Introduction

Wintec's SLM2456/33/14/03 embedded modem is based on Silicon Laboratories' ISOmodem™ chipset, which consists of a Si2456/33/14/03 modem DSP chip and an integrated direct access arrangement (DAA). The modem uses AT command set to control the functionality of modem and its internal register settings. It can be easily integrated into a host to provide a low cost communication link to the outside world. The direct access arrange (DAA) device in the modem is programmable to meet international telephone line interface requirements, with compliance to FCC, CTR21, and other country specific PTT specifications, such as AC/DC termination, ring impedance, on-hook/off-hook intrusion detection, caller ID, loop voltage/loop current monitoring, over-current detection, ring detection, and the switch-hook function.

The modem is assembled in a 40-pin Dual-in-Line (DIP) form factor and thus can be referred to as a "DIP modem". The footprint of Wintec's "DIP" modem is only 2"x1" and is one of the most concise embedded modems that meet global telephone line standards. The DIP pins are placed on the common 0.1" grid.

The SLM2456/33/14/03 modem is a DSP-based hardware modem. It is not a soft modem and is independent of the host processors. Different from competitors' half-built modems, Wintec's SLM2456/33/14/03 modem has all safety devices built-in, such as Fuse, SiDactor, notch filter, etc. User does not need to add any external safety component, except an RJ-11 connector to the product chassis. Standard UART (Universal Asynchronous Receiver Transmitter) driver is used to drive the modem if used in serial mode.

Protocol and Baud Rate

Besides being able to operate at the maximum connection rates of 56Kbps, 33.6K bps, 14.4K bps, and 2.4K bps for SLM2456, SLM2433, SLM2414, and SLM2403 respectively in full-duplex mode, all SLM24xx modems support ITU-T fall-back modes. More specifically,

SLM2456 DIP modem is V.90 compliant, with automatic fallback capability (56 kbps to 300 bps).
SLM2433 DIP modem is V.34 compliant, with automatic fallback capability (33.6kbps to 300 bps).
SLM2414 DIP modem is V.32bis compliant, with automatic fallback capability (14.4 kbps to 300 bps).
SLM2403 DIP modem is V.22bis compliant, with automatic fallback capability (2.4K bps to 300 bps).

The protocol and baud rate supported by SLM24xx modems are summarized as follows:

Features	SLM24xx (commercial)	SLM24xx-I (industrial)
Serial Mode Operation	All	All -I
Parallel Mode Operation	All	All -I
V.42 Error Correction	All	All -I
V.42bia Data Compression	SLM24 56/33/14	SLM24 56/33/14 -I
MNP2-4 Error Correction	All	All -I
MNP5 Data Compression	SLM24 56/33/14	SLM24 56/33/14 -I
V.90 56K bps Maximum	SLM24 56	SLM24 56-I
V.34 33.6K bps Maximum	SLM24 56/33	SLM24 56/33 -I
V.32bis 14.4K bps Maximum	SLM24 56/33/14	SLM24 56/33/14 -I
V.32 9.6K bps Maximum	SLM24 56/33/14	SLM24 56/33/14 -I
V.23 1200 bps	SLM24 56/33/14	SLM24 56/33/14 -I
V.22bis 2.4K bps Maximum	All	All -I

Bell212A 1200 bps	All	All -I
V.21 300 bps	All	All -I
Bell 103 300 bps	All	All -I

Note: All = SLM2456 / SLM2433 / SLM2414 / SLM2403
All-I= SLM2456-I / SLM2433-I / SLM2414-I / SLM2403-I ("-I" means industrial grade)

The modems also support V.42 and MNP2-4 error correction and V.42bis and MNP5 compression protocol, except for SLM2403. The SLM2403 modem supports modulations and protocols of Bell 103, V.21, Bell212A, and V.22bis. Extended AT commands are used to set various baud rates.

The error correction protocol ensures error-free delivery of asynchronous data sent between the host and the remote end. The error control is based on grouping the data into frames with checksums determined by the contents of each frame. The receiving modem checks the frames and sends acknowledgements to the transmitting modem. When it detects a faulty frame, the receiving modem requests a re-transmission. Frame length varies according to the amount of data transmitted or the number of re-transmissions requested from the opposite end.

