MOTOROLA

C24

Hardware Interface Manual

C24 CDMA 1X Module

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Version 0.3

Table of Contents

Revision History

Version	Date	Author
0.01	17-Oct-07 Carlos Dyk, Initial Draft	
0.02	25-Dec-07 Nimrod Zarmi Parameters spec updated, Audio updated	
0.03	21-Feb-08 David Alfi Updating following fianl review	
0.1	5-Oct-08 Nimrod Zarmi Updating Regulatory approvals requirements	
0.2	11-Nov-08 Udi Hadar Update max output power to 25dBm Update VSWR to 2.5:1	
0.3	14-Nov-08 Steve Gump Update maximum allowable gain at 1900 MHz to maximum of 4.2 dBi	

1 Regulatory Requirement

The C24 module is compliant with applicable FCC and IC requirements.
The integrated system incorporating the C24 module may be subject to further regulations and standards. Motorola strongly recommends that the system integrator seeks professional advice regarding the regulations and standards that apply to their product. The Federal Communications Commission (FCC) requires application for certification of digital devices in accordance with CFR Title 47, Part 2 and Part 15. This includes Electromagnetic
Energy Exposure (EME) testing. As the C24 modem is not a standalone transceiver but is an integrated module, the C24 cannot be tested by itself for EME certification. It is, however, the integrator's responsibility to have the completed device tested for EME certification.

The C24 module is compliant to FCC and IC requirements allowing use within North America. Use in other regions may require regional "type approvals" which the manufacturer of the final product integration or reseller will be responsible for procuring. Many regional type approvals are based upon compliance to FCC and other standards that the C24 is compliant with. It is strongly recommended that professional advice be sought before placing the finished integrated product on the market to establish local approval and marking requirements.

1.1 Safety Statement and Requirements

Certain safety precautions must be observed during all phases of the operation, usage, service or repair of any cellular terminal or mobile incorporating the C24 module. The integrator is advised to consider the following general cautions in the context of their integrated system incorporating the C24 module, and to provide the end user with the applicable warnings and advice of safe operation of the equipment. Failure to comply with these precautions violates safety standards of design, manufacture and intended use of the product. Motorola assumes no liability for customer failure to comply with these precautions.

- The C24 must be operated at the voltages described in the technical documentation
- The C24 must not be mechanically nor electrically changed. Use of connectors should follow the guidance of the technical documentation
- The integrated product incorporating the C24 moduel must be evaluated for SAR under intended use conditions, and suitable text and SAR values be provided to the end user
- No wireless device can guarantee operation at all times due to network or interference conditions, A user should never rely on a wireless device as the sole means of making emergency calls
- The C24 module complies with all applicable standards and directives, this does not guarantee that the product it is integrated into complies, expert advice should be sought to identify the applicable regulations and show compliance Suitable warning statements regarding the use of RF energy in the integrated host system should be given in the end user documentation.

1.2 Antenna and Transmission Safety Precautions

User Operation

The C24 module is normally supplied without an antenna, and is compliant with SAR requirements provided the following conditions are observed.
Do not operate your unit when a person is within 8 inches (20 centimeters) of the antenna. A person or object within 8 inches (20 centimeters) of the antenna could impair call quality and may cause the phone to operate at a higher power level than necessary.

Important: The unit must be installed in a manner that provides a minimum separation distance of 20 cm or more between the antenna and persons and must not be co-located or operate in conjunction with any other antenna or transmitter to satisfy FCC RF exposure requirements for mobile transmitting devices.

Important: To comply with the FCC RF exposure limits and satisfy the categorical exclusion requirements for mobile transmitters, the requirements described in the following section, “Antenna Installation” , must be met.

Antenna Installation

- The antenna installation must provide a minimum separation distance of 20 cm from users and nearby persons and must not be co-located or operating in conjunction with any other antenna or transmitter.
- The combined cable loss and antenna gain must not exceed +5.3 dBi (800 band). The combined cable loss and antenna gain must not exceed +4.2 dBi and total system output must not exceed 2.0W EIRP in the PCS (1900) band in order to comply with the EIRP limit of 24.232 (b). OEM installers must be provided with antenna installation instruction and transmitter operating conditions for satisfying RF exposure compliance.
- For system integrations requiring higher antenna gain, or position closer than 20cm from the body, SAR compliance testing of the completed product will be required. It is strongly recommended that the system integrator seeks the advice of a suitably accredited test laboratory to develop a test plan and carry out necessary testing.

CFR 47 Part 15.19 specifies label requirements

The following text may be on the product, user's manual, or container.
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

CFR 47 Part 15.21 Information to user

The user's manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. In cases where the manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

CFR 47 Part 15.105 Information to the user

(b) For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual:

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio

frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the
user is encouraged to try to correct the interference by one or more of the following measures:
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

2 Hardware Interface Description

The following sections describe in detail the Hardware Interface requirements and operation modes of the C-Lite Module.

2.1 Operating Modes

The module should incorporate several operating modes. Each operating mode is different in the active features and interfaces.

The following table summarizes the general characteristics of the module operating modes and provides general guidelines for operation.

TABLE 1 – Module Operating Modes

Mode	Description	Features
Not Powered	VCC supply is disconnected	Module is Off. The interface signals are tri-stated.
RTC Mode	Valid VCC supply, RESET_N signal is enabled (low).	The Module interface is tri-stated. Only the internal RTC timer is active.
Idle Mode	RESET_N signal is disabled (high), CTS_N and DSR_N signals are enabled (low).	The module is fully active and ready to communicate. This is the default power-up mode.
Low power Mode	RESET_N signal is high, CTS_N signal is disabled	The module is in low power mode. The application interfaces are disabled, but it continues to monitor the network.
CSD or Data	RESET_N signal is high, TXEN_N signal is Low.	A voice or data call is in progress. When the call terminates, The Module will return to the last operating state (Idle or Sleep).

