input		Keypad 4
2	AIN6	I/O pin	ADC-6	I2C SDA	Keypad A
1	AIN7	I/O pin	ADC-7	I2C SCL	
3	AIN5	I/O pin	ADC-5		Keypad B
4	AIN1	ADC-1			
5	AIN3	I/O pin	ADC-3	Touchscreen	Keypad C
6	AIN2	I/O pin	ADC-2	Touchscreen	
7	AIN4	I/O pin	ADC-4		Keypad D
8	AIN0	ADC-0			

Table 8: Slave Processor Configurable Pins

5.5.5.1 ADC

The expansion header J19 includes the analog inputs including dual analog ground pins.

The 8-channel ADC has a 10-bit resolution. Note that analog input 2 and 3 are not available if a touchscreen is installed. Channels 6 and 7 double as a hardware I2C interface. All ADC lines can be reconfigured as standard I/O lines.

5.5.5.2 PC/AT Keyboard with PS2 Connector

Two slave processor pins can be configured to accept the standard PC/AT keyboard protocol.

The slave processor handles the communication with the keyboard and transmits key pressures to the Rabbit processor. Commands can be send to the keyboard.

A plug-in board is available from DELGEN, which includes a standard PS/2 keyboard connector and a RC-5 receiver. The board will only work with +3.3Volt compatible PS/2 keyboards.

This specific interface is interesting for applications, which need a lot of user input and want to use off-the-shelf cheap full-size keyboard. Also a cheap barcode readers can easily be installed.

5.5.5.3 I²C interface

The slave processor also includes a hardware I²C bus driver. Two of the ADC channels can be reconfigured.

The slave processor can be configured as a I2C slave or master. It can handle multi-master setups. The interface is fully configurable and works with speeds up to the max. I2C speed, i.e. 400kHz.

All communication is handled by the slave processor. Data and commands are transferred to the Rabbit processor via the slave processor communication protocol.

5.5.5.4 Dallas 1-Wire

The time-critical Dallas 1-Wire protocol is also supported by the slave processor. This bus can be used to communicate with Dallas 1-Wire or i-Button devices, typically used for temperature and pressure measurements.

All 1-Wire commands are available. The interface can auto-detect 1-Wire devices and report there ID. Data can be send and received.

The interface can be delivered with a DS9502P protection diode (option). It can handle standard 1-Wire and bus-powered high-power 1-Wire devices.

5.5.5.5 IR Remote Control

A single pin of the slave processor can be configured as a remote control input pin. The standard slave processor firmware includes a driver to support the Philips RC-5 protocol.

5.5.5.6 Keypad Expander

A 4x4 matrix keyboard can be connected to the slave processor. The keyboard should be connected to a 8-pins of connector J19. The pins are not arranged in a single row, an adaptor pcb is needed for most keypads.

All lines not used by the keypad can still maintain there standard or other alternate functions. Rows will be assigned a pull-up resistor automatically. Columns are considered the keypad output lines.

5.5.5.7 RS232C Port

Two slave processor lines can also be configured as a fully programmable UART. The functionality of this UART includes features not offered by the Rabbit serial ports. It requires no Rabbit CPU power and can include configurable receive and transmit buffers.

Features:
- Full Duplex operation
- High resolution baudrate generator
- 5, 6, 7, 8 or 9 databus
- 1 or 2 stopbits
- Hardware odd or even parity generator
- Data overrun detection
- Framing error detection
- Hardware noise filtering
- Multi-processor mode
- Three different interrupts assure correct and fast full-duplex operation

This interface can be used to control a serial device without loading the Rabbit processor.

5.5.6 Programming the Hardware

The XG4000/XG4100 slave processor firmware is upgradeable.

A Rabbit function is included in XGSLAVE.LIB to load new firmware in the XG4100 slave processor.

New slave processor firmware will be made available by DELGEN to solve bugs, add patches or new features. With the included function it's very easy to safely upgrade the firmware in a life system.

Specific user application dependent slave processor firmware can be developed by DELGEN on request. Or users can contact DELGEN on how to develop such firmware. This could be required if the slave processor needs to handle a single interface system at a speed not attainable with the default communication protocol.

The slave processor can be directly programmed via its bootstrap mode pins connected to the Rabbit processor. DELGEN strongly discourages bootstrapping the slave processor. It does include some internal hardware management firmware, which is not open source. By erasing the slave processor memory (via bootstrap), the hardware management firmware will be removed and make the XG4100 stop working and void your warranty.