The use of asynchronous compression protocol enables the SLM24xx modem to achieve DTE (Data Terminal Equipment, host-to-modem) speeds greater than the maximum line (modem-to-modem) speed. With the support of ITU-T V.42bis compression protocol, the SLM24xxP modem can be operated at maximum DTE rate up to 307.2 kbps under the standard UART format. Upon power-up, the serial UART interface defaults to 19.2 kbps baud rate. If the SLM243xx modem is unable to negotiate a V.42 link with a remote modem, it will fall back to wire mode. Error correction (ITU-T V.42) and data compression (ITU-T V.42bis) are not active in wire mode.

The UART interface synchronizes on the start bits of incoming characters. It then samples the data bit field and stop bits. The UART interface can accommodate character lengths of 8, 9, 10, and 11 bits, giving data fields of 6, 7, 8, or 9 bits. The default character length is 8-bit.

Meet Global Telephone Standards

Wintec's SLM24xx modem has been tested and passed major homologations for global applications:

(a) FCC Part 68
(b) FCC Part 15
(c) IC-CS03
(d) CTR21
(e) CE marking
(f) UL certification

CTR21 is a consortium of 21 countries that have developed a common PTT (Post Telegraph & Telephone) modem specifications. CTR21 includes the following countries: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Liechtenstein, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

FCC includes the following countries: Caribbean, Central America, China, Hong Kong, Malaysia, Mexico, Saudi Arabia, South American, Taiwan, United Arab Emirates, and the United States.

Dual Mode Supports

Wintec's SLM2456/33/14/03 DIP modem can operate in either parallel mode or serial mode. The interface to the host is configurable either as a serial UART interface with flow control or as an 8-bit parallel interface. The parallel mode interface has an 8-bit data bus and a single bit address A0, which is used to access either Parallel Interface Register 0 (A0=0) or Parallel Interface Register 1 (A0=1). The parallel mode interface is written or read by the host in blocks by way of a 14-character deep transmit FIFO or a 12-character deep receive FIFO. By polling the bit7 (RXE) and bit6 (TXE) of Parallel Interface Register 1, the FIFOs can be guaranteed to never full/empty at all transfer rates. The INT# pin can be used to indicate FIFO full or empty if without the use of polling. On detecting off-hook intrusion, the modem alerts the host of such condition via the same INT# pin.

The selection of serial or parallel interface is determined by the state of a designated pin (AOUT/INT# pin) at the modem interface during the rise of RESET#. An internal 50-Kohm pull-up resistor at the AOUT/INT# pin sets the modem default state to serial mode operation. An external pull-down resistor of 10K-ohm can be connected to the AOUT/INT# pin to select the parallel mode operation. The CS# signal should remain high until after the rise of RESET#. In parallel mode, the DIP pins are configured as an 8-bit data bus and a single address bit, besides chip select, read/write controls, and interrupt signal. The single address bit is for the access of two control registers in the modem DSP chip.

Additional Features

Additional features of the SLM2456/33/14/03 DIP modem are:

1. Caller ID detection. The DIP modem can detect the first ring burst signal and echo it to the host for caller ID decode.

2. Over-current protection, up to 70V and 200mA. The over-current protection is to protect the DIP modem from being accidentally plugged into a digital phone line. Many digital PBX lines have a low impedance, high current voltage source cross the two terminals of an RJ-11 jack that is normally TIP and RING on an analog phone line. When an analog modem is plugged into a digital line, it goes off hook and draws excessive current to damage the hook switch components. Wintec's DIP modem can detect the over-current condition to generate an interrupt for the host to force the modem into high impedance mode or on-hook before damage occurs.

3. Parallel phone detection. The DIP modem can detect when another telephone, modem or other device is using the phone line.

4. Sleep mode. The DIP modem will enter the sleep state after a pre-programmed time of inactivity to save power. It awakes on ring.

5. Power down mode. Once the PDN bit in the control register is written, the DIP modem will enter power down mode. It can be powered back through the assertion of RESET# pin.

6. Error correction protocol minimizes potential error during data delivery between the host and a remote end.

7. The DIP modem accepts basic AT command set, along with many of the enhanced AT commands. A complete list of AT command set is available in the Programmer User Guide.

8. The DSP chip DIP modem contains an on-chip program ROM that includes firmware for all features associated with the modem. In addition, the DSP chip contains on-chip program RAM to accommodate changes to the ROM firmware. This provides support for future firmware updates to those modem already deployed in the field.