2.2 Power Supply

The Module power supply must be a single external DC voltage source of 3.0V to 4.4V.

TABLE 2 – Power supply signals

Pin (s)	Signal Name	Description
1-4	GND	Main ground connection for the module.
5-8	VCC	DC supply input for the module. V_{IN} = 3.0 V to 4.4 V $I_{MAX} \leq$ 600 mA at TX/RX

2.2.1 Power Consumption

The following table specifies typical current consumption ratings of the module in various operating modes. The current ratings refer to the overall current consumption through the VCC supply.

TABLE 3 – Current ratings (VCC = 3.6 V)

Parameter	Description	Conditions	Min	Typ	Max	Unit
I_{OFF}	RTC mode				30	uA
I_{IDLE}	Idle mode	Registered			20	mA
I_{SLEEP}	Low power mode	- SCI2 - TBR = 30 minutes **Legend** • SCI2: Paging slots every 5.12 seconds • TBR: Timer Base Registration			2.5	mA
I_{MAX}	Max TX/RX current				600	mA

2.3 Power On/Off Operation

The Module power on and off process includes two primary phases, which are indicated at the interface connector by the hardware output signals RESET_N and CTS_N.

The RESET_N signal indicates whether the module is powered on or off.
When this signal is enabled (low), the module is powered-off. When it is disabled (high), the module is powered-on.

The CTS_N signal indicates the serial communications interface (UART) status.
When this signal is high, the module serial interface is tri-stated. When it is low, the serial interface is enabled, and the module is ready to communicate.
These same conditions apply to the CTS2_N signal with respect to the second serial interface (UART2).

TABLE 4 – On-Off control signals

Pin (s)	Signal Name	Description
51	IGN	On - Off Logic level control
53	ON_N	On - Off toggle control

2.3.1 Turning the module On

When the module power supply is stable above the minimum operating level and it is powered off, it operates in RTC mode, with only the internal RTC timer active.

The C-lite consist of two HW models: basic (without charger), and charger.
The basic module will power on when the ON_N signal or IGN signal is asserted.
The ON_N and IGN signals will be active and responding only after the power supply to the module is stable at operating level.

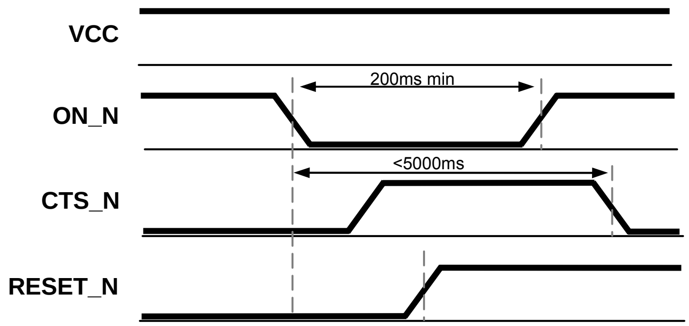
The charger module will power on when the ON_N signal or valid charger input voltage level is asserted (see “Charger Connectivity” section).
The ON_N (IGN signal is used as Charger input voltage) signal will be active and responding only after the power supply to the module is stable at operating level.

2.3.1.1 Turning on the module using ON_N

An internal pull-up resistor sets the ON_N input signal high whenever a power supply is applied to the module.

Asserting the ON_N signal low for a minimum of 200 milliseconds (0.2 seconds) will cause the module to turn-on.
The following figure illustrates the power-on process using the ON_N signal.

FIGURE 4 – ON_N power-on timings



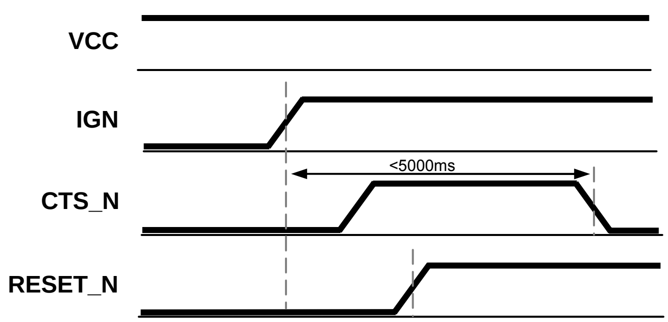
2.3.1.2 Turning on the module using IGN

This section applies only for the C-Lite standard model (without charger).

To turn on the module this signal must be set high. The IGN signal must remain high for the duration of the module's operation. The module powers down when the IGN signal is returned to its low state.

The following figure illustrates the power-on process using the IGN signal.

FIGURE 5 – IGN power-on timings



A typical IGN implementation is shortening IGN to VCC. In this method applying power to the module, shall also turn on the module simultaneously.

2.3.2 Turning the Module Off

There are several ways to turn the module off:

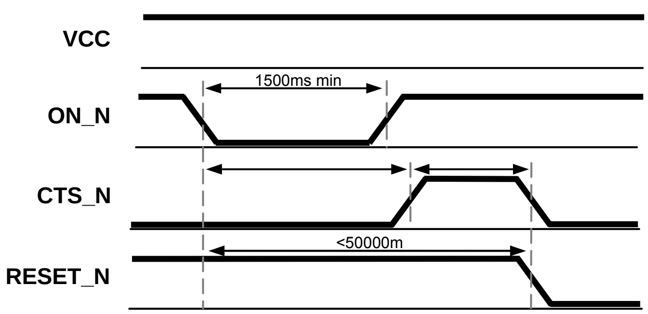
- Asserting the ON_N signal low for a minimum of 1.5 seconds.
- Setting the IGN signal low
- Low power automatic shut down
- AT command

2.3.2.1 Turning off the module using ON_N

The ON_N signal is set high through an internal pull up resistor when power is applied to the module. Asserting the ON_N signal low for a minimum of 1.5 seconds will turn the module off. This will initiate a normal power-off process, which includes disabling of all applications interfaces (UART, SIM card, audio, etc.) and closing the network connection.