6 Installation

This section provides some considerations for mounting the X-Graph.

6.1 Reliability Considerations

The X-Graph has strong environmental resistance and high reliability, but you can maximize the systems reliability by avoiding or eliminating the following conditions at the installation site:
• Abrupt temperature changes and condensation
• Ambient temperatures exceeding a range of 0°C to 50°C
• Relative humidity exceeding a range of 20% to 70%
• Strong magnetism or high voltage
• Corrosive gasses
• Direct vibration or shock
• Excessive iron dust or salt
• Spray from harsh chemicals
• Strong magnetic fields
• High voltage lines

6.2 Mechanical Installation

The mechanical dimensions are described in chapter 7. The board is intended to be used in an XG4000 Standard enclosure. It can be mounted in any type of X-Graph or non-X-Graph enclosure using the 4 mounting holes.

6.3 Installation Guidelines

Please notice the following advises for incorporating the X-Graph into your application to comply with the CE requirements, described in chapter 7.

The customer should provide a CE-compliant power supply adapter for the end-product application.
• When connecting the X-Graph to outdoor cables, the customer is responsible for providing CE-approved surge/lightening protection.
• DELGEN recommends using shielded cables in noisy electromagnetic environments.
• While the X-Graph meets the EN61000-4-2 (ESD) requirements in that it can withstand contact discharges of ± 4 kV and air discharges of ± 8 kV, it is the responsibility of the end-user to use proper ESD precautions to prevent ESD damage when installing or servicing the X-Graph.
• Damage to the Rabbit 4000 microprocessor may result if voltages outside the design range of 0 V to 3.5 V DC are applied directly to any of its digital inputs.
• Since the X-Graph is designed to be connected to other devices, good EMC practices should be followed to ensure compliance. CE compliance is ultimately the responsibility of the integrator.
• If it becomes necessary to clean the screen overlay, use a mild detergent, then rinse with lukewarm water using a clean sponge or a soft cloth. Dry thoroughly with a chamois or a moist cellulose sponge to prevent water spots. Do not use abrasives, which will scratch the hard coating on the overlay. Fresh paint splashes, grease, and smeared glazing compounds can be removed by rubbing gently with a isopropyl alcohol. Never use gasoline, acetone, carbon tetrachloride, or highly alkaline cleaners. Rinse afterwards with lukewarm water as described above. Cleaning is not recommended when the X-Graph is exposed to the hot sun or elevated temperatures.

7 Technical Information

7.1 CE Compliance

Electrical equipment is generally divided into two classes.

Class A	Class B
Digital equipment meant for light industrial use	Digital equipment meant for home use
Less restrictive emissions requirement: less than 40 dB μV/m at 10 m (40 dB relative to 1 μV/m) or 300 μV/m	More restrictive emissions requirement: 30 dB μV/m at 10 m or 100 μV/m

These limits apply over the range of 30–230 MHz. The limits are 7 dB higher for frequencies above 230 MHz. Although the test range goes to 1 GHz, the emissions from Rabbit-based systems at frequencies above 300 MHz are generally well below background noise levels.

The X-Graph has been tested and was found to be in conformity with the following applicable immunity and emission standards. The X-Graph is also CE qualified. Boards that are CE-compliant have the CE mark.

7.1.1 Immunity

The X-Graph meets the following EN55024/1998 immunity standards.
● EN61000-4-2 (ESD)
● EN61000-4-3 (Radiated Immunity)
● EN61000-4-4 (EFT)
● EN61000-4-6 (Conducted Immunity)
Additional shielding or filtering may be required for a heavy industrial environment.

7.1.2 Emissions

The X-Graph meets the following emission standards emission standards with the Rabbit 3000 spectrum spreader turned off.
This microprocessor is used on the X-Graph that carry the CE mark.
● EN55022:1998 Class B
● FCC Part 15 Class B
Your results may vary, depending on your application, so additional shielding or filtering may be needed to maintain the Class B emission qualification.