Power-on State

On reset, the SLM2456/33/14/03 modem defaults to command mode and accepts AT commands. All register settings are reverted to the default values stored in the program memory residing in the modem chipset. After the device is configured, an outgoing modem call can be made by way of the ATDT# (tone dial) or ATDP# (pulse dial) command. If handshake is successful, the modem replies with a response code and immediately enters data mode. The "ATO" command can also be used to enter data mode. In data mode, AT commands are no longer accepted. The modem reverts to command mode if the modem connection is terminated, or through the use of +++ escape sequence.

Power Consumptions

Depending upon the state the SLM24xx is in, it consumes different powers under 3.3V supply voltage.

Communicating Mode	26mA nominal	35mA maximum
Sleep Mode (wake up on ring)	3 mA nominal	5mA maximum
Power Down Mode (wake up on reset)	35uA nominal	100uA maximum

The DAA section draws power from the phone line and does not consume power from the system.

The absolute maximum current for SLM2456/33/14/03 digital input pin is +/- 10 μA. The current rating for all output pins is +/- 2mA (output pads are 2mA driver).

Operating Conditions:

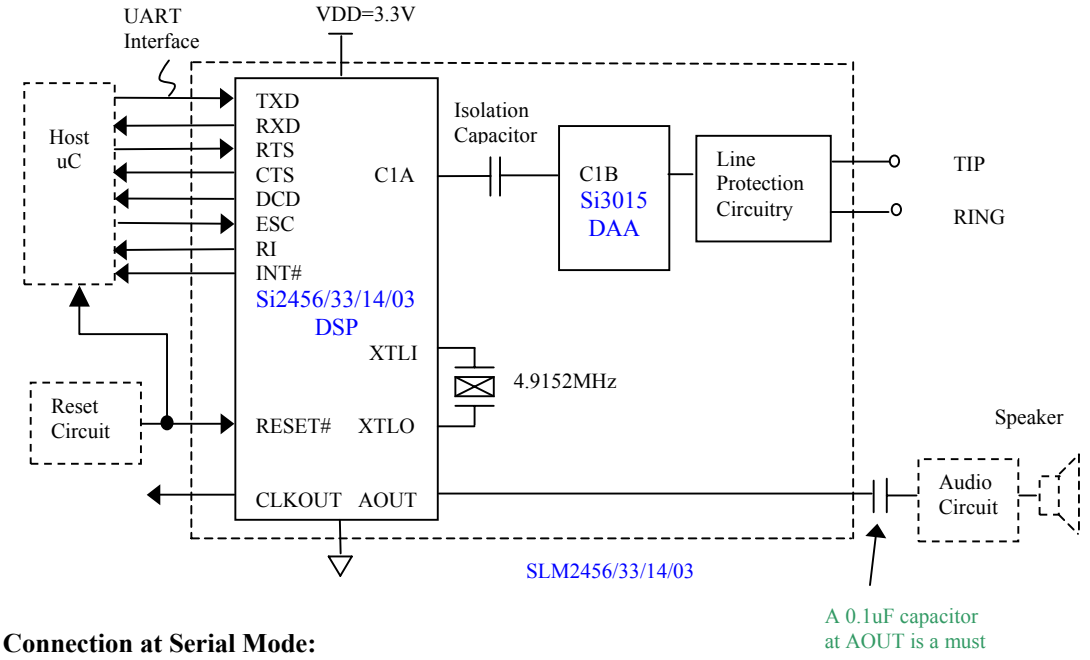
Ambient Temperature (T_A): Minimum 0 °C Typical 25 °C Maximum 70°C (commercial grade)
Minimum -40°C Maximum 85°C (industrial grade)

Si2433/14 Digital Supply Voltage Minimum 3.0V Typical 3.3V Maximum 3.6V (pin is 5V tolerant)

The Si2456/33/24/03 DSP interface supports 5V logic (5V tolerant), except the XTALI/CLKIN input pin which supports 3.3V only. The absolute maximum voltage for digital input is –0.3V to 5.3V.

All un-used input pins of SLM2456/33/14/03 should be tied to known, idle state externally while the un-used output pins are left open.

