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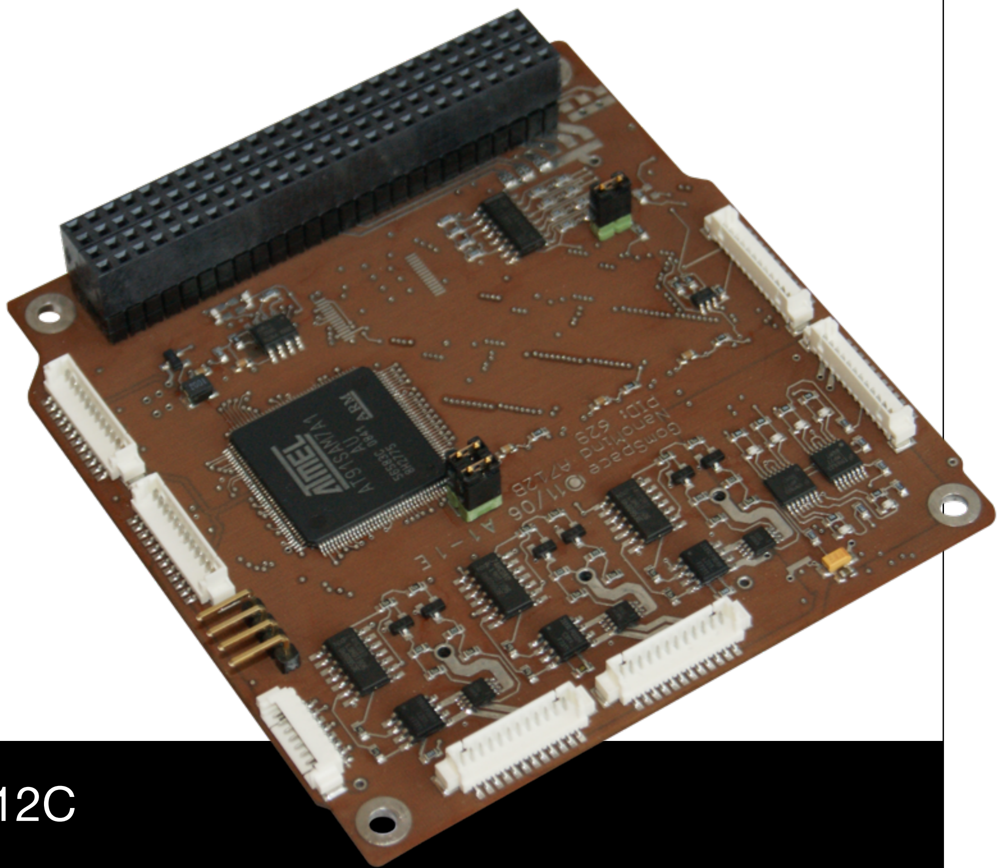


NanoMind A712C
Datasheet

On-board Computer System for mission critical
space applications with limited resources

NanoMind A712C

Feature Overview

- High-performance 32-bit ARM7 RISC CPU
- Compatible with FreeRTOS and eCos realtime operating systems
- Extensive software library for FreeRTOS
- Clock speed: 8-40 MHz
- 2MB Static RAM
- 4MB Data Storage (Flash Memory)
- 4MB Code Storage (Flash Memory)
- 2GB MicroSD card support
- 104-pin CubeSatKit bus connector
- CAN bus interface
- I^2C interface
- USART interface
- RTC - real time clock w/backup power keeps time 30-60 minutes without external power
- On-board temperature sensors
- Attitude stabilization system:
    - 3-Axis magnetoresistive sensor
    - 3 PWM bidirectional output 3.3-5V/±3A
    - Interface to 6-analog inputs (e.g. sunsensors)
    - SPI interface to e.g. gyroscopes
- Power monitor/ power-on reset.
- 3.3V single supply voltage.
- Temperature tolerance -40 to 85 °C.
- PCB: Space grade Glass/Polyamide IPC 6012C cl. 3/A
- Dimensions: 96mm x 90mm x 10mm.
- Mass: 50-55g (depending on configuration)

Applications

- CubeSat satellites
- Nano satellites

Compatibility

- GomSpace products
- CubeSatKit products
- Innovative Solutions in Space products
- Clyde-Space products

Flight Heritage

- Confirmed operational state on spacecraft launched on ESA Vega maiden flight 13/2-2012.
- The technology and design are derived from with heritage in such satellites projects as ESA's SSETI-Express, AAUSAT- II and Baumanetz.

Functional Description

General Overview

The NanoMind on-board computer is designed as an efficient system for space applications with limited resources, such as e.g. for Cubesat or nano-satellite missions. In addition to a fully capable computer system it provides a 3-Axis magnetometer to sense the Earth's magnetic field and coil-drivers that can be used to implement attitude control based on magnetic sensing and actuation. Its main interface to other subsystems are a CAN bus and a I^2C bus.

Microcontroller

The computer is based on the ARM7TDMI embedded processor. This processor has a high-performance 32-bit RISC architecture with a high-density 16-bit instruction set and very low power consumption.

CAN Bus Interface

One of the main interfaces of the NanoMind to communicate with other subsystem hardware is a CAN bus interface. The Controller Area Network (CAN) is a serial communications protocol that supports distributed real-time control with a very level of security. The maximum bus speed is 1Mbits/s.

