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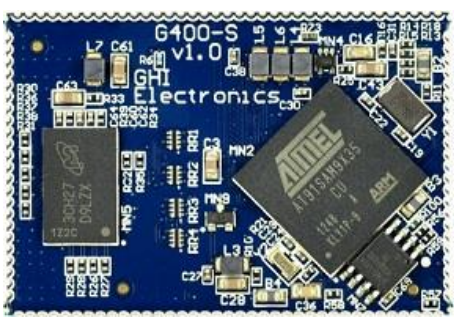
G400S and G400D SoM Datasheet



G400S SoM

G400D SoM

Where Hardware Meets Software

1 Contents

2 Introduction

The G400 SoMs are powerful, low-cost, surface-mount System on Modules (SoM) running Microsoft's .NET Micro Framework. The .NET Micro Framework enables the SoM to be programmed from Microsoft Visual Studio using a USB or serial cable. Programming in a modern managed language, such as C# or Visual Basic, allows developers to accomplish more work in less time by taking advantage of the extensive built-in libraries for networking, file systems, graphical interfaces, and more.

A simple two-layer circuit board with a power source and a few connectors can utilize the G400 SoMs to bring the latest technologies to any product. There are no additional licensing or other fees and all the development tools are provided freely.

Throughout this document, the G400S SoM and the G400D SoM will be referred to as the G400S and G400D, respectively. When only G400 is listed, the information applies to both the G400S and the G400D unless specified otherwise.

For more information and support, please see https://www.ghielectronics.com/support/netmf and the product catalog entry. For advanced electrical characteristics and details on the underlying SAM9X35 processor, please consult the processor's datasheet.

2.1 G400S vs G400D

The G400 comes in a standard and an extended format. They are not pinout compatible. The below table lists the differences.

	G400S	G400D
Package	120 pin surface-mount module (SMT)	200 pin SODIMM module
Dimensions	48.3 x 33.1 x 4.6 mm	67.6 x 31.8 x 4.1 mm
GPIO	89	102
Analog Input	12	8
Ethernet	ENC28J60 over SPI	ENC28J60 over SPI and/or Built in base 100 Ethernet PHY

2.2 Key Features

- .NET Micro Framework
- RoHS Lead Free
- 400 MHz ARM 9 Atmel SAM9X35
- 64 Mbytes available RAM
- 1.4 Mbytes available flash
- Embedded LCD controller
- 89 to 102 interrupt capable GPIO
- 2 SPI
- 1 I2C
- 6 UART
- 2 CAN
- 4 PWM
- 8 to 12 10-bit analog input
- 4-bit SD/MMC memory card interface
- Low power modes
- -40°C to +85°C operational
- RTC
- Watchdog
- Threading
- USB host
- USB client
- SQLite database
- TCP/IP with SSL
  - Full .NET socket interface
  - Ethernet
  - Wi-Fi
  - PPP
- Graphics
  - Images
  - Fonts
  - Controls
- File System
  - Full .NET file interface
  - SD cards
  - USB drives
- Native extensions
  - Runtime Loadable Procedures
  - Device register access
- Signal controls
  - Generation
  - Capture
  - Pulse measurement

2.3 Example Applications

- Vending machines
- POS Terminals
- Measurement tools and testers
- Networked sensors
- Robotics
- Central alarm system
- Smart appliances
- Industrial automation devices

3 The .NET Micro Framework

Inspired by the full .NET Framework, Microsoft developed a lightweight version called .NET Micro Framework (NETMF). NETMF focuses on the specific requirements of resource-constrained embedded systems. Development, debugging, and deployment are all conveniently performed using Microsoft's powerful Visual Studio through a standard USB or serial cable.

Programming is done in C# or Visual Basic with libraries that cover sockets, memory management with garbage collection, advanced file system support, multitasking services, and many others. In addition to supporting many standard .NET features, NETMF has additional embedded extensions supporting microcontroller specific needs such as PWM outputs and analog inputs.

