X-MAX-1: the world's smallest PC

The MAX module X-MAX-1 contains a complete PC with 100-MHz 486-CPU and memory on a module no bigger than a matchbox. The numerous on-board functions are led out through two or three 40-pole plug connectors:

Connector A (= Outside world) provides some standard interfaces and basic functions. Connector B (= Bus) interfaces with the X-Bus, and Connector C (= Control) is optional, essentially intended for graphics, keyboard and the two PCMCIA-Slots. Special hardware configurations can also be provided from certain quantities upwards.

A version with on-board 10-Base T Ethernet connection, up to 32 MByte RAM and 8 MByte flash will be available shortly. All other interfaces are identical.

- o 486 CPU with 100 MHz and 8 kByte Cache (33, 66 or 100 MHz)
- o 16 MByte RAM (2, 4, 8 or 16 MByte) <1>
- o 4 MByte Flash (0.5, 1, 2 or 4 MByte) <1,2>
- o Keyboard connection for XT (AT keyboard is emulated)
- o LCD graphics interface up to 640x480 <3>
- o PCMCIA controller for 2 PC cards <3,4>
- o Parallel-Port EPP (LPT1 or LPT2) <4>
- o RS-232 (COM1 or COM2) <5>
- o iRDA-Interface (infra-red) <5>
- o 2 Interrupt-Controllers, 2 DMA controllers
- o Watch-dog, ext. reset, RTC, 3 x 16-bit timer
- o Connections for battery and dig. loudspeaker
- o Voltage monitor A for NMI, voltage monitor B for reset
- o On-board LED with ext. connection
- o Various digital inputs and outputs
- o Ext. interrupt inputs
- o Serial debug interface
- o X-Bus connection with multi-processor capability
- o Measures only 29 x 58 x 10 mm
- <1> Version with 64 MByte and 8 MByte flash under preparation
- <2> On-board flash can be used as a flash-file system
- <3> Optionally available without graphics and PCMCIA interface
- <4> PCMCIA-Slot B and parallel port cannot be used simultaneously
- <5> Serial interface can be used as RS-232 or iRDA



The software of the MAX-PC

The X-MAX-1 module is a complete PC. All on-board interfaces conform to the standard PC architecture, unless otherwise stated. It can therefore safely be assumed that a program developed on a PC under one of the customary PC operating systems will also run without modifications on the "MAX-PC". Nonetheless, a test is advisable, e.g. using the evaluation boards available from SORCUS. The performance corresponds to that of a 100-MHz 486 PC.

Each X-MAX-1 module is supplied with SORCUS's own realtime multi-tasking OsX operating system. Alternatively. a BIOS can also be pre-installed, from which all customary PC operating systems, such as DOS, Windows 3.x, 95, 98, Windows NT, Embedded NT, Windows CE, QNX or Linux can be started. All operating systems have their specific memory requirements, which will depend on the integrated drivers and of course on the size of the application programs involved. Examples for minimal memory requirements are specified in an Application Note.

Developing your own programs

This is done using the same development environments customarily found on PCs. Libraries for the module's SORCUS-specific functions are supplied as standard. There is also an option for using the MAX-PC in stand-alone mode. For this purpose, too, programs can be developed on an(other) PC. They are then download into the on-board RAM or flash via one of the MAX-PC's interfaces. This also applies for programs running under the realtime multi-tasking OsX operating system, which are like wise developed like PC programs. The programs created are loaded as .EXE files from a host computer onto the X-MAX-1 module, and installed as tasks there.

Booting the system:

2 phases must be distinguished here: Phase H (hardware boot) and Phase S (software boot).

Phase H: the on-board flash is empty (blank) or incorrectly programmed.

To ensure that after a reset the CPU does not fetch the firs commands from the on-board flash, the BOOT pin at Connector A must be set to log. 1. This means that booting can be run using a memory card in PCMCIA Slot A. For this purpose, two preconditions must be met:

1) The X-MAX-1 module must be provided with a PCMCIA controller.

2) A memory card with a boot program must be inserted in PCMCIA Slot A.