The NanoMind uses the SN65HVD230 as a CAN transceiver. Designed for operation in harsh environments, this device features cross-wire protection, loss-of-ground and over-voltage protection, over-temperature protection, as well as wide common mode range. This device provides different modes of operation: high-speed, slope control, and low-power modes.

I²C Interface

NanoMind has an I²C bus supporting bidirectional data transfer between masters and slaves, multi-master bus, arbitration between simultaneously transmitting masters without corruption of serial data on the bus. Serial clock synchronization allows devices with different bit rates to communicate via one serial bus and and is used as a handshake mechanism to suspend and resume serial transfer.

The I²C bus provides a high-speed of 400kbit/s, with a transmit hardware buffer of 68 bytes and a receive hardware buffer of 68 bytes (packets can be longer than buffer size).

3-Axis Magnetometer

The NanoMind includes a 3-Axis magnetometer to sense the Earth's magnetic field, the HMC5843 from Honeywell. The device is based in the Honeywell's Anisotropic Magnetoresistive (AMR) technology. The sensor features precision in-axis sensitivity and linearity, and its solid-state construction with very low cross-axis sensitivity designed to measure both direction and magnitude of Earth's magnetic field, from 10 micro-gauss to 4 gauss.

The magnetometer interfaces to the MCU via a dedicated I²C bus using a software driver included in the software library.

3-PWM Bidirectional Output

The NanoMind has 3 bidirectional outputs from 3 H-bridge drivers designed to be controlled by a PWM output from the microcontroller. The main purpose of these bidirectional outputs are to be used for external magnetorquers to implement attitude control. The drivers are fully compatible to the GomSpace NanoPower solar panel products.

Analog Input

The NanoMind provides an analog interface to connect six photodiodes to measure the incident sun light. The interface is fully compatible to the GomSpace NanoPower solar panel products.

Software

The system is prepared for operation with the FreeRTOS realtime operating system and a software framework is included to allow a swift start-up of the on-board software development. The software package includes an Eclipse based development library, library with device drivers, and a tool for debugging & software upload.

Feature Overview

Feature	A712C
ARM7 8-40MHz RISC CPU	●
2 MB SRAM	●
4MB parallel FLASH memory for code storage	●
4MB parallel FLASH memory for code and data storage	●
MicroSD card socket	●
I²C interface	●
CAN interface	o
Serial diagnostics interface with USB adapter	●
3 PWM outputs with bi-directional H-bridge drivers	●
6 analogue photo-diode amplifiers connected to AD-converters	●
SPI interface (for NanoPower Solar 100 panels with gyroscopes)	●
USART interface	●
2 on-board temperature sensors	●

● : Included feature
o : Optional feature (may be omitted)

Contents of the box

Contents of the box from left to right:

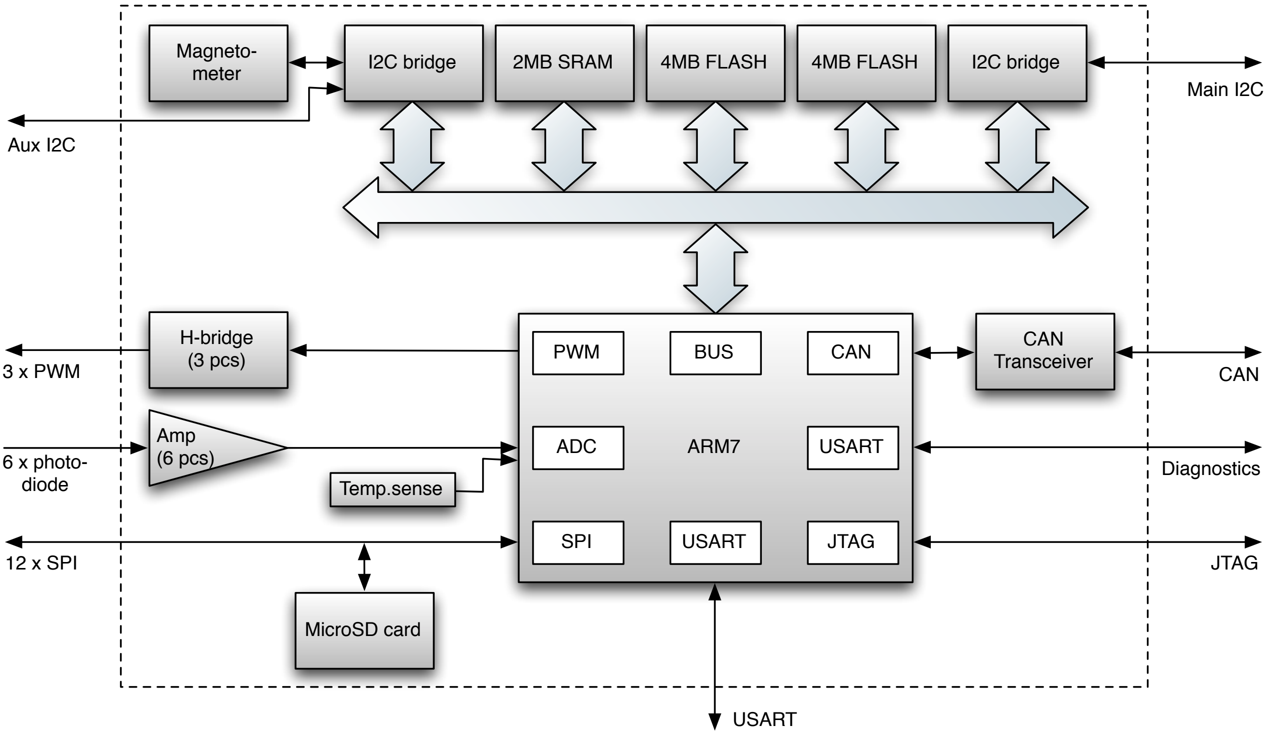
1. NanoMind A712C
2. Diagnostics interface
3. USB cable