Interface Configuration for Serial Mode Operation



Pin Connection at Serial Mode:

Pin 1	TIP	Pin 40	NC (no connect)
Pin 2	RING	Pin 39	NC (no connect)
Pin 3	NC (no connect)	Pin 38	NC (no connect)
Pin 4	NC (no connect)	Pin 37	NC (no connect)
Pin 5	NP (no pin)	Pin 36	NP (no pin)
Pin 6	NP	Pin 35	NP
Pin 7	NP	Pin 34	NP
Pin 8	NP	Pin 33	NP
Pin 9	NP	Pin 32	NP
Pin 10	NP	Pin 31	NP
Pin 11	NP	Pin 30	NP
Pin 12	CLKOUT (open, if un-used)	Pin 29	RFU (tied to GND, if un-used)
Pin 13	RFU (tied to GND, if un-used)	Pin 28	DCD
Pin 14	VDD (3.3V)	Pin 27	ESC (tied to GND, if un-used)
Pin 15	GND	Pin 26	VDD (3.3V)
Pin 16	RTS	Pin 25	GND
Pin 17	RXD	Pin 24	RFU (open, if un-used)
Pin 18	TXD	Pin 23	RI
Pin 19	CTS	Pin 22	INT# (open, if un-used)
Pin 20	RESET#	Pin 21	AOUT (open, if un-used)

The connection order of TIP and RING is exchangeable. A polarity rectifier in SLM2456/33/14/03 can automatically correct the polarity of TIP and RING before being input to DAA.

Serial Mode Interface Signal Description:

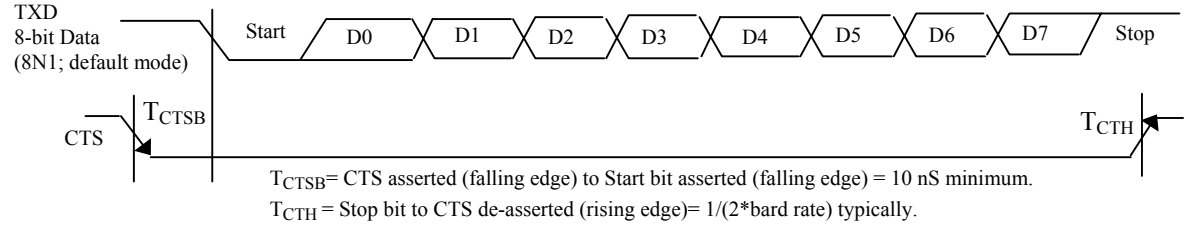
The serial mode interface can be directly connected to an UART in the host or to a RS232 interface though a level conversion IC. RS stands for "recommended standard". The original standard was established before the days of TTL logic, it is not a surprise to see the standard does not use 5V/3.3V and ground logic level. Instead, a high level for driver output is defined as +5 to +15V and a low level for driver output is defined as being between -5 and -15V. The receiver logic level was defined to have a 2V noise margin. As such, a high level for the receiver is defined as +3 to +15V and a low level is -3 to -15V. For RS-232 communication, a low level (-3 to –15) is defined as a logic 1 and is referred to as "marking". Likewise, a high level (+3 to +15V) is defined as a logic 0 and is referred as "spacing". The flow control signal in serial interface is asserted if it is in logic 0 state. There is no "#" or "~" symbol appended to the serial interface signal to indicate it is asserted in logic 0 to avoid confusion. The serial mode interface signals in SLM24xx modems are:

TXD: Transmitted Data; generated by DTE (PC or host), received by DCE (modem).
RXD: Received Data; output by DCE, received by DTE.

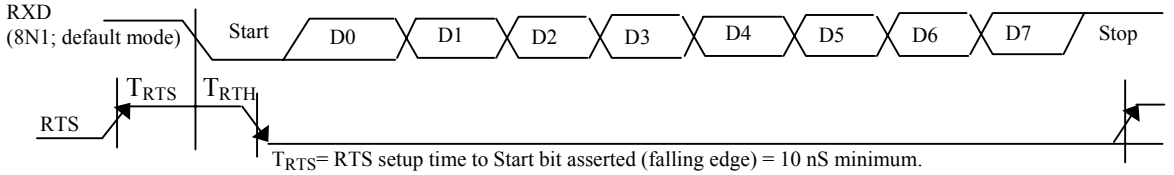
RTS: Request to Send. When DTE is ready to transmit data to DCE, RTS is turned on ("ON" refer to a high in RS-232, or logic "0"). An "ON" condition maintains the DCE in receive mode. After RTS is asserted, the DCE must assert CTS (Clear to Send) before communication commence.
CTS: Clear To Send. CTS is used along with RTS to provide handshaking between the DTE and the DCE. After the DCE sees an asserted RTS, it turns CTS ON when it is ready to communicate.
DSR: Data Set Ready. DSR is turned on by DCE to indicate it is connected to telecommunication line.