If no PCMCIA Slot A is provided, and you nevertheless want to boot in Phase H, then an X-Bus interface must be provided on the carrier board card onto which the X-MAX-1 module is plugged. A ROM or flash containing the actual boot program must be directly connected to this X-Bus interface. The NOPCA pin at this X-Bus interface and the BOOT pin at Connector A must both be set to log. 1. The X-Bus interface will then switch to the externally connected ROM, irrespective of whether PCMCIA-Slot A is provided or not.

Boot from	PCMCIA-Slot A	Pin BOOT	Pin NOPCA (at X Bus interface)
	provided	(at Connector A)	(at X-Dus Interface)
On-board Flash	yes	n.c. or 0	n.c. or 0
PCMCIA-Slot A	yes	1	n.c. or 0
Ext. ROM	yes	1	1
On-board Flash	no	n.c. or 0	n.c. or 0
Ext. ROM	no	1	1

n.c.: = not connected

Phase S: the on-board flash contains a boot program, in which a decision is made on how the further boot operation is to proceed.

Normally, after a reset, the system starts from the on-board flash (BOOT pin at Connector A unconnected or at log. 0) and starts Phase S. Here, it then loads the desired operating system likewise from the on-board flash or from an external medium, e.g. from a hard disk in the PCMCIA slot or at an IDE interface, from a floppy, etc.

The execution of the boot operation in Phase S can be influenced by a variety of mechanisms, e.g. by the program in the on-board flash, by entries in the on-board serial EEPROM, by whether a card is inserted in PCMCIA Slot A, etc.

The hardware of the MAX-PC

The CPU

The MAX-PC can be delivered with the AMD-CPU SC400 with graphics and PCMCIA controllers or with the SC410 without these two controllers. In both cases, the CPU involved is a 486 type, without an arithmetical coprocessor, with 8 kByte cache. Both CPUs are available in 3 speed variants: 33 MHz, 66 MHz and 100 MHz. The external CPU clock pulse is 33 MHz at maximum, but can be reduced in steps down as far as 2 MHz by the software in order to reduce power consumption. The internal clock pulse, too, (max. 100 MHz) can be set using the software. It can be switched over at any time during operation.

Memory

The MAX-PC contains 4 different types of memory:

- o DRAM (dyn. RAM)
- o Flash-ROM
- o Serial EEPROM (SPI)
- o CMOS-RAM in the RTC, bufferable with an external battery

The on-board DRAM can be provided in the following size variants: 2 MByte, 4 MByte, 8 MByte and 16 MByte. 32 and 64 MByte options are under preparation. Here, too, the size of the memory can be customized from a certain quantity of units upwards.



The on-board flash ROM variants currently available are 512 kByte, 1 MByte, 2 MByte and 4 MByte. A version with 8 MByte flash is under preparation. Via an external X-Bus module, the flash-ROM memory can at present be expanded by 32, 64 or 128 MByte for each X-Bus module. The limitation to 64 MByte entailed by the processor's addressing space does not constitute a restriction for a flash file system, for example. More than one flash module can be plugged on, too. The SORCUS flash-file system administers the flash memory like one or more hard disk drives.

A serial EEPROM (SPI-Bus) can at present be up to 16 kByte in size. It contains configuration data for the module. It can be accessed both by the on-board CPU and via the X-Bus.

The CMOS-RAM is, as is customary with PCs, incorporated in the RTC. It is 114 bytes in size. Its use corresponds to that in a PC. Like the RTC as well, it can be buffered by an external battery.

Serial interfaces

The MAX-PC contains two serial interfaces, one of which is 16550-compatible. It can be configured as COM1 or COM2, and operated as an RS-232 or infra-red interface. Both interfaces can be provided simultaneously in one system; the user can switch over between them at any time using the software.

The RS-232 drivers (3x) and receivers (5x) are provided on the MAX-PC. The max. baudrate programmable is 115.2 kBaud. The interface also senses whether a remote station is connected. If no signal is being received, into goes to a power-down state. In order to save current, it can be switched off completely using the software.