General Characteristics

Parameter	Condition	Min	Typ	Max	Unit
VCC	Supply voltage	3.08	3.30	3.40	V
Reset Voltage			3.06		V
Current Consumption, 3.3V	Executing from RAM: 40MHz nominal 8MHz Additional current consumption: Erasing FLASH Writing to FLASH Executing from FLASH (e.g. at startup) Magnetometer on CAN bus		 70.0 37.0 8.9 5.1 3.0 5.3 10.0	 89.0 48.0 11.0 6.0 17.0	 mA
Clock Frequency		8	40	40	MHz
Operating temperature		-40		60	°C
PWM output - Supply voltage - Voltage output - Current output - Frequency - Resolution	 Maximum per channel AND total for all	 3.3 -5	 153 8	 5 5 3 1M	 V V A Hz bit
Photo-diode input - Input current - Resolution	 Current resulting in saturated measurement Analog to digital conversion		 10	 1.67	 mA bit
Magnetometer - Field range - Measurement time - Resolution - SNR		 -4	 10 7 70	 4	 gauss ms mG dB
I^2C - Voltage - Bit-rate		 0	 337	 3.3 400	 V kbps

Block Diagram

A block diagram of the system and its interfaces is provided on the figure below:

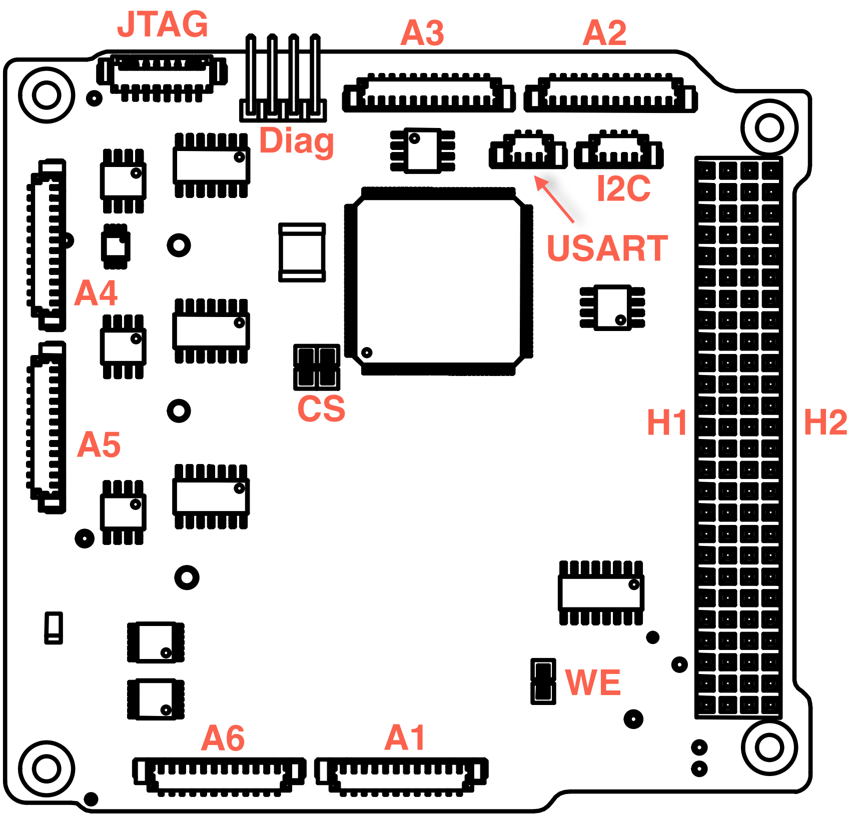


Connections

The NanoMind A712X is equipped with the following connectors:

- **H1+H2**: 104 pin CubeSatKit connector (SAMTEC ESQ-126-49-G-D or compatible)
- **A1-A6**: Signals for external photo-diodes, gyros, temp.sensor and magnetorquers. The interface is fully compatible with the GomSpace NanoPower Solar Panel products
- **WE**: Jumper to protect the code storage flash memory
- **Diag**: Diagnostics input module
- **USART**: extra USART interface
- **I2C**: Access to the I²C interface used by the magnetometer
- **JTAG**: Programming and debugging interface

The drawing on the right shows the connection on the top-side of the circuit board.



Pinout for A1-6 :
1. PWM B (only available in connector A4, A5 & A6)
2. PWM A (only available in connector A4, A5 & A6)
3. GND
4. Vgyro (option sheet dependent)
5. Not SPI chip select 1
6. SPI MOSI
7. AGND (analogue ground, reference pin 5)
8. Photo-diode analog input
9. SPI SCLK
10. SPI MISO
11. Vcc (option sheet dependent)
12. SPI chip select 2

Connector type is Molex PicoBlade (tm) 1.25mm pitch male connectors (part: 53398-1271).