The following figure illustrates the power-off timings when using the ON_N signal.

FIGURE 6 – ON_N power off timings



2.3.2.2 Turning off the module using IGN

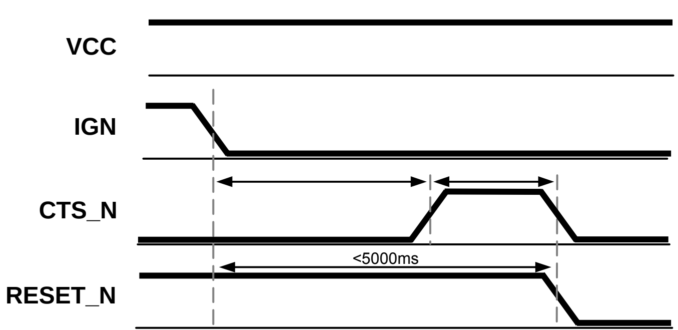
This section applies only to the C-Lite standard model (without charger).

The IGN signal may be used to power off the module only if it was also used to power it on. When the IGN signal is set low the module will turn off. This will initiate a normal power-off process, which includes disabling of all applications interfaces (UART, SIM card, audio, etc.) and closing the network connection.

The IGN signal will not power off the module before 30 seconds have elapsed since it was powered-on. This delay mechanism is implemented to protect the module from unexpected transients on the IGN line during power up.

The following figure illustrates the power-off timings when using the IGN signal.

FIGURE 7 – IGN power off timings



2.3.2.3 Turning off the module using AT+MRST

The AT+MRST command initiates a system reset operation, which powers off the module. This command emulates the ON_N signal operation for power off.

2.3.2.4 Power Loss shut down

A low power shut down occurs when the module senses the external power supply is below the minimal operating level of 3.0V. The module will respond by powering down automatically.

2.4 Low Power Mode

The module incorporates an optional low power mode, sleep mode, in which it operates in minimum functionality, and therefore draws significantly less current. In low power mode the module network connection is not lost. It continues to monitor the network constantly for any incoming calls or data.

During low power mode, all the module interface signals are inactive and are kept in their previous state, prior to activating low power mode. To save power, the module's internal clocks and circuits are shut down, and therefore serial communications is limited.

The module will not enter low power mode in any case when there is data present on the serial interface or incoming from the network or an internal system task is running. Only when processing of any external or internal system task has completed, the module will enter low power mode according to the ATS24 command settings.

2.4.1 Activating Low Power Mode

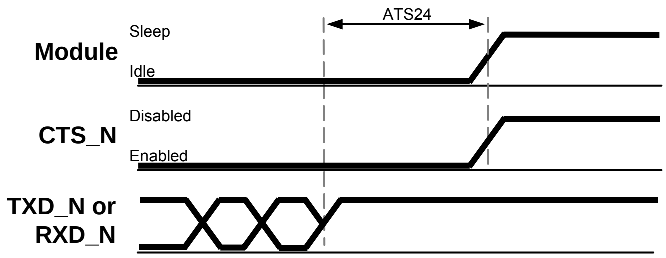
By default, the module powers on in Idle mode. In this mode the module interfaces and features are functional and the module is fully active.

Low power mode is activated by the ATS24 command. The value set by this command determines the duration of inactivity, in seconds, the module will take before switching to low power mode.
For example:

ATS24 = 1 activates low power mode within 1 second of inactivity.
ATS24 = 5 activates low power mode within 5 seconds of inactivity.
ATS24 = 0 disables low power mode (default).

The following image illustrates the ATS24 command operation:

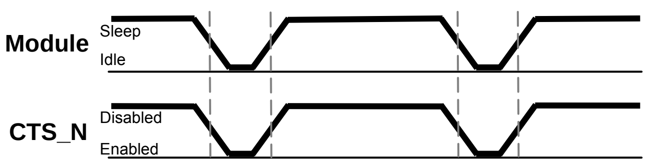
FIGURE 9 – ATS24 Operation



2.4.2 Serial Interface during Low Power Mode

During low power mode the serial interfaces are inactive.
The module wakes up periodically from low power mode to page the network for any incoming calls or data. After this short paging is completed, it returns to low power mode. During this short awake period, the serial interfaces are enabled and communications with the module is possible.
The CTS_N signal is alternately enabled and disabled synchronously with the network paging cycle. CTS_N is enabled whenever the module awakes to page the network. This indicates the serial interfaces are active.

FIGURE 10 – CTS signal during Sleep mode



The periodical enabling and disabling of the CTS_N signal during low power mode can be controlled by the AT+MSCTS command.
Setting AT+MSCTS=1 permanently disables the serial interface during low power mode, even during a network page. The CTS_N signal is disabled, and therefore the serial interfaces are blocked.

2.4.3 Terminating low power mode

Terminating the low power mode, or wake-up, is defined as the transition of the module operating state from Sleep mode to Idle mode. There are several ways to wake-up the module from low power mode, as described below.

During low power mode the module's internal clocks and circuits are disabled, in order to minimize power consumption. When terminating low power mode, and switching to Idle mode, the module requires a minimal delay time to reactivate and stabilize its internal circuits before it can respond to application data. This delay is maximum 15 milliseconds long, and is also indicated by the CTS_N signal inactive (high) state. The delay guarantees that data on the serial interface is not lost or misinterpreted.

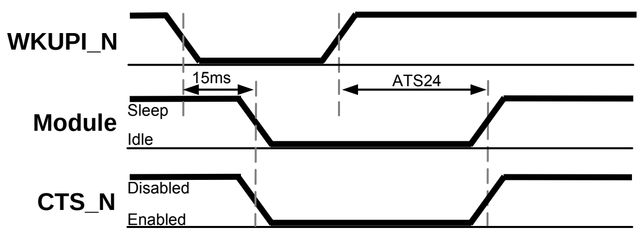
2.4.3.1 Temporary Termination of Low Power Mode

Temporary termination of low power mode occurs when the module switches from Sleep mode to Idle mode for a defined period, and then returns automatically to Sleep mode.