As an infra-red interface it supplies the signals for direct connection of an infra-red transmitter/receiver. The baudrate can likewise be programmed here up to max. 115.2 kBit/s or in DMA mode fixed at 1.152 MBit/s. The second serial interface is very simple, and merely provided as a debug interface. It consists only of a transmit/receive line with logic levels. The level converters, e.g. for RS-232 or RS-485, must be provided externally.

The parallel interface

This can be used as LPT1 or LPT2 in 3 modes of operation: first of all in the customary mode as a printer interface (as with the PC/AT), then 8-bit bidirectional (as in PS/2 systems) and finally as an Enhanced Parallel Port (EPP).

Simultaneous use of the parallel interface and the PCMCIA-Slot B is not possible.

Graphics interface

This provides for direct connection of an LCD display with up to 8-bit data. It supports Single-Scan and Dual-Scan Monochrome LCDs and Color STN-Displays. The interface is software-compatible with CGA, MDA and HGA text and graphics modes. Typical resolutions, for example, are 640x480, 480x320, 320x240 with up to 16 gray levels or colors. Drivers for special displays and different resolutions can be created on request. We also offer solutions for displays featuring a touch-screen. Inquiries are welcomed.

Keyboard interface

The MAX-PC provides a direct connection for an XT keyboard. An interface can be emulated for connecting an AT keyboard. The interface provided by the microcontroller for a matrix keyboard is not available on the MAX-PC.

Interrupt and DMA controllers

The use of interrupts is largely identical to that in the PC/AT architecture, or can be correspondingly configured. Four interrupts can be connected to the X-Bus. They can additionally be multiplied by means of interrupt-sharing. Each of them can be connected to one of the MAX-PC's 15 interrupt inputs. Another interrupt is connected to the MAX-PC's mailbox register, and is triggered if another X-Bus master writes something into the mailbox register. Two further interrupts are connected to external inputs at Connector A.

The DMA controllers likewise conform to the PC/AT architecture. One channel (programmable to 8 or 16 bits) is connected to the X-Bus. Others can be used for the on-board peripherals, for example.

It should be noted that the limitation on the specified number of interrupt and DMA channels on the X-Bus relates only to the X-MAX-1 module. In multi-processor systems with several of these modules, each of them possesses this number independently of the others.

Voltage monitoring, watch-dog, NMI

In contrast to a standard PC, the MAX-PC possesses expanded safety features, specifically for industrial applications. The 3.3V supply voltage is monitored with two voltage thresholds. If the supply voltage drops below the upper threshold, an NMI (Non-Maskable Interrupt) is requested. This gives the CPU time to start an emergency program. If the supply voltage also drops below the lower threshold, a hardware reset will be released.

The on-board watch-dog timer can be activated through the software. It must then be retriggered within 200 ms. If this is not done, an NMI will also be requested.

RTC, timer

The Real Time Clock (RTC) conforms to the standard PC architecture, and is compatible with the MC146818A with 114 bytes of user RAM. The interrupt output is connected to IRQ-8. The RTC can be buffered using an external battery.

The 3 timers, too, are PC-compatible, though the input frequency is 0.3 % lower than with a standard PC. Channel 0 has interrupt capability, and is connected to IRQ0; Channel 1 can be used as a software timer. The output of Channel 2 is available at Pin SPKR (loudspeaker output). In addition, Channel 2, in contrast to a standard PC, has interrupt capability. The software can be used to connect it to any of the MAX-PC's 15 interrupts.

PCMCIA slots A and B

The MAX-PC is provided with a standard controller for PCMCIA cards, which is 82365-compatible, with expansions for up to 5 memory windows and 2 I/O windows for each PCMCIA-Slot. DMA is not supported. Both slots support power control, auto power-down, if no card is inserted, and automatic detection if a card is inserted. Some signals for the PCMCIA slots are led out directly (at Connector C), others via the X-Bus. For this reason, an X-Bus chip and the buffers/switches for hot-plugging are required on the carrier board into which the MAX-PC is plugged.