Pinout for Diag:
1. GND (black wire on diag interface!! Left-most pin on drawing on previous page)
2. Vcc 3.3V supply input (*Do not use this when powered from the stack connector*)
3. RX (USART0 input 3.3V 8N1 500kbps)
4. TX (USART0 output 3.3V 8N1 500kbps)

Pinout for USART:
1. RX (USART1 input 3.3V 8N1 500kbps)
2. TX (USART1 output 3.3V 8N1 500kbps)
3. GND

Connector type is Molex PicoBlade (tm) 1.25mm pitch male connectors (part: 53398-0371).

Pinout for I2C:
1. SCL
2. SDA
3. VCC
4. GND

Connector type is Molex PicoBlade (tm) 1.25mm pitch male connectors (part: 53398-0471).

Pinout for JTAG:
1. TDO
2. TCK
3. TMS
4. TDI
5. RST (not used)
6. RST (not used)
7. VCC
8. GND

Connector type is Molex PicoBlade (tm) 1.25mm pitch male connectors (part: 53261-0871).

Pinout for WE:

Apply jumper to enable writing on FLASH0

Pinout for CS:

Default position routes chip select 0 to FLASH0 and chip select 1 to FLASH1. If needed, the jumpers can be rotated 90 degrees to route chip select 0 to FLASH1 and chip select 1 to FLASH0.

Stack Connector

The following table shows the pinout for the CubeSat Kit Connector H1 and H2. Pins with red dots are optional (to be agreed upon time of order placement). Some pins are shown multiple times as they can be configured to either of multiple connections (see product option sheet).

Pin#	Mnemonic	Description	Opt
H1-1	CANL	CAN Low	•
H1-3	CANH	CAN High	•
H1-41	I2C-SDA	I2C serial data	
H1-43	I2C-SCL	I2C serial clock	
H1-47	Vpwm	Alternative supply for PWM up to 5V	•
H1-48	VCC	3.3V supply	•
H1-49	Vpwm	Alternative supply for PWM up to 5V	•
H1-50	VCC	3.3V supply	•
H1-51	Vpwm	Alternative supply for PWM up to 5V	•
H1-52	VCC	3.3V supply	•
H2-27	VCC	3.3V supply	•
H2-28	VCC	3.3V supply	•
H2-29	GND	Power ground	
H2-30	GND	Power ground	

SPI Channels

The NanoMind has two SPI chip-selects on each side panel. When using the GomSpace NanoPower Solar P100U side panels, the SPI chip select on pin 5 is used for a Gyro and the chip select on pin 12 for an LM70 temperature sensor. Furthermore, an SPI channel is used for the SD-Card interface. Five of the side panel connectors support two SPI chip selects (gyro and temperature) but connector A1 only supports one channel (side panel temperature). The following table lists the chip select allocations for the different panel connectors and the optional memory.

Connector	PIN 12	PIN 5
A1	CS2	N/A (Reserved)
A2	CS4	CS3
A3	CS6	CS5
A4	CS9	CS8
A5	CS11	CS10
A6	CS13	CS12
SD-Card	15	

Diagnostics Interface

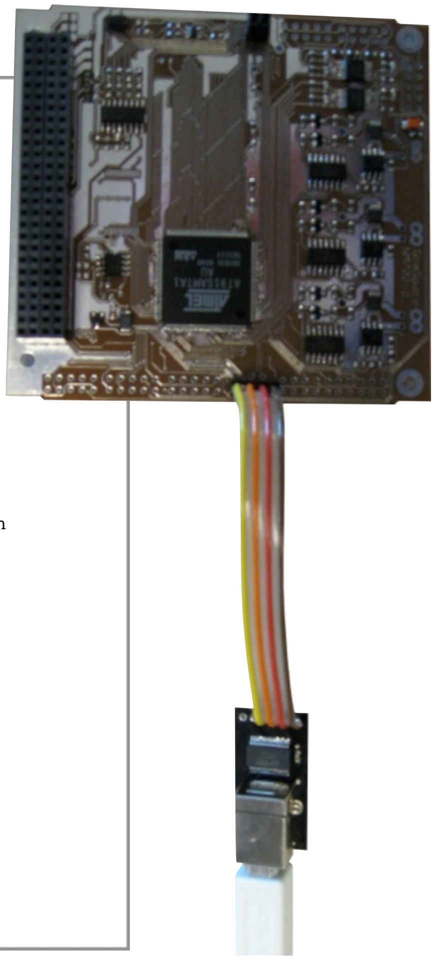
The NanoMind computer is equipped with a diagnostics interface enabling software upload to the on-board code storage and interaction with the computer via a simple console-like debugging screen. The interface consists of a logic-level RS232 connection which is converted to USB via an external adapter which is supplied with the computer. The USB connection is capable of powering the NanoMind so no external power supply is needed to start testing and uploading software. The interface runs at "500000 baud 8N1" RS232 emulation via USB using a FTDI device driver so using a terminal program connected to the virtual COM port the following start-up screen should appear a few seconds after connecting the diagnostics interface to the NanoMind computer.