Using the WKUPI_N signal
The WKUPI_N signal is an active low input, which is set high by default. By asserting this signal low the application can wake-up the module from low power mode and switch to Idle mode.

The module will remain in Idle mode, awake and fully active, as long as WKUPI_N signal remains low. When this signal is set high again, the module will return to Sleep mode automatically, according to the ATS24 settings.

FIGURE 11 – WKUPI_N signal operation



The WKUPI_N signal must be used to wake up the module from low power mode if the serial interface has been disabled by the AT+MSCTS command.

Incoming Network Data
During low power mode the module continues to monitor the network for any incoming data, message or voice call.

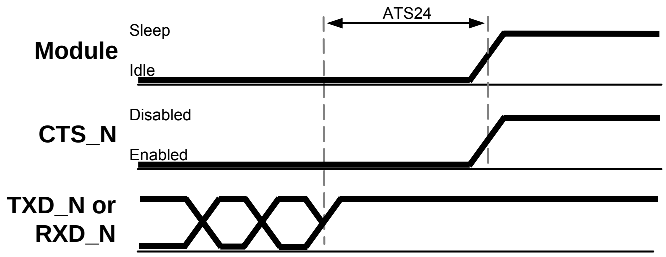
When the module receives an indication from the network that an incoming voice call, message or data is available, it automatically wakes up from low power mode to alert the application. When it wakes up to Idle mode all the interfaces are enabled.

Depending on the type of network indication and the application settings, the module may operate several methods, which are configurable by AT commands, to alert the application of the incoming data:

- Enable the WKUPO_N signal to wake-up the application from low power.
- Send data to the application over the serial interface.
- Enable the serial interface's Ring Indicator (RI_N) signal.

Data on the Serial interface
During low power mode, serial communications is limited to short periods, while the module is paging the network. When the serial interface is active, data can be exchanged between the application and the module.
The module will not return to low power mode until the serial interface transmission is completed and all the data is processed.
Only when the serial interface transfer is completed and the data is processed, The module will return to low power mode automatically, according to the ATS24 settings.

FIGURE 12 – Serial Interface data



2.4.3.2 Permanent termination of Low Power Mode

The module low power mode is enabled and disabled by the ATS24 command.
To permanently terminate the low power mode, the ATS24 = 0 command must be used. Setting ATS24 = 0 disables the currently active low power mode and switches the module to Idle mode.
The module will not return to low power mode until an ATS24 > 0 commands is set again.

2.5 Real Time Clock

The module incorporates a Real Time Clock (RTC) mechanism that performs many internal functions, one of which is keeping time and alarm operation. The RTC subsystem is embedded in the module and operates in all the different operating modes (Off, Idle, Sleep), as long as power is supplied above the minimum operating level.

The module time and date can be set by the following methods:

- Automatically retrieved from the network.
  In case the module is operated in a network that supports automatic time zone updating, it will update the RTC with the local time and date upon connection to the network. The RTC will continue to keep the time from that point.

- Using the AT+CCLK command.
  Setting the time and date manually by this AT commands overrides the automatic network update. Once the time and date are manually updated, the RTC timer will keep the time and date synchronized regardless of the module operating state.

When the power supply is disconnected from the module, the RTC timer will reset and the current time and date will be lost. On the next module power-up the time and date will need to be set again automatically or manually

2.6 Serial Interfaces

The module includes 3 completely independent serial communications interfaces, which may be used by the application for several purposes.

TABLE 5 – Serial Interfaces signals

Pin (s)	Signal Name	Description
9	RTS_N	Primary UART “Ready -To - Send” signal
11	RXD_N	Primary UART “Receive Data” signal
13	DSR_N	Primary UART “Data - Set - Ready” signal
15	CTS_N	Primary UART “Clear -To - Send” signal
17	DCD_N	Primary UART “Carrier Detect” signal
19	DTR_N	Primary UART “Data - Terminal - Ready” signal
21	TXD_N	Primary UART “Transmit Data” signal
23	RI_N	Primary UART “Ring Indicator” signal
29	RXD2	Secondary UART “Receive Data” signal
31	TXD2	Secondary UART “Transmit Data” signal
33	RTS2	Secondary UART “Ready -To - Send” signal
35	CTS2	Secondary UART “Clear -To - Send” signal
10	USB_VBUS	USB bus power
12	USB_DP	USB bus differential serial data (positive)
14	USB_DN	USB bus differential serial data (negetive)

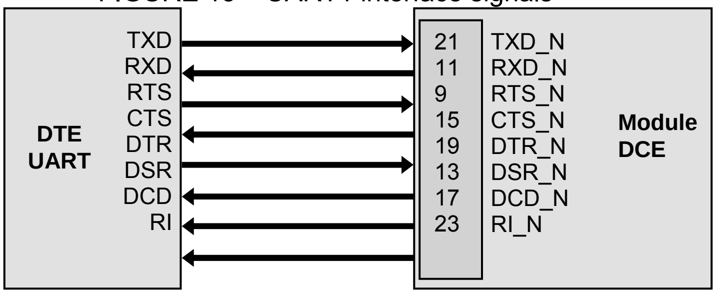
2.6.1 Primary UART (UART1)

The module’s primary UART is a standard 8-signal bus. The primary UART is used for all the communications with the module – AT commands interface, Data Calls and CSD data, programming and software upgrades.

The UART signals are active low CMOS level signals. For standard RS232 communications with a PC, an external transceiver is required.

The module is defined as a DCE device, and the user application is defined as the DTE device. These definitions apply for the UART signals naming conventions, and the direction of data flow, as described in the following figure.