3.1 GHI Electronics and NETMF

Since signing the partnership agreement with Microsoft in 2008, GHI Electronics has become the leading Microsoft partner on NETMF through its work on integrating and extending the NETMF core. GHI Electronics's NETMF products are extended with important features extending the NETMF libraries such as databases, USB Host, Wi-Fi, and native programming.

4 Pinout Tables

Many signals on the G400 are multiplexed to offer multiple functions on a single pin. Developers can decide on the pin functionality to be used through the provided libraries. Any pin with no name, function, or note must be left unconnected.

4.1 G400S Pinout

Pin	Name	Function	Pin	Name	Function	Pin	Name	Function
1	PD0		41	PB10	ADC11	81	PA23	SPI2 SCK
2	PD4		42		3.3 V	82	PA28	
3			43		VBAT	83[1]	PA31	I2C SCL
4	PA27		44	PB7	ADC8	84		3.3 V
5	PA16	SD CMD	45	PB2		85		
6	PA8	COM4 RX	46	PC0	LCD B0	86		USBC D+
7	PA3	COM2 CTS	47	PC6	LCD G1	87		USBC D-
8	PA2	COM2 RTS	48		1.8 V	88		USBH0 D+
9	PC28	LCD HS	49	PC10	LCD G5	89		USBH0 D-
10	PC23		50	PC3	LCD B3	90		USBH1 D+
11	PC5	LCD G0	51	PC15	LCD R4	91		USBH1 D-
12	PC1	LCD B1	52	PC18	PWM0	92		
13		1.8 V	53		1.0 V	93		RESET
14			54	PC13	LCD R2	94		
15			55	PC31		95		
16		GND	56		GND	96		
17	PB3		57	PC26		97		GND
18	PB1		58	PC30	LCD CLK	98		SPI1 SCK
19			59		SPI1 MOSI	99	PA19	SD D2
20	PB18		60	PB16	ADC5	100	PA21	SPI2 MISO
21	PB8	ADC9	61	PB17	ADC6	101	PA24	LDR0
22	PB14	ADC3	62	PB9	ADC10	102	PA25	MODE
23	PB12	ADC1 TOUCH YU	63	PB4		103		1.0 V
24	PB6	ADC7	64	PC4	LCD B4	104		
25	PB15	ADC4	65	PC7	LCD G2	105		
26	PB0		66	PC8	LCD G3 COM5 TX	106	PA6	COM3 RX CAN2 RD
27	PB5		67	PC14	LCD R3	107	PA17	SD CLK
28	PC2	LCD B2	68	PC16	COM6 TX	108	PA22	SPI2 MOSI
29	PC9	LCD G4 COM5 RX	69	PC20	PWM2	109	PA26	
30	PC11	LCD R0	70	PC17	COM6 RX	110[1]	PA30	I2C SDA
31	PC12	LCD R1	71	PC27	LCD VS	111	PA29	
32	PC24		72	PC29	LCD OE	112		
33	PA0	COM2 TX	73	PA5	COM3 TX CAN2 TD	113		
34	PC21	PWM3	74	PA1	COM2 RX	114	PD2	TOUCH XR
35	PC19	PWM1	75		SPI1 MISO	115	PD1	TOUCH YD
36	PC22		76	PA10	COM1 TX CAN1 TD	116	PD7	
37	PA7	COM4 TX	77	PA9	COM1 RX CAN1 RD	117	PD3	
38	PA4	LDR1	78	PA15	SD D0	118	PD5	
39	PB11	ADC0	79	PA18	SD D1	119	PD6	
40	PB13	ADC2 TOUCH XL	80	PA20	SD D3	120		GND