7.2 Mechanical Dimensions

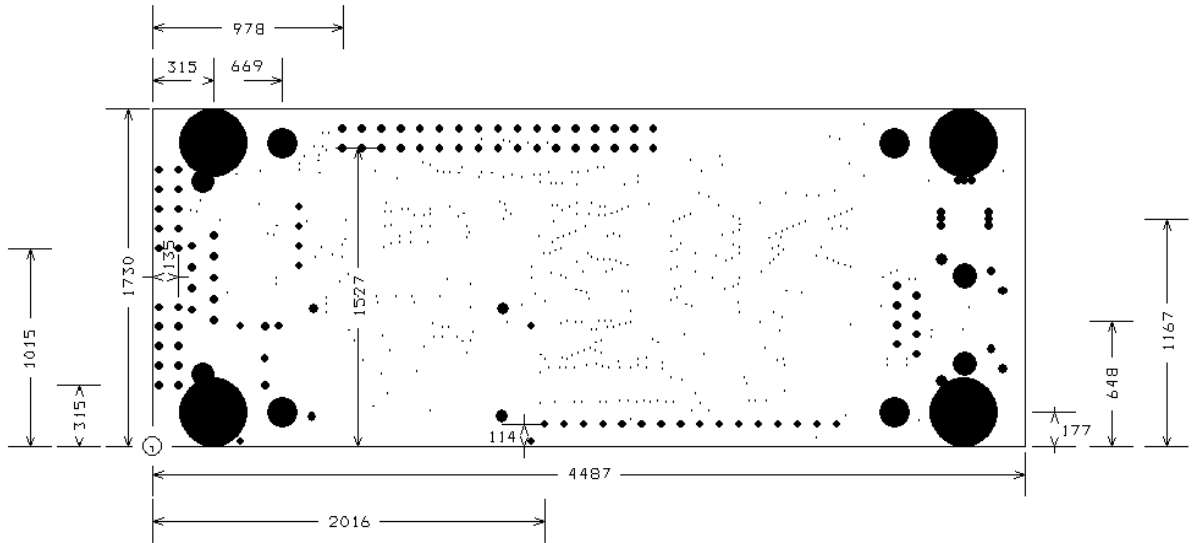All dimensions are in mils (1/1000 inch).

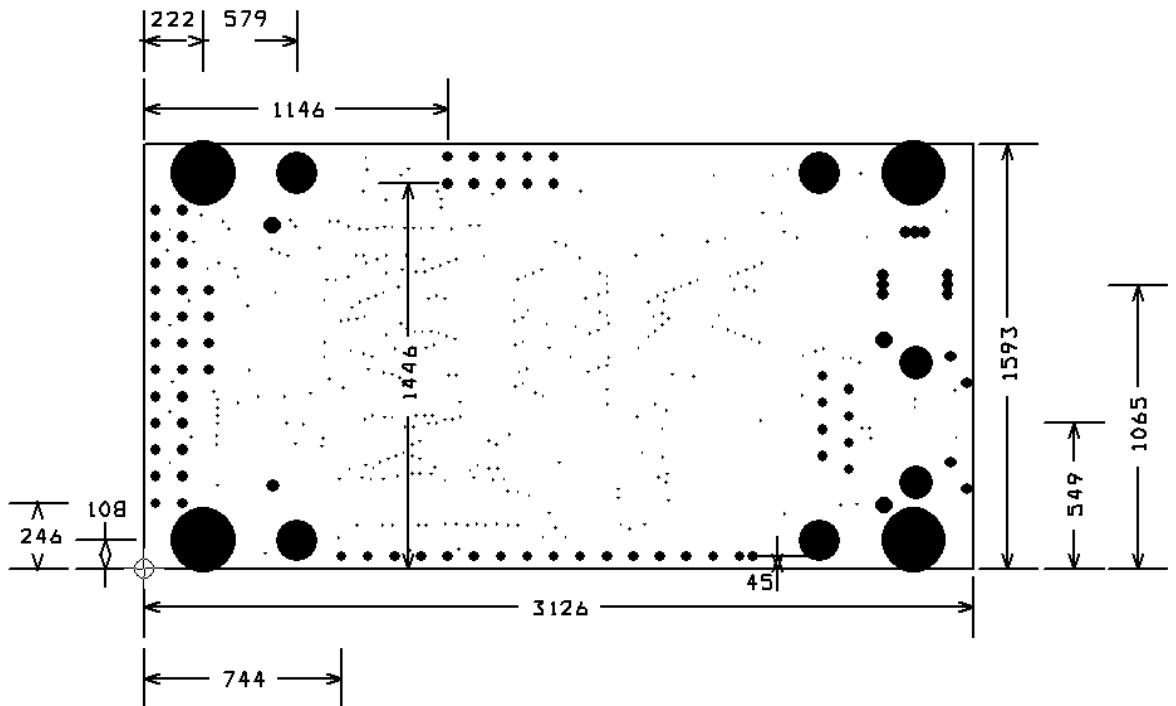*Figure 17: XG4100 board and connector dimensions*