FIGURE 13 – UART1 interface signals



The primary UART supports the baud rates 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200 bps.
Auto baud rate detection is not supported. Default baud rate is 1115200 bos.
All flow control handshakes are supported: hardware, software, or none.
Parity bit and Stop bit definitions are also supported.

The UART default port configuration is 8 data bits, 1 stop bit and no parity, with hardware flow control and auto baud rate detect enabled.

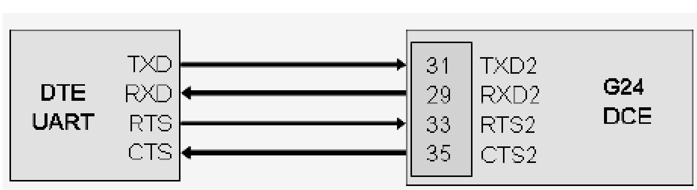
2.6.2 Secondary UART (UART2)

The module's secondary UART is a standard 4-signal bus, which only provides data and flow control signals. The secondary UART is used for all the communications with the module – AT commands interface, Data Calls and CSD data, programming and software upgrades.

The UART signals are active low CMOS level signals. For standard RS232 communications with a PC, an external transceiver is required.

The module is defined as a DCE device, and the user application is defined as the DTE device. These definitions apply for the UART signals naming conventions, and the direction of data flow, as described in the following figure.

FIGURE 14 – UART2 interface signals



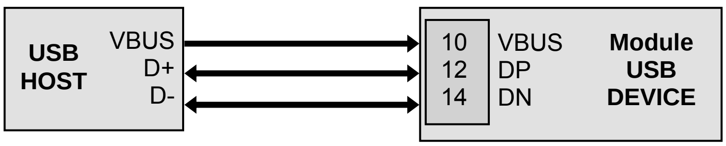
The secondary UART supports the baud rates 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200 bps.
Auto baud rate detection is not supported. Default baud rate is 115200 bps.
All flow control handshakes are supported: hardware, software, or none.
Parity bit and Stop bit definitions are also supported

2.6.3 USB Interface

The module incorporates a standard Universal Serial Bus (USB) interface.
The USB electrical interface and protocol conform to the USB 2.0 full-speed specifications. The module is defined as a USB device on the USB bus and does not support hub or host functionality.

USB may be used for standard communications with the module, as done through the UART interfaces. When USB is active, the module's low power mode cannot be operated.

FIGURE 15 – USB interface signals



2.7 Removable-User Identify Module (R-UIM) Interface

The module incorporates a standard Removable-User Identify Module (R-UIM) interface.

TABLE 6 – R-UIM interface signals

Pin	Signal Name	Description
48	UIM_PWR	Card supply voltage
44	UIM_RESET	Card reset
52	UIM_DATA	Data I/O
46	UIM_CLK	Card clock
50	UIM_CR_DET	Card detect

2.8 Audio Interface

The module supports the following audio devices:

- Two single-ended biased analog microphone inputs for use in a variety of modes.
- Two differential mono analog speaker outputs for use in a variety of modes.
- A digital serial interface using PCM coding.

TABLE 7 – Audio Interface signals

Pin (s)	Signal Name	Description
55	HDST_INT_N	Headset detection signal
57	HDST_MIC	Headset microphone signal / Differential Microphone (positive)
59	AGND	Audio Ground
61	MIC	Handset microphone signal / Differential Microphone (negative)
63	ALRT_N	Differential Loud speaker (negative)
65	ALRT_P	Differential Loud speaker (positive)
67	SPKR_N	Handset differential speaker (negative)
69	SPKR_P	Handset differential speaker (positive)
18	PCM_DIN	Digital audio receive
20	PCM_DOUT	Digital audio transmit
22	PCM_CLK	Digital audio clock
24	PCM_FS	Digital audio frame sync.

2.8.1 Handset Microphone Port

The handset microphone port is the module's power-up default active audio input for voice calls. It is located on pin 61 at the interface connector, named MIC.
It is designed as a single-ended input and should be referenced to the module analog ground.

The microphone input includes all the necessary circuitry to support a direct connection to an external microphone device. It incorporates an internal bias voltage of 1.8V through a 2.2KΩ resistor, and has an impedance of 1KΩ.

TABLE 8 – Microphone Port Specifications

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage	No load			1.58	V_{PP}
Gain	Programmable in 1 dB steps	0		31	dB
AC Input Impedance			1		KΩ
Bias voltage	R_{BIAS} = 2 KΩ $I_{BIAS} \leq$ 1 mA	1.7	1.8	1.9	V
Bias Current				1	mA

2.8.2 Headset Microphone Port

The headset microphone port is designed for use with, but not limited to, a headset audio device. It is located at pin 57 on the interface connector, named HDST_MIC.
It is designed as a single-ended input and should be referenced to the module analog ground.

The microphone input includes all the necessary circuitry to support a direct connection to a headset microphone device. It incorporates an internal bias voltage of 1.8V through a 2.2KΩ resistor, and has an impedance of 1KΩ.

TABLE 9 – Headset Microphone Port Specifications

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage	No load			1.58	V_{PP}
Gain	Programmable in 1 dB steps	0		31	dB
AC Input Impedance			1		KΩ
Bias voltage	R_{BIAS} = 2 KΩ $I_{BIAS} \leq$ 1 mA	1.7	1.8	1.9	V
Bias Current				1	mA

2.8.3 Speaker Port

The analog speaker port is the module's power-up default active output for voice calls and DTMF tones. It is located at pins 67 and 69 on the interface connector, named SPKR_N and SPKR_P respectively.
It is designed as a differential output with 32Ω impedance, but may also be used as a single-ended output referenced to the module's analog ground.

The speaker output is used for both the handset and the headset audio paths.