DCD: Data Carrier Detect. DCD is turned on when DCE is receiving a signal from a remote DCE. This signal remains ON as long as a suitable carrier signal can be detected. SLM24xx modem asserts DCD after it receives a carrier signal from a remote modem
DTR: Data Terminal Ready. DTR indicates the readiness of DTE. This signal is turned ON by DTE when it is ready to transmit or receive data from the DCE.
RI: Ring Indicator. When RI is asserted, it indicates that a ringing signal is being received on the communication channel.
ESC: Escape. A level-sensitive input pin. A high to this pin returns the modem to Command mode. In the 9-bit data transfer (9N1), a 1 detected on the 9th data bit also returns the modem to Command mode if such function is enabled via the \B6 AT commands. The escape sequence "+++" can returns modem to Command mode too.
INT#: Active low interrupt to host.

Timing Requirement:

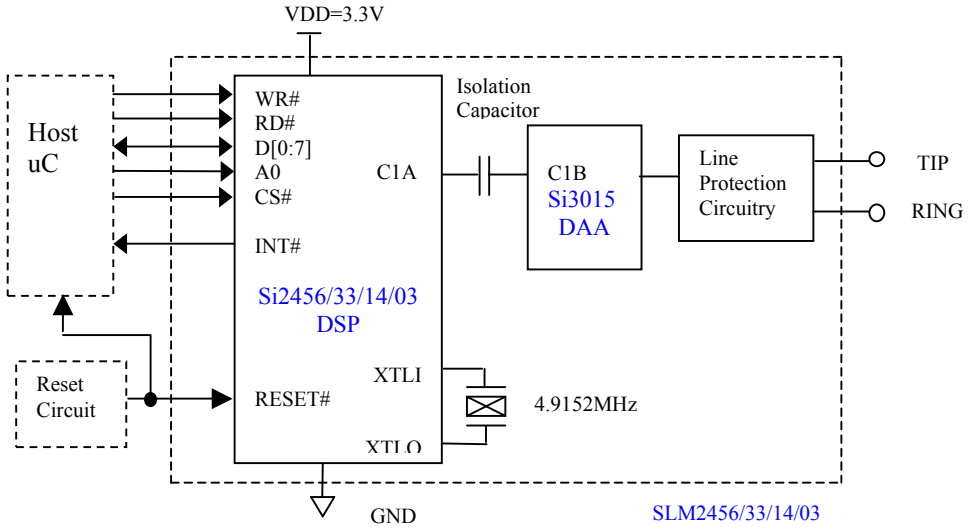


T_{CTSB}= CTS asserted (falling edge) to Start bit asserted (falling edge) = 10 nS minimum.
T_{CTH} = Stop bit to CTS de-asserted (rising edge)= 1/(2*bard rate) typically.



T_{RTS}= RTS setup time to Start bit asserted (falling edge) = 10 nS minimum.
T_{RTH}= RTS hold time with respect to the falling edge of Start bit = 1/(2*bard rate) typically.

Parallel Mode Interface



Parallel Mode Pin Connection:

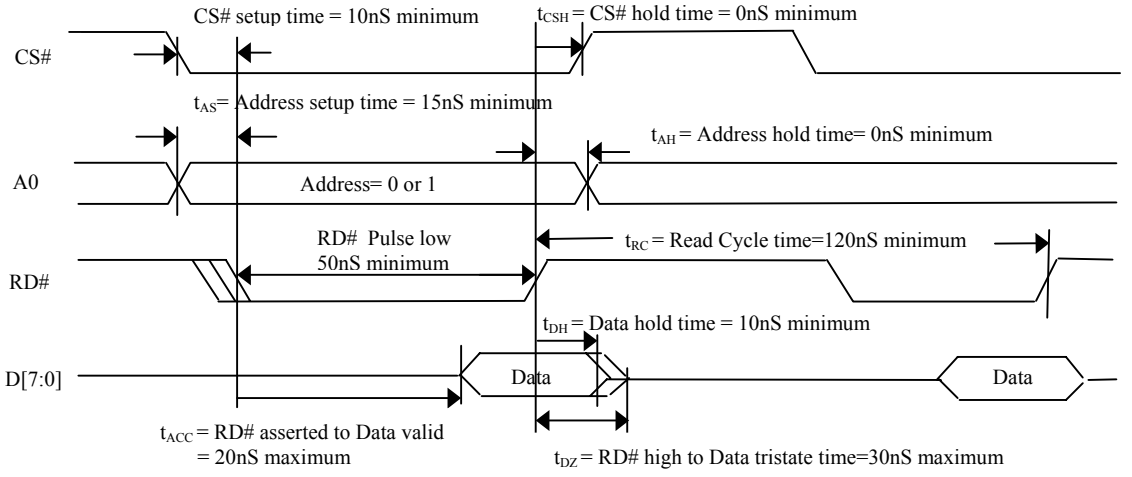
Pin 1	TIP	Pin 40	NC (no connect)
Pin 2	RING	Pin 39	NC (no connect)
Pin 3	NC (no connect)	Pin 38	NC (no connect)
Pin 4	NC (no connect)	Pin 37	NC (no connect)
Pin 5	NP (no pin)	Pin 36	NP (no pin)
Pin 6	NP	Pin 35	NP
Pin 7	NP	Pin 34	NP
Pin 8	NP	Pin 33	NP
Pin 9	NP	Pin 32	NP
Pin 10	NP	Pin 31	NP
Pin 11	NP	Pin 30	NP
Pin 12	A0	Pin 29	D5
Pin 13	D6	Pin 28	D4
Pin 14	VDD (3.3V)	Pin 27	D3
Pin 15	GND	Pin 26	VDD (3.3V)
Pin 16	D7	Pin 25	GND
Pin 17	RD#	Pin 24	D2
Pin 18	WR#	Pin 23	D1
Pin 19	CS#	Pin 22	D0
Pin 20	RESET#	Pin 21	INT#

Parallel Mode Interface Signal Description

D[7:0] : 8-bit data bus
A0 : 1-bit address bus
CS# : active low chip select.
WR# : active low write control pulse
RD# : active low read control pulse
INT# : active low interrupt. The INT# pin in parallel model operates differently than in serial mode. In parallel mode, the INT# pin is used to control FIFOs. The INT# is automatically asserted to host on Receive FIFO full or Transmit FIFO empty to ensure no FIFO overflow or underflow.
RESET#: active low reset pulse.

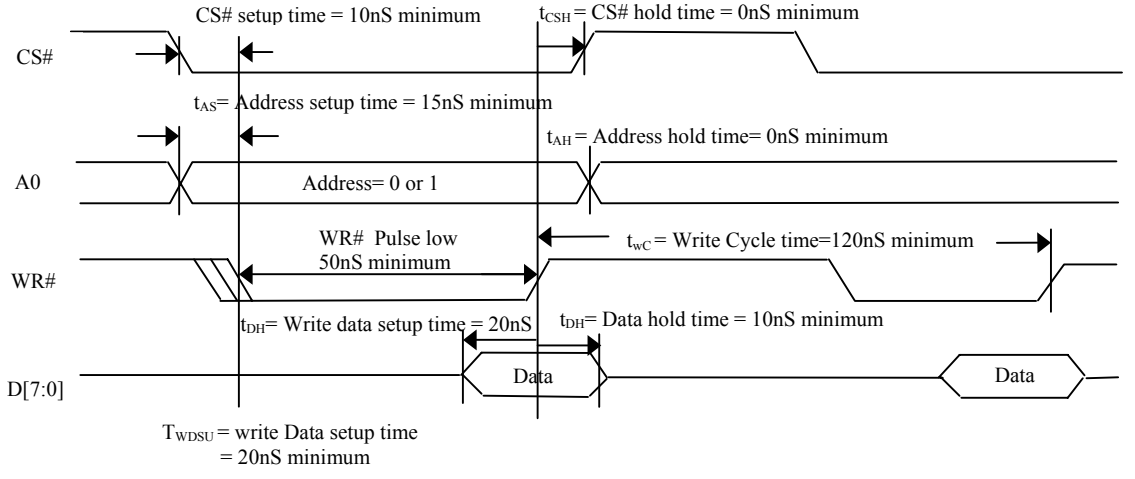
Parallel Mode Timing Diagram

Parallel Interface Read Timing



The minimum CS# pulse low width is the sum of CS# set up time with respect to RD# going low and the width of RD# low. The sum is 60nS. A port pin from an external micro-controller can be used to drive the CS# pin. Thus, the minimum cycle time is 120nS, i.e. twice of the minimum width of CS# low. Each data transfer between the SLM24xx and the host can be done in two host bus cycles.