[1]Open drain requiring a 2.2 kΩ pull-up resistor

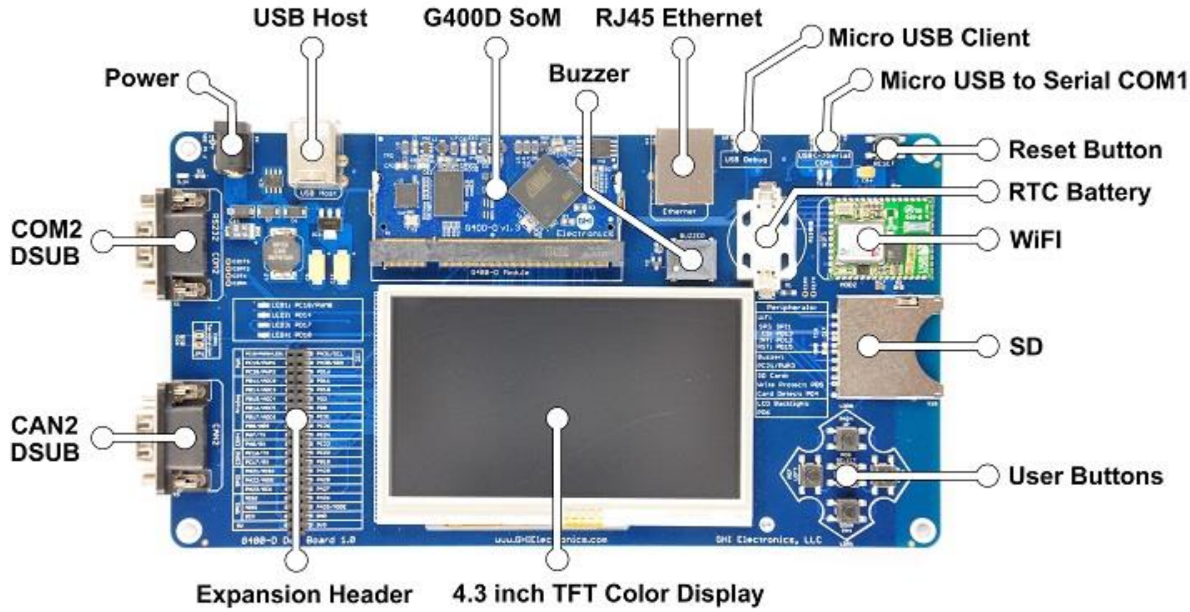
4.2 G400D Pinout

Pin	Name	Function	Pin	Name	Function	Pin	Name	Function	Pin	Name	Function
1		GND	51		GND	101	PC31		151		GND
2		ETH PHY TX-	52			102	PA0	COM2 TX	152	PC0	LCD B0
3			53			103	PA1	COM2 RX	153	PC1	LCD B1
4		ETH PHY TX+	54			104	PB12	ADC1 / TOUCH YU	154	PC2	LCD B2
5		GND	55			105	PC18	PWM0	155	PC3	LCD B3
6		ETH PHY RX-	56			106		3.3 V	156	PC4	LCD B4
7			57	PD18		107		SPI1 MISO	157	PB13	ADC2 / TOUCH XL
8		ETH PHY RX+	58	PD17		108		SPI1 MOSI	158	PB14	ADC3
9			59	PD16		109		SPI1 SCK	159	PB15	ADC4
10		ETH PHY SPEED	60		3.3 V	110	PB17	ADC6	160		3.3 V
11		ETH PHY LINK	61	PD15		111	PA4	LDR1	161	PC5	LCD G0
12			62	PD14		112	PC19	PWM1	162	PC6	LCD G1
13		GND	63	PD13		113		GND	163	PC7	LCD G2
14			64	PD12		114	PB16	ADC5	164	PC8	LCD G3 / COM5 TX
15			65		GND	115[1]	PA30	I2C SDA	165	PC9	LCD G4 / COM5 RX
16			66	PD11		116[1]	PA31	I2C SCL	166	PD1	TOUCH YD
17			67	PD10		117	PA9	COM1 RX / CAN1 RD	167	PA8	COM4 RX
18			68	PD9		118	PA10	COM1 TX / CAN1 TD	168	PC15	LCD R4
19			69	PD8		119	PC24		169		GND
20		3.3 V	70			120	PA2	COM2 RTS	170	PC10	LCD G5
21			71			121	PA3	COM2 CTS	171	PC11	LCD R0
22			72		3.3 V	122	PD7		172	PC12	LCD R1
23			73			123	PA15	SD D0	173	PC13	LCD R2
24			74			124		3.3 V	174	PC14	LCD R3
25			75			125	PA16	SD CMD	175	PA23	SPI2 CLK
26			76			126	PA17	SD CLK	176	PA21	SPI2 MISO
27		GND	77			127	PA18	SD D1	177		
28			78			128	PA19	SD D2	178	PA22	SPI2 MOSI
29			79		GND	129	PA20	SD D3	179		
30			80			130	PC21	PWM3	180		3.3 V
31			81			131		GND	181		
32		3.3 V	82			132	PC26		182		USBH1 D+
33			83			133	PC20	PWM2	183		VBAT
34			84			134	PA24	LDR0	184		USBH1 D-
35			85			135	PA25	MODE	185		GND
36			86			136	PA26		186		GND
37			87			137	PA27		187		RESET
38			88		3.3 V	138	PA28		188		USBH0 D+
39			89			139	PA29		189		
40		GND	90			140	PC16	COM6 TX	190		USBH0 D-
41		GND	91	PB8	ADC9	141	PC17	COM6 RX	191		
42			92	PD2	TOUCH XR	142		3.3 V	192		3.3 V
43			93	PC23		143	PC27	LCD VS	193		
44			94	PD0		144	PC28	LCD HS	194		USBC D+
45			95		GND	145	PC30	LCD CLK	195		
46		3.3 V	96	PB18		146	PC29	LCD OE	196		USBC D-
47			97	PB11	ADC0	147	PD3		197		
48			98	PA5	COM3 TX / CAN2 TD	148	PD4		198		GND
49			99	PA6	COM3 RX / CAN2 RD	149	PD5		199		
50			100	PC22		150	PD6		200	PA7	COM4 TX

[1]Open drain requiring a 2.2 kΩ pull-up resistor

5 Reference Design