TABLE 10 – Speaker Port Specifications

Parameter	Conditions	Min	Typ	Max	Units
Output Voltage	No load			2	V_{PP}
Gain	Programmable in 3 dB steps Handset mode Headset mode (See table 17)	-35.8 -28.8		-14.8 -7.8	dB
AC Output Impedance			32		Ω
DC voltage			1		V
THD	32Ω load			0.15	%
Isolation	Speech, f > 4 KHz	60			dB

2.8.4 Headset Detection

The module operates by default in the basic audio mode with the handset audio path, for DTMF tones and speech, and the alert loudspeaker device, for rings and alert tones, active.

The headset path is an alternate audio path in basic mode. It is designed for, but not limited to, a personal hands-free audio device, a headset, using the headset microphone input device and the speaker output device. When this path is selected all the audio sounds are passed through to the headset path.

The HDST_INT_N signal is used to switch between handset and headset audio paths in basic audio mode. This signal is set high by default at power up. Asserting the HDST_INT_N signal low enables the headset audio path and disables the handset and alert paths. Setting this signal high will disable the headset path and enable the handset and alert audio paths.

The module supports dynamic switching between the handset and headset audio paths, during operation and call handling.

The HDST_INT_N signal does not operate in advanced audio mode. This signal's functionality is overridden by the AT+MAPATH command settings.

2.8.5 Alert Loudspeaker Port

The alert loudspeaker is the module's default power-up ringer. It is used for, but not limited to, sounding the module's alerts, melodies, and rings. It is located at pins 63 and 65 on the interface connector, named ALRT_N and ALRT_P respectively.
It is designed with an internal amplifier supplied directly from VCC, which supplies up to 0.5W to the audio device. It may also be used as a single-ended output referenced to the module's analog ground.

TABLE 11 – Alert Port Specifications

Parameter	Conditions	Min	Typ	Max	Units
Output Voltage	No load			2.8	V_{PP}
Gain	Programmable in 5dB steps	-16		12	dB
AC Output Impedance			8		Ω
DC voltage			VCC/2		V
THD	8Ω load			2	%
Isolation		45			dB

2.8.6 Digital Audio Interface

The module's digital audio interface is a serial Pulse Code Modulation (PCM) bus, which uses linear 2's compliment coding. The module is the PCM bus master, supplying the clock and sync signals to the application.

The module's digital interface is a 4 signal PCM bus, which includes a bit clock output signal for the bus timing, a frame sync output signal for audio sampling timing, and serial data input and output signals.

The digital audio interface supports Voiceband audio – Intended for speech during voice calls and for mono rings and alerts.

The PCM bus configuration is defined by the audio data format that is sounded through the digital audio path, as described in the following table.

TABLE 12 – Digital Audio modes

Audio Mode	Frame-Sync Sampling	Bit Clock	AT+CRTT tones
Voice	8 KHz	2048 kHz	
Mono tones	8 KHz	2048 kHz	

This digital voice audio format is used for speech during voice calls and for mono rings and alerts.
The PCM bus signal's configuration for voiceband audio is:

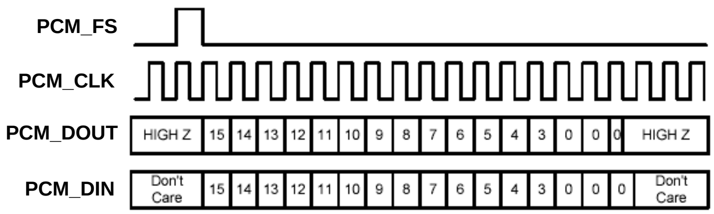
- PCM_CLK – 2048 KHz serial clock
- PCM_FS – 8 KHz bit-wide frame-sync
- PCM_DOUT – 13-bit linear audio data output
- PCM_DIN – 13-bit linear audio data input

The analog audio is sampled at an 8 KHz rate and converted to linear 16-bit serial PCM audio data. The serial data is transferred on the PCM bus in 16-bit word format,.

The 16-bit serial data is transferred in both directions after each sync signal's falling edge. The sync signal pulse duration is one clock period, after which the serial data is transferred in both directions for 16 consecutive clock periods.

Following the 16-bit data transfer, the serial input and output data signals inactivate until the next sync pulse, which occurs every 125 uS (8 KHz). It is recommended the serial data signals will be High-Z during the inactive period. The bus clock and sync output signals remain active all the time.

FIGURE 22 – Voiceband mode PCM bus coding format



2.8.7 Audio Operating Modes

The module's audio interface includes 2 modes of operation. Each operating mode defines the audio input and output devices to be used for each audio sound type and their programmable settings.

2.8.7.1 Basic Mode

Basic audio mode is the module's default power-up audio configuration. Several audio paths are available in this mode, and their settings can be programmed through the AT command set.

The following table describes the available audio paths in Basic mode.

TABLE 13 – Basic mode audio paths

Audio Path	Input Signal	Output Signal	Description
Handset	MIC	SPKR_N, SPKR_P	Default audio path for speech and DTMF tones.
Headset	HDST_MIC	SPKR_N, SPKR_P	Alternate path for headset device. Enable by setting HDST_INT_N interface signal low.
Alert		ALRT_N, ALRT_P	Default alert and ringer loudspeaker output device.
Digital	PCM_DIN	PCM_DOUT	Enable digital path by AT+MADIGITAL=1

2.8.7.2 Advanced Mode

An expanded AT command set enables to define a specific audio path and setting, which are not part of the default configuration, for each type of audio sound (speech, DTMF tones, rings and alerts).

The following table describes the advanced mode audio programming features. These features are only a part of the complete advanced audio AT command set.

TABLE 14 – Advanced mode commands

Command		Description
AT+MAPATH		Sets the input device for voice, and the output devices for voice, DTMF tones, rings and alerts.
AT+MAFEAT		Enables and disables the speech processing algorithms – Echo suppression, noise suppression and sidetone.
AT+MAVOL		Sets the gain (amplification) level of the selected analog output device.
AT+MMICG		Sets the gain (amplification) level of the selected analog input device.
AT+MADIGITAL		Switches between analog and digital audio paths.