Various digital inputs/outputs

The MAX-PC puts some digital inputs and outputs at the user's disposal. In addition, there are severa others ones, available only if other functions are not required and have been deactivated (using the software), if the system is reprogrammed in the factory or if different components have been provided. The inputs and outputs can be tabulated as follows:

Pin name	Function
SPKR	Loudspeaker output resp. Timer Channel 2 output
PIRQ6	Interrupt input
HOST	Interrupt input, digital input/output, used for the serial debug interface
LEDint	Output of the on-board LED
GPIOCS0	Input/output

Some functions preclude the simultaneous use of certain other functions. In some cases users can switch over using the software, others have to be reprogrammed in the factory.

When the parallel port is being used, then PCMCIA-Slot B is no longer available. When neither the parallel port nor PCMCIA-Slot B is in use, the pins can be utilized as digital inputs/outputs.

If the X-Bus connection is not required, then another 25 pins are available as digital inputs/outputs. They can be reprogrammed individually in the factory. Each of them can be programmed as a digital input, output or as a bidirectional input/output. Inputs can also be given interrupt capability. In addition, digital functions, such as counters, SSI or async. serial interfaces, pulse-width-modulated outputs, another parallel port, etc. can be implemented in the on-board CPLD's.

Functions you give up	Signals you get	What has to be done?	
PCMCIA-Slot A	4 I/O	Configuration by software	
PCMCIA-Slot B	3 I/O	Configuration by software	
Parallel port and PCMCIA-Slot B	12 I/O, 8 Outputs	Configuration by software	
	20 I/O	Reprogram the CPLD's in the factory	
RS-232 and iRDA	5 interrupts	Configuration by software	
Debug interface	1 interrupt, 1 output	Configuration by software	
X-Bus	25 I/O and interrupts	Reprogram the CPLD's in the factory	

Power consumption

The X-Bus and all modules work with 3.3 V as their supply voltage. But +/- 12 V are also carried on the X-Bus. This option is required only when a module actually needs these voltage. The power consumption will depend on a number of factors. It will be influenced by the software-settable clock frequency of the CPU, by the devices activated on the module (the graphics controller can be switched off, for instance), and also by the software currently being run.

Power Management

The CPU can assume the following operating modes: Hyper-Speed, High-Speed, Temporary Low-Speed, Standby, Suspend, Critical Suspend.

The X-Bus

The X-Bus is a synchronous 8-, 16- or 32-bit-wide bus with an active bus termination. In the case of the X-MAX-1 module, it is running at 33 MHz and is 16 bits wide. The bus has plug-and-play and multi-processor capabilities. After power-up or after a system reset, each module first receives a slot number. This is determined automatically, and can lie between 0 and 255 (8 bits). In the subsequent initialization phase, first of all an initialization master is determined (if more than one bus master is present) and then each module is configured. Each module now, for example, is assigned one or more memory and/or I/O address ranges, which are entered as what are called base addresses in the configuration area of each module. These ranges can basically be any size desired. They are used for controlling each module's actual functions. In addition, all module also have what is called an information area, containing everything which the module concerned wants and can. In particular, these data are used during the configuration phase.

Virtual Interface Lines (VILs)

Virtual Interface Lines can link X-Bus modules with each other over any desired number of lines. The MAX-PC utilizes this, fore example, by receiving 4 interrupts over VILs. Each module can request an interrupt via a VIL; more than one module can also share the same VIL, and thus share an interrupt (interrupt-sharing). The X-Bus DMA channel (DMA-Request and DMA-Acknowledge) of the MAX-PC is also handled via VILs, as is master arbitration.

Multi-processor systems

The X-Bus enables several CPU modules or bus masters to work on the same bus. In principle, the number of masters can be as large as the maximum permitted number of modules. Due to the architecture of the X-MAX-1 module, however, the number of bus masters is restricted here at present to 4. Note that each bus master can access all other modules. In the MAX-PC and in all I/O and PC peripheral modules, care has been taken to ensure that more than one CPU module can also access the same module. An intelligent piece of software called module device drivers makes sure that no conflicts arise.



Communication between bus masters

For this purpose, each bus master, i.e. each X-MAX-1 module as well, possesses a 16-bit mailbox register in its configuration area. Another bus master can write a message into this mailbox, which triggers an interrupt.