The G400D Dev Board is an excellent starting point and reference design for anyone interested in evaluating and developing with the G400. See the product catalog entry for more information and additional resources.



6 Device Startup

The G400 is held in reset when the reset pin is low. Releasing it will begin the system startup process. It is pulled high internally.

There are four different components of the device firmware:

1. GHI Bootloader: initializes the system, updates TinyBooter when needed, and executes TinyBooter.
2. TinyBooter: executes TinyCLR, updates TinyCLR when needed, and updates the system configuration.
3. TinyCLR: loads, debugs, and executes the managed application.
4. Managed application: the program developed by the customer.

Which components get executed on startup can be control by manipulating the LDR0 and LDR1 pins. LDR0 and LDR1 are pulled high on startup.

LDR0	LDR1	Effect
Ignored	High	Execute the managed application.
High	Low	Wait in TinyBooter
Low	Low	Wait in GHI Bootloader

Additionally, the communications interface between the host PC and the G400 is selected on startup through the MODE pin, which is pulled high on startup. The USB interface is selected when MODE is high and COM1 is selected when MODE is low.

The above discussed functions of LDR0, LDR1, and MODE are only during startup. After startup, they return to the default GPIO state and are available to use as GPIO in the user application.

7 Libraries

Similar to the full .NET Framework, NETMF includes many built in libraries to help in modern application development with additional libraries to support embedded systems.

Please see https://www.ghielectronics.com/support/netmf for more information.

7.1 General Purpose Input and Output (GPIO)

GPIOs can read and write logical high and low signals. Keep the following in mind:

- They default to inputs with internal weak pull-up resistors
- They operate on 3.3 V logic levels.
- They are not 5 V tolerant.
- They have controllable pull up and pull down resistors.
- All pins are interrupt capable.
- See the processor's documentation for information on sourcing and sinking current.

7.2 Analog Input

Analog inputs can read voltages from 0 V to 3.3 V with 10-bit resolution. The built in analog circuitry uses the source voltage as a reference which can cause some noise on the analog signal. High accuracy ADCs with a dedicated reference can be added externally.