2.8.8 Audio Programming Interface

The module incorporates an audio programming interface, through AT commands, which controls the following audio features:

- Audio Path – Defines the input and output devices for speech, DTMF tones, rings and alerts.
- Audio Gain – Defines the amplification (gain) level for input and output audio devices.
- Audio Algorithm – Defines the speech processing features for voice calls.

2.8.8.1 Audio Algorithms

The module's audio interface support speech processing algorithms for echo suppression, noise suppression and side-tone feedback
Enabling or disabling the algorithms can be configured separately for each audio path and operating mode through the AT command interface.

The module supports the following speech coding algorithms:

TABLE 15 – Speech processing features

Feature	AT command		Default Setting	Description
	Basic	Advancd		
Echo Suppression	ATS96	AT+MAFEAT	Disabled	Controls the echo and noise suppression.
Noise Suppression				
Sidetone	ATS94	AT+MAFEAT	Enabled	Controls the sidetone.

2.8.8.2 Gain Control

The amplification (gain) level for each input and output device can be configured through AT commands. Both basic and advanced audio modes provide AT commands to set the desired gain levels for each audio path and audio sound type.

TABLE 16 – Gain Control Features

Device	Gain Command		Default Gain	Description
	Basic	Advanced		
Microphone	AT+MMICG	AT+MMICG	3	Sets input speech gain level.
Headset Microphone			3	Sets input speech gain level.
Speaker	AT+CLVL	AT+MAVOL	4	Sets voice and DTMF gain.
Alert Speaker	AT+CRSL		4	Sets rings and alerts gain.

The gain levels for the input and output devices, which correspond to the values set by the AT commands, are described in the following tables.

TABLE 17 – Rx port Gains

AT Command Value	Handset Vs. 0dBm0		Headset Vs. 0dBm0	
	0dBm0 gain level (dB)	0dBm0 output level (mV_{RMS})	0dBm0 gain level (dB)	0dBm0 output level (mV_{RMS})
0	-35.8	12	-28.6	29
1	-32.9	17.5	-25.7	40
2	-29.8	25	-22.8	55.9
3	-27	34.5	-19.8	79.4
4	-23.8	50	-16.8	111.5
5	-20.8	70	-13.8	158
6	-17.8	100	-10.7	226
7	-14.8	140	-7.7	316.8

TABLE 18 – Microphone and Headset-Microphone port Gains

AT Command Value	0dBm0 Input Level (mV_{RMS})	Maximum Input Level (mV_{RMS})
0	87	350
…	…	…
3	63	250
…	…	…
16	15	55
…	…	…
31	4	11

2.8.8.3 Analog Ground

The module's interface incorporates a dedicated analog ground contact, AGND pin 61, which is internally connected to the module's ground. The AGND signal is intended to provide a separate ground connection for the application's external audio devices and circuits.
This signal provides an isolated ground connection directly from the module, which is separated from the noisy digital ground of the customer application.

2.9 A/D Interface

The module includes 4 Analog to Digital Converter (ADC) signals with 8-bit resolution, for environmental and electrical measurements.
The A/D signals operation and reporting mechanism is defined by the AT+MMAD command.
The following section describes A/D interface

TABLE 19 – A/D Interface signals

Pin (s)	Signal Name	Description
-	VCC	Power supply A/D
37	ADC1	General Purpose A/D
43	ADC2	General Purpose A/D
47	ADC3	General Purpose A/D / Battery Temperature A/D

2.9.1 Power Supply A/D

The main power supply (VCC) is sampled internally by the module through a dedicated A/D port, which is not accessible on the interface connector.

TABLE 20 – Supply A/D Specifications

Parameter	Conditions	Min	Typ	Max	Units
Sampling Range	Operating range	3.0		4.4	V
Resolution				10	mV

2.9.2 Battery Temperature A/D

The module incorporates a dedicated A/D port for battery thermistor measurements. This feature is implemented only in the charger model version.

TABLE 21 – Temperature A/D Specifications

Parameter	Conditions	Min	Typ	Max	Units
Temperature Range	Operating range	-30		85	°C
Tolerance				5	%
Resolution			1		°C

2.9.3 General Purpose A/D

The module provides 3 additional general purpose A/D (GPAD) signals for customer application use. Each A/D signal can monitor a separate external voltage and report its measured level independently to the application, through the AT command interface. The A/D Signals are available at the connector in the following pins: 37, 43 and 47.

The GPAD signals can sense a DC voltage level of 0 – 2.3 V, which is converted internally to a 10-bit digital value.

TABLE 22 – GPAD Specifications

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage		0		2.9	V
Sampling Range		0.05		2.5	V
Resolution				10	mV

2.10 Control and Indicators Interface

The module incorporates several interface signals for controlling and monitoring its operation. The following section describes these signals and their operation.

TABLE 23 – Controls and Indicators

Connector Pin	Signal Name	Description
25	RESET_N	System reset output indicator. When high, the module is operating.
27	VREF	2.8V regulated output. Supplies external circuits up to 150mA.
26	WKUPO_N	Host application wake-up signal indicator.
41	ANT_DET	Antenna physical connection detect indicator.
49	CDMA	Network status indicator.
39	TXEN_N	Transmission burst indication.
28, 30, 32, 34, 36, 38, 40, 42	GPIO 1-8	General purpose IO signals for customer use.

2.10.1 Reset

The RESET_N output signal indicates the module's operating status. This signal is set high after power up, when the module is operating. It is set low when the module is powered off.
When the RESET_N signal is low, the module's application interface signals are disabled and do not represent any valid data or state. Once the unit is turned-on, this signal must be disabled (high) for all SW modes (including modes as re-programming, sleep etc.)