Connecting the Diagnostics Interface

The diagnostics interface must be connected as described on page 5. Make sure that the brown wire is connected to GND. Then insert the USB cable. The diagnostics interface supplies 3.3V to the board so no other supply is needed and no other supply should be connected at the same time. The supply wire on the diagnostics interface is red and can be removed if it is desired to supply the board via another supply source. Do not try to supply the board from both the diagnostics interface and another supply at the same time!

```
GomSpace built-in shell (gosh)
Enter 'help' for a list of built-in commands.

# help
adc                 ADC commands
append              UFFS append data to file
buffer              Show buffer table
buffree             Buffers free
cam                 CAM subsystem
cat                 UFFS show contents of file
chksum              UFFS CRC32 checksum file
clear               Clear screen
com                 COM subsystem
conn                Show connection table
cpu                 CPU commands
debug               Toggle CSP debug levels ON/OFF
df                  UFFS disk free
echo                Display a line of text
eps                 EPS subsystem
help                Show this help and command description
hexdump             UFFS Hexdump file
history             Show command history
i2c                 I2C commands
ifc                 Show interfaces
log                 LOG subsystem
ls                  UFFS list files
mag                 Magnetometer commands
memfree             Memory free
mkdir               UFFS create directory
mkfs                UFFS format file system
obc                 OBC subsystem
param               Parameter commands
ping                Ping subsystem
ps                  List tasks
pwm                 PWM commands
rdping              Ping subsystem with RDP
rdpopt              Set RDP options
reboot              Reboot subsystem
```



Available Software Libraries

GomSpace has developed an extensive set of libraries for the NanoMind computer ranging from simple drivers to advanced attitude control algorithms. The table below shows a list of included libraries in the standard product.

Name	Description	Availability
FreeRTOS Operating System	The standard software is written to use the FreeRTOS micro-kernel. This includes full task-control, semaphores, interrupt handling and assembler startup code. *Documentation: FreeRTOS.org official API.*	Included as source and binary.
GomSpace Driver Library	The Driver library includes the basic Atmel-drivers with some extensions such as Queued RX/TX and DMA access for improved performance. (A full list of drivers can be found on the next page) *Documentation: Inline IDE + Doxygen HTML*	Included as source and binary.
NewLib C-Library	The tool-chain provided with the product includes the NewLib C-library. This gives access to standard C-functionality like, memcpy, printf, and math-functions. *Documentation: NewLib official homepage*	Included as source and binary.
Cubesat Space Protocol, Network Library + API for sub-systems.	All GomSpace products use the CSP protocol on either I2C bus or RS232/Kiss for communication. The network library will give you extensive and transparent control of GomSpace subsystems though a high-level API. For example to get housekeeping from the EPS, just call “eps_get_hk()”. No need to worry about I2C protocol and data-formatting. *Documentation: Inline IDE + Doxygen HTML* *Open source documentation:* *http://code.google.com/p/cubesat-space-protocol/*	Included as source and binary.

GomSpace is planning to release additional software packages specifically developed for the NanoMind A7XXX system including a high-level Command and Datahandling Software framework and an Attitude Determination and Control Software Framework. Check the GomSpace homepage for availability and pricing[1].