7.3 Pulse Width Modulation (PWM)

PWM is used to create a waveform with a specified frequency and duty cycle. It uses built-in hardware so no processing resources are needed to keep it running. Frequencies can range from 2 Hz to 24 MHz.

7.4 Signal Generator

Signal Generator is used to generate a waveform on any GPIO with varying frequency and duty cycle. The feature is software driven and can generate frequencies up to 200 kHz ±10%. More processing time is required for higher frequencies.

7.5 Signal Capture

Signal Capture monitors any GPIO pin and records the time from the last change. This feature is software driven and can measure frequencies up to 400 kHz ±10%. Lower frequencies have higher accuracy.

7.6 Pulse Feedback

Pulse Feedback is used for sensing capacitance on any GPIO input and measuring pulses from ultrasonic distance and other sensors. When used for sensing capacitance, a 100 pF capacitor and 1 MΩ resistor between the pad and ground are recommended.

7.7 Universal Asynchronous Receiver Transmitter (UART)

UART is a common, full duplex, communications interface. Baud rates from 2,400 to 1,500,000 are supported. Handshaking is supported on COM2 only. Data bits between 5 and 8 are supported. Stop bits of 1, 1.5, and 2 are supported. Space, mark, even, and odd parities are supported.

7.8 Serial Peripheral Interface (SPI)

SPI is a common three or four wire serial interface. The G400 can act as a SPI bus master only. The maximum supported clock is 66.6 MHz and all four SPI modes are supported. The SPI bus is designed to interface with multiple SPI slave devices. The active slave is selected by asserting the chip select line on the slave device.

SPI1 is shared internally with the flash memory on the G400. Use of a chip select with devices on this channel is required or the G400 will not function properly. The use of another SPI channel is recommended.

7.9 Inter-Integrated Circuit (I2C)

I2C is a two-wire addressable serial interface. The G400 can act as an I2C bus master only with 7-bit slave addresses. It can connect to one or more slave devices over the same connection with a maximum clock of 400 kHz. The I2C bus interface requires pull up resistors to be added on both the SCL and SDA pins, usually 2.2 kΩ.

It is possible to simulate an independent I2C bus on any two GPIO pins with the appropriate resistors though the software I2C class, but performance will be lower.

7.10 Controller Area Network (CAN)

CAN is a common interface in industrial control and the automotive industry. CAN on the G400 is compliant with the CAN 2.0B specifications. Bitrates up to 1 Mbit/s are supported. For systems with higher traffic, different message filter options are available.

7.11 1-Wire

Through 1-Wire, a master can communicate with multiple 1-Wire slaves using any GPIO.

7.12 Graphics

The G400 supports 16-bit color TFT displays up to 800x600. Displays require the horizontal sync, vertical sync, clock, enable, and the 16 color lines. The color format is 565 (5 bits for red, 6 bits for green, and 5 bits for blue). If the display has more than 16 color lines, connect the most significant color lines to the G400 and the remaining lines to ground.

While SPI displays can be utilized as well, the native TFT interface is recommended as it allows for a faster update rate.

NETMF includes support for drawing though the bitmap object. TrueType font files can be used once converted to the TinyFont format used by NETMF.

7.13 Touch Screen

The G400 supports displays with four-wire restive touch without the need for any additional hardware, though using an external controller is possible. The default touch pins can be remapped if required. Capacitive touch displays can be used through the I2C interface.

7.14 USB Host

USB host allows the use of USB mass storage devices, joysticks, keyboards, and mice. Additionally, for USB devices that do not have a standard class included, low level USB access is provided for bulk transfers. USB hubs are supported allowing multiple devices to be connected.

7.15 USB Client

The USB client interface is typically used as the G400 debug interface and for application deployment through Visual Studio. However, it is controllable and may be used to simulate other USB devices such as mice, keyboards, and Communications Device Class (CDC) interfaces using low level access instead of the debug interface.