2.10.2 VREF Reference Regulator

The module incorporates a regulated voltage output, VREF. The regulator provides a 2.8V output for use by the customer application. This regulator can source up to 150 mA of current to power any external digital circuits.

TABLE 24 – VREF Specifications

Parameter	Conditions	Min	Typ	Max	Units

Parameter	Conditions	Min	Typ	Max	Units
V_{OUT}	$I_{OUT} \leq 150$ mA	-2%	2.8	+2%	V
I_{OUT}				150	mA
Load regulation			0.65		mV/mA
Line regulation				5.6	mV
PSRR	20 Hz – 20 KHz		45		dB

The VREF regulator incorporates 3 operating modes that are controlled by the AT+MVREF command. These modes define the regulator operating state relative to the module's operating mode. The following figure sows the VREF power-up timing.

- **OFF Mode**

In this mode the VREF regulator is disabled and its output drops to 0V, regardless of the module's operating state.

- **Standby Mode**

The Standby operating mode is the default mode when module powers on. In this mode VREF follows the module's operating state.
When the module is in low power mode, Sleep mode, the VREF regulator is also in a low power state. In this state the VREF regulated output is limited to providing only 1mA of current maximum, while maintaining the 2.8V output level.
When module is in Idle mode, or wakes up temporarily from low power mode, the VREF regulator returns to full operation, supplying up to 150 mA.

- **Active Mode**

In this mode the VREF regulator is always fully active while module is operating, regardless of the module operating mode.

2.10.3 Wake-Up Out

The wakeup-out (WKUPO_N) signal is an active low output, which is designed to support a low power mode feature in the host application. This signal is used by the module to indicate that it requires to communicate with the host application through the serial interface, due to an incoming call or data, or an unsolicited event.

The wakeup out mechanism, using the WKUPO_N signal, is controlled by 2 AT commands:

- **ATS102** - Defines the delay time in **milliseconds** that the module will wait, after asserting the WKUPO_N signal low, before sending data on the serial interface. This delay is required to allow the application enough time to reactivate from low power mode and switch to normal

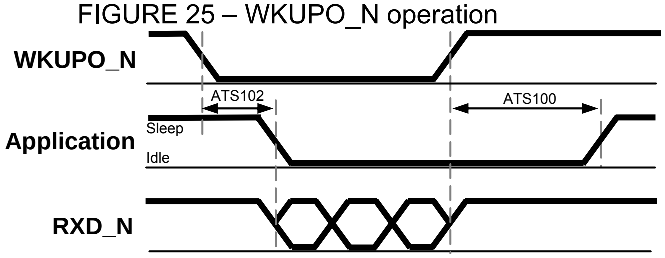
mode. If ATS102=0, which is the default value, the WKUPO_N signal and mechanism is disabled.
In case the serial interface incorporates hardware flow control signals, the data will be sent according to their state, after the ATS102 delay time has expired.

- **ATS100** - Defines the application minimal wakeup duration, in **Seconds**, for a single wakeup event. This time definition is required to avoid frequent unnecessary wakeup events and consequent ATS102 delays.
  The application may return to low power mode after the serial interface has been inactive for the duration set by ATS100. This duration is measured from the last data sent or received on the serial interface.

The following guidelines apply to the wakeup-out mechanism:

- The module will set the WKUPO_N signal low to indicate that in has data to send through the serial interface.
- The module will start sending the data to the application after the delay defined by ATS102.
- The WKUPO_N signal will remain low while data is being sent to the host application.
- The host application should keep its serial interface active, and not switch to low power mode, while the WKUPO_N signal is low.
- The module will set the WKUPO_N signal high when it has completed sending the data.
- The application serial interface must stay active, and not switch to low power mode, for the duration set by ATS100, after WKUPO_N is set high.
- The module will not set the WKUPO_N signal low if it needs to send additional data during the ATS100 delay time.
- The application may switch to low power mode after the WKUPO_N signal is set high and the serial interface has been inactive for the duration set by ATS100.

FIGURE 25 – WKUPO_N operation



2.10.4 Antenna Detection

The module incorporates an internal antenna detection circuit, which senses the physical connection and removal of an antenna or antenna circuit on the module's antenna connector. The antenna detection state is reported to the application through the ANT_DET output signal, and may also be queried by the ATS97 command.

The detection circuit senses DC resistance to ground on the module's antenna connector.
A DC resistance below 100KΩ (± 5%) is defined as a valid antenna connection, and the ANT_DET output signal is set high.
A DC resistance above 100KΩ (± 5%) is defined as an antenna disconnection, and the ANT_DET output is set low.

2.10.5 CDMA NW Detection

The CDMA output signal indicates the network CDMA connection status. When module is connected to a CDMA network, this signal is enabled. When module is not connected to the module network this signal is disabled.

2.10.6 Transmission Indicator

The TXEN_N output signal indicates when the module is transmitting over the CDMA network. This signal follows the module's transmit bursts. This signal is set low during transmission, and set high when no transmission is in progress.

2.10.7 General Purpose I/O

The module incorporates 8 general purpose IO signals for the user application. Each GPIO signal may be configured and controlled by AT command. These signals may be used to control or set external application circuits, or to receive indications from the external application.
Each GPIO shall have internal pull-up resistor of 6KΩ (± 5%

2.11 Antenna Interface

The module's antenna connector is the RF interface to the network.
The antenna interface is terminated by an MMCX connector type, which is 50Ω impedance matched at the relevant frequencies.

The antenna or antenna application must be installed properly to achieve best performance.

TABLE 25 – Antenna Interface Specifications

Parameter	Conditions	Specifications	
Sensitivity	1900 MHz	-106dBm	
	800 MHz	-106dBm	
RF output power		Max Average Power	Max Peak Power
	1900 MHz	25dBm	30dBm
	800 MHz	25dBm	30dBm
Gain		0 dBi (unity) gain or greater	
Impedance		50Ω	
VSWR		Less than 2.5:1	