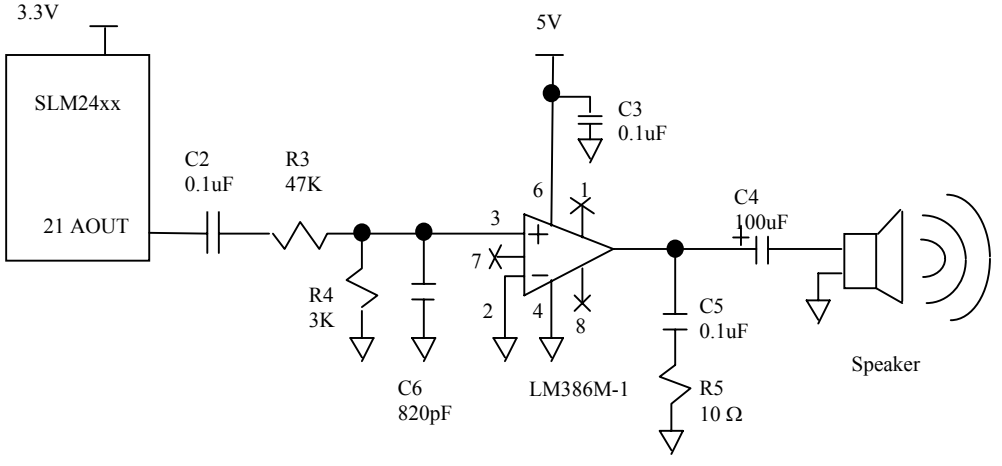
Parallel Interface Write Timing



The minimum CS# low pulse is 60nS. The minimum write cycle time is 120nS. A host port can be use to drive the parallel mode control signals. Because of separate address and data bus, it takes only two host bus cycles to complete a write data transfer from the host to the SLM24xx modem.

Audio Circuit Reference Design

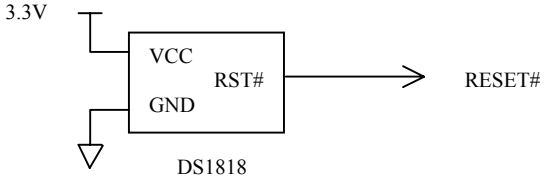
An external speaker circuit can be connected to the AOUT pin in serial mode to monitor the call-progress signals, such as dial tone, DTMF dialing, ring, busy signal, and modem negotiation. Enable or disable of this signal is provided by way of AT commands and register settings. It is extremely important to note that AOUT cannot be used to directly drive an external Audio Amplifier, such as National LM386M-I. Both inputs (V+ and V-) to the bipolar differential pair of LM386M are biased to ground with a 50KΩ resistor. The voltage divider between the AOUT internal pull-up resistor and the input bias resistor in external audio amplifier can result in an undetermined state in selecting a parallel or a serial mode operation. An isolation capacitor between AOUT and external audio amplifier is required. A reference design for AOUT is shown:



In serial mode operation, AOUT is a digital audio PWM output. In the audio circuit, C2 provides a DC blocking for AOUT. It also prevents SLM24xx modem from accidentally running into parallel mode by external pull-down resistor, such as R4. R3 and R4 form a voltage divider to charge the capacitor C6. The voltage level at C6 is applied to the V_+ input of Audio Amplifier, such as National Semiconductor LM386, while the V- input is tied to ground. With differential inputs being ground-referenced, the output is biased to one-half the supply voltage (V_{cc} =5V). The pins 1and 8 of LM386 are open. An internal 1.35KΩ resistor between these two pins sets the gain at 20. C3 is a power supply bypass capacitor and should be located as close to the power supply pin of LM386 as possible. C5 and R5 form a compensation circuit to prevent the oscillation of the high-current PNP transistor in the LM386 output stage on negative signal peaks. These oscillations can occur between 2MHz-5MHz and can pose a radiation compliance problem if C5 and R5 are omitted. C4 provides a DC blocking for the output of LM386, which is biased at approximately 2.5V(Vcc/2) and forms a high-pass filter with the impedance of loudspeaker.

RESET Circuit Reference Design

User can also use a reset chip (such as Dallas Semiconductor DS1818 for 3.3V Vcc supply) to generate a reliable reset signal for the modem to use.



HyperTerminal Applications

Any standard terminal communication program such as HyperTerminal under Microsoft Windows can be used to evaluate the AT command sets for SLM24xx modem. Wintec SLM24xxEVB evaluation board can be connected to any PC as a standard serial modem. The following procedure can be used to set up HyperTerminal:

a. Check if HyperTerminal is installed in your PC. If not, see HELP on Windows Operating System for HyperTerminal installation.