A faster option for communication, particularly when amounts of data are involved, is obtained when the system also incorporates a RAM memory module. Then two masters can also communicate with each other by this means. First, they allocate an area in the RAM for interchanging data. If one of the masters has provided data for the other there, it informs it by writing a message into the latter's mailbox.

Both communication options are provided for in the libraries supplied by SORCUS.

The address ranges of X-Bus and X-MAX-1 (all figures in bytes)

Address range	Max. size for X-Bus	Max. size with X-MAX-1	On-board X-MAX-1	X-MAX-1 as an X-Bus peripheral
Memory	4GB+ per master	64M per master	216M	-
I/O	64K+ per master	64K per master	64K	-
Configuration	64K per module	64K per module	256	256
Info	32M per module	32M per module	216K	216K

In the "Max. size for X-Bus" column, the maximum addressing range of the X-Bus is specified. The "+" sign here signifies the following: on the X-Bus an option is provided for individual modules to be addressed by only one or by more than one bus master. Each module knows who is currently bus master. When a bus access operation is performed, each module checks whether the current bus master has access permission. If this is the case, the system checks whether the bus address falls in one of the areas which has been specified by one of the modules configured base addresses. Only when this is also the case will the module react. Thus provision is made for an expansion of the addressable memory and I/O spaces, by the 8 bits which identify the current bus master. This means, for example,

that on one bus more than one module can occupy the same I/O address. Each of these module, however, is assigned to a different bus master.

In the case of the X-MAX-1 module, this option for master tracking is not provided, nor is it necessary, because a second bus master, e.g. another X-MAX-1 module, has access only to the configuration and information spaces of the X-MAX-1 module, but not to the latter's on-board devices (see the "X-MAX-1 as X-Bus peripheral" column).

The "Max. size with X-MAX-1" column specifies the actual addressing range of this module. A part of this is already occupied by on-board memory or peripherals. The CPU of the X-MAX-1 will execute an (external) X-Bus access operation only of the address concerned does not relate to the on-board memory or the on-board peripherals. If an on-board device is provided, but has been deactivated by the software, e.g. the serial interface, an X-Bus access operation will be performed.

Testability of the X-MAX-1 module's hardware

The module can be tested in its entirely using JTAG, both in regard to the CPU and to all other devices. It is through the JTAG pins TMS, TCK, TDO and TDI at Connector B that the on-board CPLDs are programmed in the factory. A second JTAG connection at Connector C, via which the CPU can be tested, must first be activated using a pull-up resistor at the JTAG pin. This causes some pins of Connector C to alter their functions, and become a second JTAG port.

Hardware expansions

Since the MAX-PC possesses an X-Bus connection, it can (like any other PC) be expanded by plugging in cards or modules. When the on-board peripherals are disabled, e.g. COM1, then the system will automatically access the addresses involved via the X-Bus. Practically all customary PC peripheral functions are provided on modules resp. are under preparation, e.g.:

General PC peripherals, communication

- o Color graphics up to 1024x768, CRT and LCD connection (VGA-comp.)
- o Sound-Blaster-compatible module
- o IDE controller
- o Floppy interface
- o ISDN interface
- o 56K-Modem
- o 2 serial interfaces
- o 4 serial interfaces
- o Ethernet with 10-BaseT connection
- o Ethernet with 100-BaseTX (10/100 MBit)
- o FireWire IEEE-1394
- o CAN interface
- o PROFIBUS-Interface

Memory expansions

- o RAM 32 MByte (stackable)
- o Flash 32 MByte (stackable)

Process peripherals, instrumentation and control

- o Analog inputs, 20 channels, 12-bit resolution
- o Analog inputs, 4 channels, 16 Bit res., el. isolated
- o Analog outputs, 4 channels, 12 Bit res., el. isolated
- o Analog outputs, 4 channels, 16 Bit res., el. isolated
- o Relay outputs, 8 relays
- o Digital inputs/outputs, 38 channels
- o Digital inputs, 20 channels, opto-isdated
- o Digital outputs, 20 channels, opto-isdated
- o 3-channel counter and incremental encoder interf.(el. isolated)

Typical applications for X-MAX-1 and MAX modules