7.16 File System

The G400 supports accessing files on SD cards and USB memory devices formatted as FAT16 or FAT32. SD cards use a true 4-bit interface. SD/SDHC/SDXC cards in full, mini, and micro formats and any USB device with mass storage class are supported. Access speeds are dependent on many different factors and can be up to 500 Kbyte/s.

7.17 Networking

The G400 supports Ethernet, Wi-Fi, and PPP through the built in LwIP stack. The full stack includes TCP, UDP, DHCP, DNS, HTTP, FTP, and others. Secure connections can be created using the built in SSL stack.

7.17.1 Ethernet

Ethernet support is available using the built-in NETMF TCP/IP and SSL stack through the on-board base-100 Ethernet PHY on the G400D and through an external ENC28J60 SPI Ethernet chip on both the G400S and the G400D.

7.17.2 Wi-Fi

Any Wi-Fi module with a built-in TCP/IP stack can be used with the G400. However, these modules are typically limited. Through the supported Redpine RS9110-N-11-22-04 and RS9110-N-11-22-05 chips, Wi-Fi is usable with the built-in NETMF TCP/IP and SSL stacks.

7.17.3 Point to Point

The Point to Point (PPP) protocol is often used for devices needing to connect to mobile networks. While typical embedded devices use the mobile modem's built-in and very limited TCP/IP stack, systems using the G400 can use these modems with the internal NETMF TCP/IP and SSL stack.

7.18 Extended Weak References

Extended Weak References are a way for managed applications to store data in non-volatile memory. This is meant to be used as a configuration store that does not change frequently where the data can be recreated if needed. There are 128 KBytes available for use.

7.19 Configuration

Access to the configuration sector of the device is provided for storage of small, infrequently changing, entries. The data will be lost if the configuration is reflashed. Space is limited and varies based on other information stored in the configuration.

7.20 Real Time Clock

The real time clock (RTC) is used to keep time while the processor is off, drawing its power from a backup battery or super capacitor providing 1.65 V to 3.6 V. The required circuitry and crystal are included.

7.21 Watchdog

Watchdog is used to reset the system if it enters an erroneous state. The G400 supports timeouts between 1 ms and 15,995 ms. Watchdog support is included through the GHI Electronics libraries replacing the built in NETMF version.

7.22 Power Control

The G400 supports entering sleep, deep sleep, and off modes in order to reduce power usage. It can consume as little as 56 mA in sleep, 27 mA in deep sleep, and 20 mA in off. It may be woken from an RTC alarm or a GPIO interrupt. Sleep pauses execution of the program. Deep sleep pauses execution of the program and shuts down many internal functions. Off shuts down all internal functions and can only be woken by the RTC alarm or a system reset. The system will be automatically reset when exiting off mode.

7.23 In-Field Update

Through In-Field Update, the G400 can update its firmware and managed application. The update can come from the network, a bus, or connected media.

7.24 SQLite Database

SQLite can be used to created databases that can be stored in memory or on a supported storage device such as a USB drive or SD card.

7.25 Direct Memory Access

Low level device registers and memory can be accessed to further configure the G400’s underlying processor. Not all functionality of the processor is available as some functions may be used or configured internally for use in NETMF.

7.26 Battery RAM

Battery-backed RAM is provided as part of the internal RTC. This memory retains its contents when the power is lost as long as there is a backup battery. There are 16 bytes of battery backed RAM available. Consult the processor's documentation for details on use.

7.27 Runtime Loadable Procedures

Similar to code loaded from a DLL, Runtime Loadable Procedures (RLP) allows a binary or ELF image to be loaded into memory and executed on the device. This is useful for advanced and critical performance scenarios. The RLP region starts at address 0xA0000000 and is 0x16FFFFC bytes in size. Your compiled images must fall completely within that range.