[1] First products to be announced in April 2011

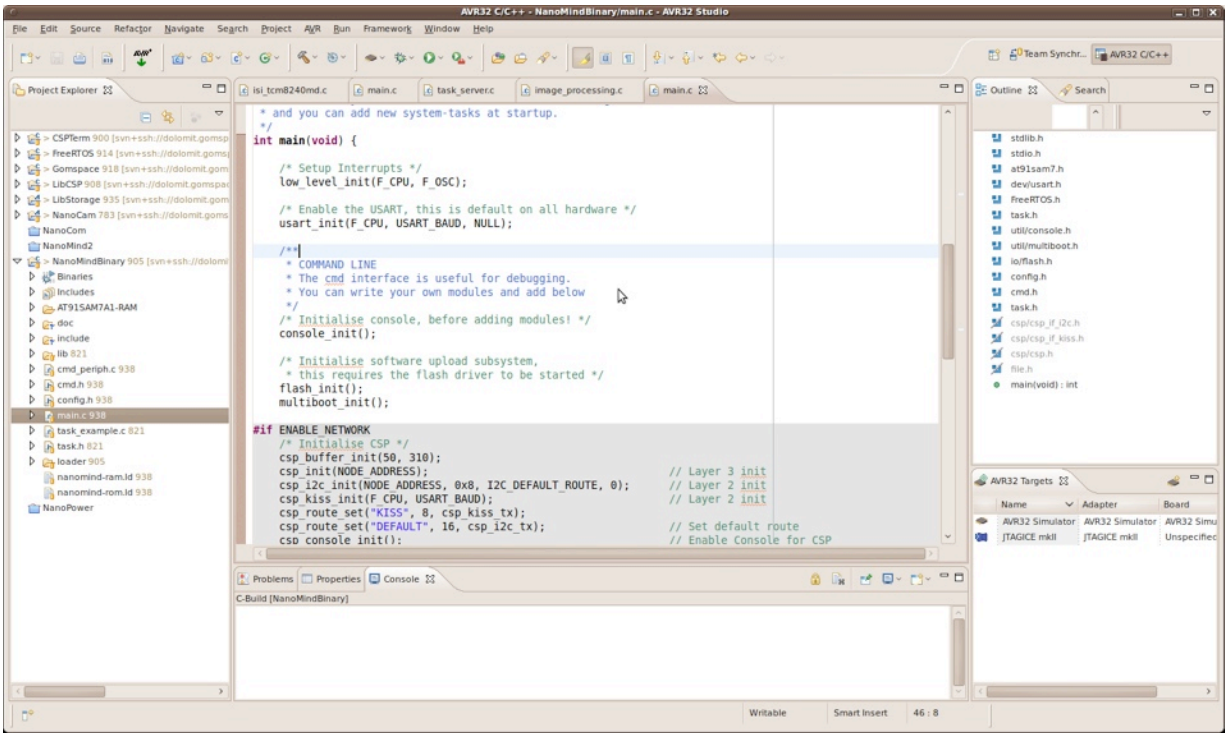
List of included drivers

The Driver Library includes the following drivers:

Peripheral	Comment	Availability
I^2C	Fully integrated, Interrupt driven driver, support for simultaneous use of both on-board I2C channel for sensors and I2C channel for sub-system communication.	Included as source and binary.
SPI	Full support of up to 16 chip-select lines and DMA transfer for SD-card up to 10 Mbit	Included as source and binary.
USART	DMA based driver for high speeds and low CPU utilization. (the printf function by default uses the USART driver)	Included as source and binary.
ADC	Simple driver which returns 8-touple of all channels.	Included as source and binary.
FLASH	Supports writing to on-board flash for firmware uploads.	Included as source and binary.
Magnetometer	Supports read-out of converted magnetometer data.	Included as source and binary.
PWM	Directly controls the external magnetic-torquers	Included as source and binary.
AIC	Driver for the Advanced Interrupt Controller	Included as source and binary.

Integrated Development Environment

Together with the NanoMind Computer, the debug-interface and the software libraries, a full Eclipse-based development IDE is included. The software can be imported into any eclipse workspace using the included project file and compiled directly from the IDE. All system header files are included for full code-indexing and function-completion. Eclipse provides inline documentation of all GomSpace library functions, which is also available in HTML format.

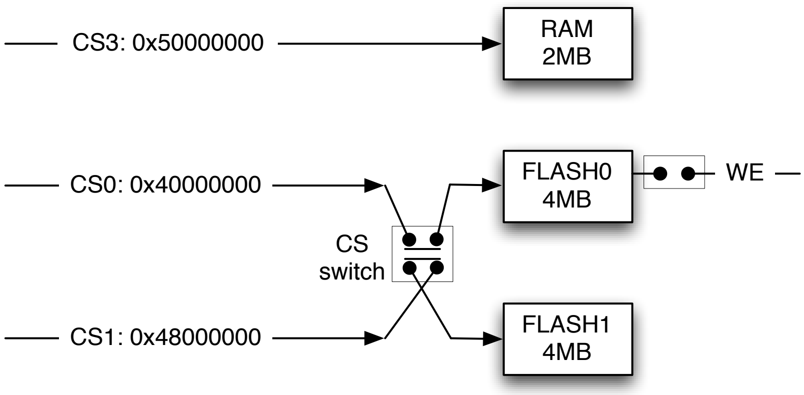


The source-code of the pre-programmed firmware is included, ready to extend with new functions, tasks and drivers for your own equipment and sub-systems. An extended guide is provided in the “NanoMind: Getting Started” document.

The IDE is operating system independent, and runs on Mac, Windows and Linux. However the recommended and fully supported platform by GomSpace is Linux.

Memory Layout

The general memory layout is shown in the figure below.



RAM is connected to chip select 3 which is mapped to address 0x50000000 spanning 2MB.
FLASH1 (User/Data storage) is default connected to CS1 mapped to address 0x48000000.
FLASH0 (Read-Only, ROM) is default connected to CS0 mapped to address 0x40000000.

Both FLASH chips are the Atmel AT49BV320DT, and internal block layout can be obtained from the datasheet from Atmel.

The CS switch allows swapping the connection of chips select 0 and 1 making it possible to boot from FLASH1 in case something unintended has happened to the bootstrap in FLASH0. As default FLASH0 cannot be reprogrammed as its "write enable" pin is not connected. Programming of FLASH0 requires insertion of a jumper. **Caution:** Neither CS switch nor the WE jumper may be changed when power is on.