Figure 18: XG4000 board and connector dimensions

7.3 Electrical Schematics

The latest electrical schematics can be downloaded from the X-Graph website
www.x-graph.be .

8 Custom Made Designs

8.1 Mechanical Enclosures

The X-Graph can be delivered without an enclosure as a separate module or build in one of several X-Graph enclosures (chapter 4).

Ccustom-made aluminum or plastic enclosures can be provided. Contact DELGEN for more information.

It is possible to modify existing enclosures and/or openings can be milled. Keypads can be integrated in existing or custom enclosures.

Enclosures can also be painted in any RAL color.

8.2 Keypads

The X-graph can be delivered with an analog touchscreen. The combination of a display and touchscreen provides the possibility to develop the most configurable user interface one can imagine.

Your X-Graph module also has a keypad extension connector fitting a 4x4 keypad (larger available as option). Part of our total custom design service, DELGEN can provide custom-made self-adhesive keypad which perfectly fit the selected enclosures and customer requirements.

8.3 I/O Expansion Cards

As described in chapter 5, the X-Graph module has several expansion connectors. By adding plug-in cards the functionality can be increased. DELGEN can develop and deliver any type of plug-in card with a very short turnaround.

8.4 X-Graph PCB Changes

For any order of 100pcs or higher DELGEN can make changes to the standard X-Graph pcb. We can integrate extra I/O functions, remove not necessary functions, add or remove connectors ... And we can adapt the size of the pcb to fit your enclosure perfectly.

8.5 Software Development

8.5.1 Use X-Graph with Dynamic C

Program development for the Rabbit processor on the X-Graph module is possible with all available Rabbit development tools. This includes the Z-World Dynamic C compiler and Softools WinIDE C Compiler.

Registered X-Graph users will receive the necessary specific X-Graph DC libraries required to support the additional hardware features. DELGEN is working continuously on new and improved libraries. Registered users will receive these libraries for free for an unlimited time. Please check the 'X-Graph and Dynamic C' manual.

8.5.2 xgConsole & xgBASIC

The X-Graph module is delivered with the xgConsole/xgBASIC firmware pre-installed. This firmware supports medium-level commands to control most hardware including the graphic display on the X-Graph module. You can use the RS232C and Ethernet ports as a terminal window.

With the xgConsole there is no need to purchase a C compiler or to spend hundreds of hours of 'C' development time.

8.5.3 Custom Made GUI

If you feel uncomfortable with Dynamic C and/or do not have the necessary resources to development software, DELGEN can develop the GUI and all support software for your application. Just contact (custom@xgraph.be) us and add a complete software requirement specification, so we can send you a quote.

DELGEN has many years experience with embedded applications and software development. We also know perfectly the capabilities of the Rabbit processor and our X-Graph module. So we should be the best informed people to develop software for your X-Graph based applications.

Warranty

DELGEN warrants that the product delivered hereunder shall conform to the applicable DELGEN datasheet or mutually agreed upon specifications and shall be free from defects in material and workmanship under normal use and service for a period of 1 year from the applicable date of invoice. Products which are "samples", "design verification units", and/or "prototypes" are sold "AS IS," "WITH ALL FAULTS," and without a warranty.

If, during such warranty period, (1) DELGEN is notified promptly in writing upon discovery of any defect in the goods, including a detailed description of such defect; (2) such goods are returned to DELGEN, DDP DELGEN's facility accompanied by DELGEN's Returned Material Authorization form; and (3) DELGEN's examination of such goods discloses to DELGEN's satisfaction that such goods are defective and such defects are not caused by accident, abuse, misuse, neglect, alteration, improper installation, repair, improper testing, or use contrary to any instructions issued by DELGEN, DELGEN shall (at its sole option) either repair, replace, or credit Buyer the purchase price of such goods.

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Change List

1.0

Initial release