8 Design Considerations

8.1 Required Pins

Exposing the following pins is required in every design to enable device programming, updates, and recovery:

- LDR0
- LDR1
- Desired debug interface(s)
- MODE if required to select a debug interface
- SPI1 MISO to update TinyBooter in SDK 2015 R1 and earlier and to install the GHI Bootloader once for SDK 2016 R1 and later

8.2 Power Supply

A typical clean power source, suited for digital circuitry, is needed to power the G400. Voltages should be within at least 10% of the needed voltage. Decoupling capacitors of 0.1 µF are needed near every power pin. Additionally, a large capacitor, typically 47 µF, should be near the G400 if the power supply is more than few inches away.

Additionally, the G400 requires additional voltages beyond the typical 3.3 V to function properly. See the pinout table for details.

8.3 Crystals

The G400 includes the needed system and RTC crystals and their associated circuitry.

8.4 SPI Channels

SPI1 is shared internally with the flash memory on the G400. Use of a chip select with devices on this channel is required or the G400 will not function properly. The use of another SPI channel is recommended.

8.5 Ethernet

The built in Ethernet available on the G400D includes all needed Ethernet circuitry internally. However, an appropriate magnet and connector, like the J0011D or similar, are required.

8.6 Direct Memory Access

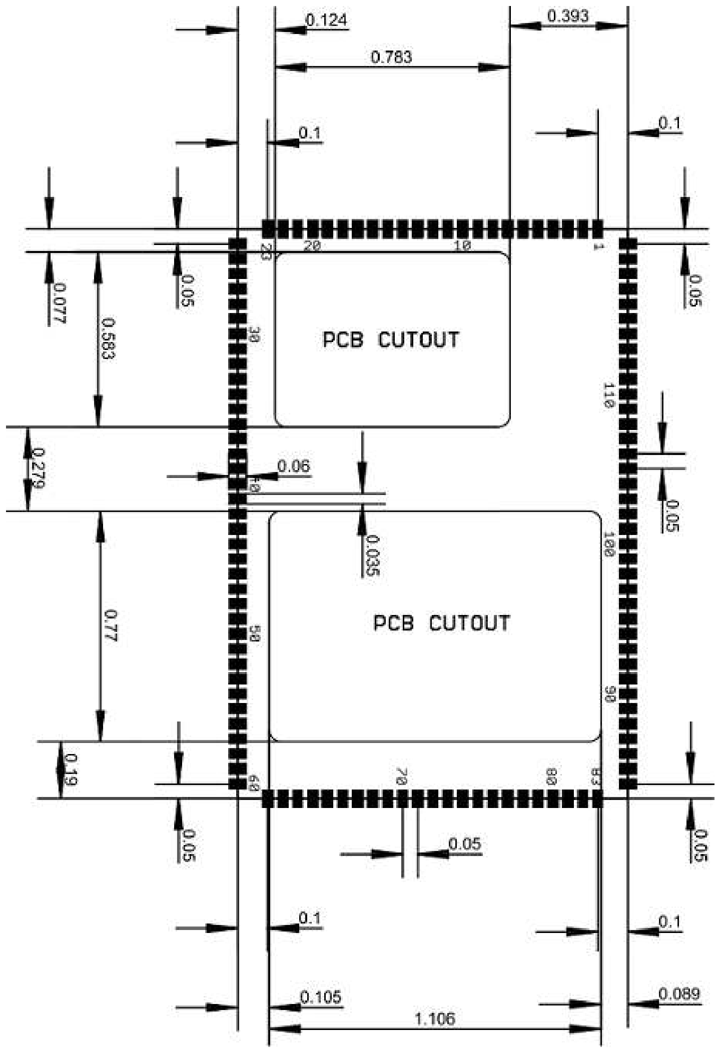
Most of the core processor's resources are used by NETMF. Some resources are permanently used, like the main system timer while others are used when specific features, like the timers for PWM, are enabled. Used resources can change from one firmware version to another so care must be taken when using these resources through RLP or other direct memory access methods.

When absolutely required, applications can use resources in conjunction with NETMF. For example, creating a special baud rate, utilizing the timer capture feature, and making use of many other features supported by the processor. Please contact GHI Electronics's consulting services to determine exactly what resources are available and if the G400 can fulfill the specific requirements.