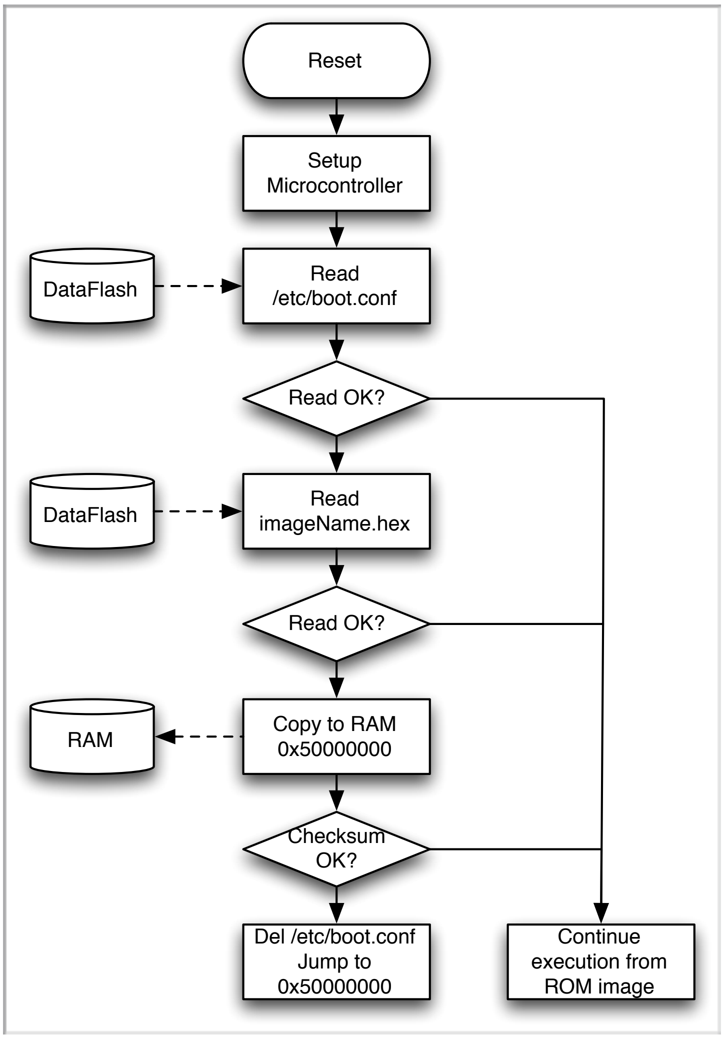
Boot sequence

When the system is powered up and the reset signal is de-asserted by the reset controller, the computer starts execution from address 0x0 which is mapped to 0x40000000 on CS0, which means the instruction on address 0x0 in FLASH0 is the first instruction to be fetched.

After a system reset, the ROM image sets up the memory controller, and stack pointer. It then calls the c-function *low_level_init()* in boot.c. This function initializes the PLL to increase the speed of the processor from 8 MHz to 40 MHz and sets up the AIC (Advanced Interrupt Controller), it also copies the .data section from ROM to RAM and clears the .bss section. After calling *low_level_init()* the *main()* function is called using a long jump.

When the main-routine starts, it initializes the UART and the CSP network stack. This ensures communication is possible at an early stage of the boot process. Then it starts several tasks that are default in the ROM image.

- Console Task: Enables commanding the NanoMind OBC using the serial port.
- Server Task: Enables the CSP protocol using serial port or I2C.
- USART RX Task: Helper task for the DMA USART driver, needed to be able to run 500.000 baud
- Init Task: Initializes filesystem, mounts devices and runs the boot sequence shown below.



After starting the tasks, the scheduler will enter the idle state if no processing is required from any of the tasks. The idle task will make the CPU sleep in order to save power.

Loading and image to RAM

During the boot sequence, the init task will check the filesystem and search for a boot configuration file. If this exists it will look for the specified image-file and copy it to ram and check the checksum. If all goes well the image is executed from RAM, if at any point an error occurs during this process the default ROM image continues to execute. Before executing a loaded software image, the boot configuration is deleted. This is a safety measure to ensure the system will not enter an endless reboot-loop if the software image is invalid.

In order to have the same image startup again, the image must itself restore the boot configuration file using the *obc_boot_conf()* function. **Caution:** It is important not to call this function before every part of the software is verified and all necessary tasks are up and running so it is absolutely certain that the boot-up sequence does not cause a crash as this will put the system into an endless reboot-loop which cannot be detected by the boot-loader.

Operation and Handling

The NanoMind system employs components based on CMOS and therefore requires anti-static handling precautions to be observed. Do not touch or handle the product without proper grounding!

Customization Options

As GomSpace realizes that different applications place different requirements to a computer system, the NanoMind products present a variety of options for customization. Options to be agreed upon time of order placement include:

- All pin-connections indicated with red dots
- Different conversion factors for analogue measurements may be implemented
- Conformal coating using NASA approved CV-1152 silicone coating (at an extra cost)
- More options may be available at the customers request

Quality Assembly

GomSpace space hardware is hand-assembled in a procedure where all parts are cleaned with IPA and then soldered in an anti-static environment to “IPC-A-610 Class 3” specifications. All solder-work is done under a microscope with tin-lead 63/37 using rosin flux. All solder joints are re-checked for class 3 compliance and the PCB is finally cleaned with IPA and ready for testing.