9 Footprints

We recommend no traces or vias under the module. Dimensions are in inches.

9.1 G400S Recommended Footprint



9.2 G400D Recommended Footprint

The G400D uses a standard SODIMM 200 form factor. We recommend the use of TE Connectivity AMP Connectors's connector with part number 1565917-4.

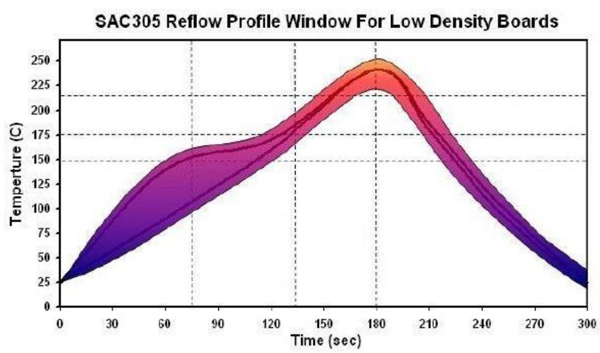
10 Soldering the G400S

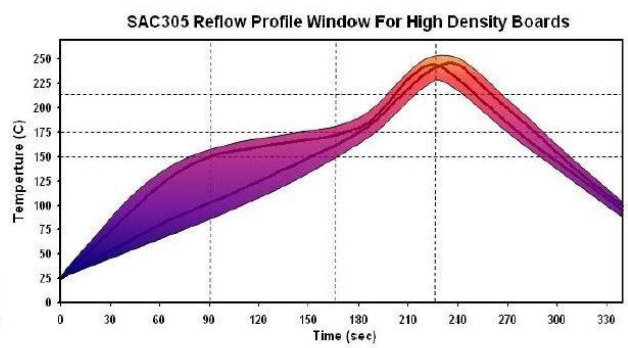
The G400S is designed to be easily machine-placed or hand-soldered. Static sensitive precautions should be taken when handling the module.

10.1 Oven Reflow

The G400S is not sealed for moisture. Baking the module before reflow is recommended and required in a humid environment. The process of reflow can damage the G400 if the temperature is too high or exposure is too long.

The lead-free reflow profile used by GHI Electronics is shown below. The profiles shown are based on SAC 305 solder (3% silver, 0.5% copper). The thermal mass of the assembled board and the sensitivity of the components on it affect the total dwell time. Differences in the two profiles are where they reach their respective peak temperatures as well as the time above liquids (TAL). The shorter profile applies to smaller assemblies, whereas the longer profile applies to larger assemblies such as back-planes or high-density boards. The process window is described by the shaded area. These profiles are only starting-points and general guidance. The particulars of an oven and the assembly will determine the final process.





	RATE OF RISE 2°C / SEC MAX	*RAMP TO 150°C (302°F)*	*PROGRESS THROUGH 150°C-175°C (302°F-347°F)*	*TO PEAK TEMP 230°C-245°C (445°F-474°F)*	*TIME ABOVE 217°C (425°F)*	*COOLDOWN ≤ 4 °C / SEC*	*PROFILE LENGTH AMBIENT TO COOL DOWN*
Short Profiles	≤ 75 Sec	30-60 Sec	45-75 Sec	30-60 Sec	45± 15 Sec	2.75-3.5 Min
Long Profiles	≤ 90 Sec	60-90 Sec	45-75 Sec	60-90 Sec	45± 15 Sec	4.5-5.0 Min

11 Legal Notice

11.1 Licensing

The G400S SoM and G400D SoM, with all their built-in software components, are licensed for commercial and non-commercial use. No additional fee or licensing is required. Software, firmware, and libraries provided for the G400S SoM and the G400D SoM are licensed to be used on the G400S SoM and the G400D SoM only.

11.2 Trademarks

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12 Revision History

Revision	Date	Change
1.1	2017-01-17	Clarified TinyBooter update pin
1.0	2015-11-12	Initial release.