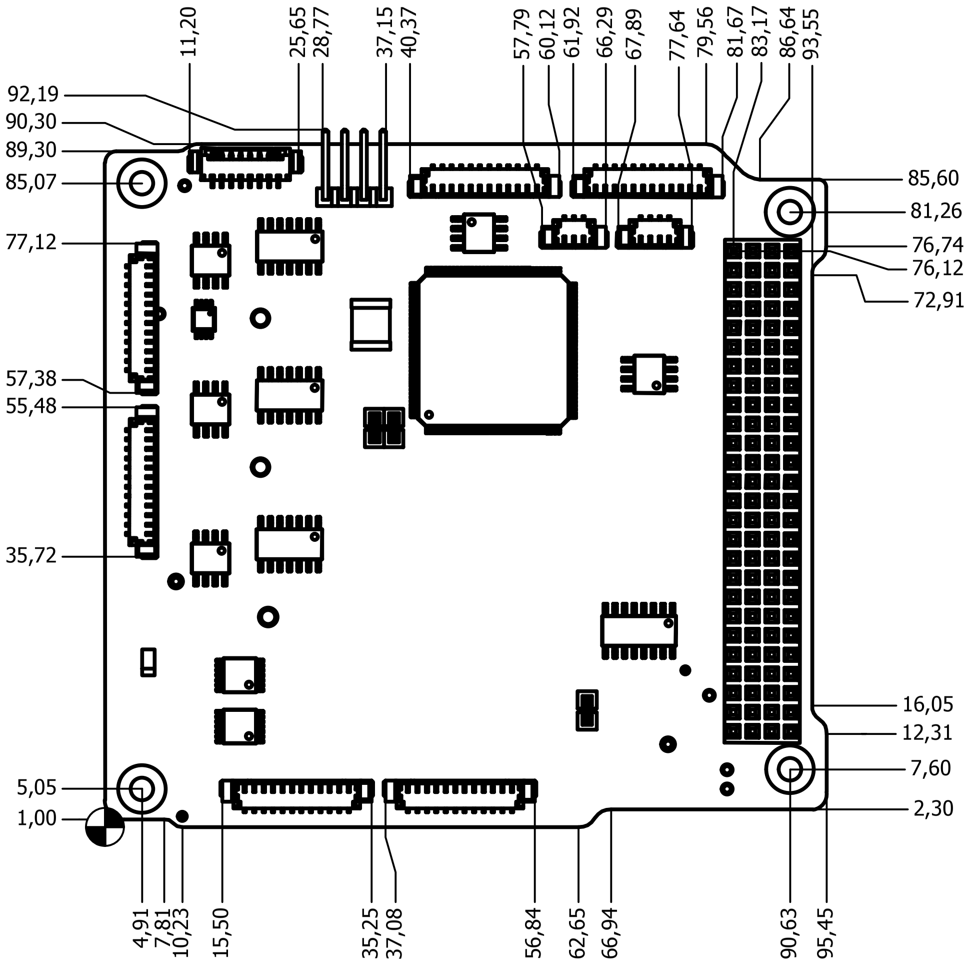
Physical Dimensions

Technical drawing on last page. Dimensions are given in mm.

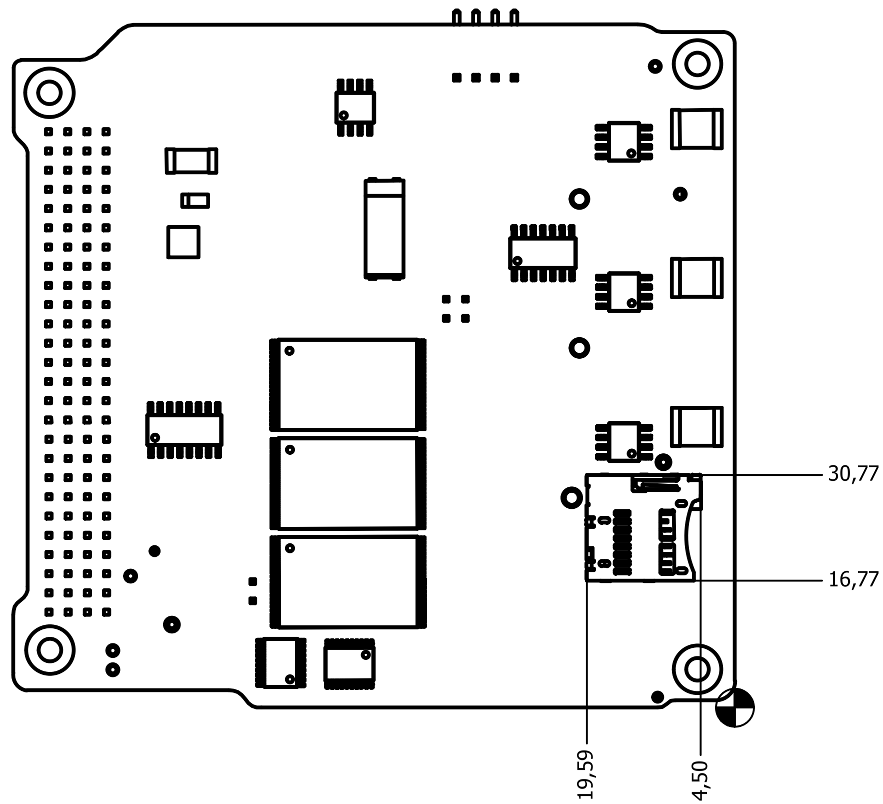
PCB-type is glass/polyamide, 6 copper layers, tin-lead fused surface, 1.6 mm thick. Mass: 50-55 gram (depending on configuration).

GomSpace ApS • Niels Jernes Vej 10 • 9220 Aalborg E • Denmark
Tel: +45 9635 6111 • Fax: +45 9635 4599 • Web: www.gomspace.com

Top (1 : 1)



Bottom (1 : 1)



Designed by	Checked by	Approved by	Date	Date	
KKL				14-10-2011	

GomSpace ApS Niels Jernes Vej 10 DK-9220 Aalborg East Denmark	NanoMind A712C	Edition 1.0	Sheet 1 / 1