   Start -> Program -> Accessories -> Communications -> HyperTerminal

   When the HyperTerminal is open for the first time, the application will ask for a title for storing all parameters you want to key in.

   After a title is given, there will be a prompt for the COM port to be used. Choose the corresponding port (COM1 is recommended). And then the port setting will be asked. Configure the terminal emulation program to 19200 bps, 8 data bits, no parity, one stop bit, and hardware (CTS) handshaking.

b. With the terminal program properly configured and running, type "AT<cr>" inside the terminal window and the modem should return "OK", indicating the modem is working in the command mode and communicating with the terminal. If the "OK" response is not received, try resetting the modem by pressing the manual reset switch (S1) then again type "AT<cr>". If not working, check if the right COM port is selected and make sure a correct Port setting is entered.

c. If there is no line-feed after the "OK" response, click File->Properties. In properties panel, choose Setting. In Setting panel, choose ASCII setup.. In ASCII panel, click the append linefeeds to incoming lines. Click OK,OK. You are now talking to one modem with the PC.

d. Use similar procedure to setup other modem with a different COM port.

e. Once the second modem is set up, the user can choose either one of the modems as the ANSWER modem.

f. If the evaluation board is chosen as the ANSWER modem, type "ATI6<cr>". The modem should respond with "2456", "2433", "2414", or "2403", indicating the terminal is communicating with a SLM2456/33/14/03 DIP modem.

g. Type "ATS0=2<cr>". It means answer the phone after the second ring.

h. To take the modem off-hook, type "ATH1<cr>". The modem should go to the off-hook state, draw loop current, and respond with an "OK".

i. Next type "ATH<cr>" or "ATH0<cr>" and the modem should hang-up (go on-hook) and stop drawing loop current.

j. To make a modem connection, type "ATDT(called modem phone number)<cr>". Once the connection is established, a "CONNECT" message will appear indicating the two modems are in the data mode and communicating. Typing on one terminal should appear on the other terminal.

k. To return to the command mode without interrupting the connection between the two modems, type "+++". Approximately two seconds later, "OK" will appear. The modem is now in command mode and will accept "AT" commands.

Note: The +++ escape sequence is disabled at power up or at reset. ATS14=20 enables +++ escape. S-Register address and values are entered in hex (e.g. ATS0F=2B).

l. To return to the data mode, type "ATO<cr>". The modem will resume the data connection and no longer accept AT commands.

m. Type "ATH<cr>" (or "ATH0<cr>") to terminate the data connection.

n. AT commands are required to enable the speaker:

ATSF4=00 removes TDX and RDX audio mute.
ATM2 turns on speaker continuously.
ATM1 turns on speaker until carrier is established.
ATM0 Disable speaker.

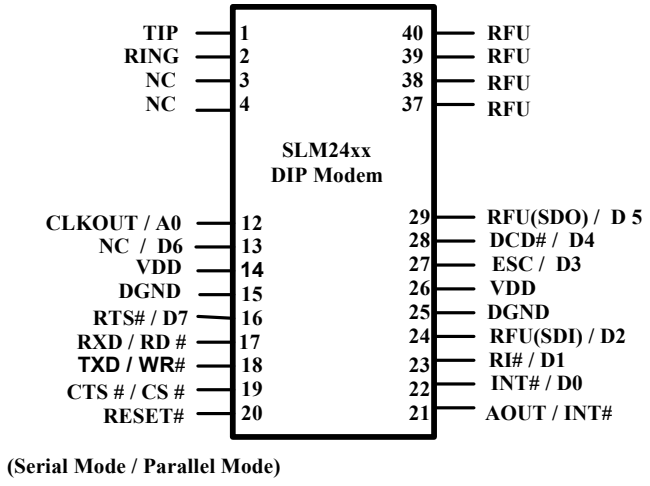
A partial list of other commonly used AT commands are:

AT	The attention command prefix, a set/reset command.
ATA	Answer
ATDT101	Dial the number (101)
ATH0	Forces the modem on-hook. Hangs up the modem's connection to the telephone line.
ATH1	Forces the modem off-hook.
ATI	Information - asks the modem for its product ID code.
ATO	Goes online. The ATO command is used to re-enter Data mode.
ATS0=1	Set number of rings (1) before answering
ATX0	Blind dial – no dial tone necessary.
AT*Y1D2	Send continuous DTMF digit (2).

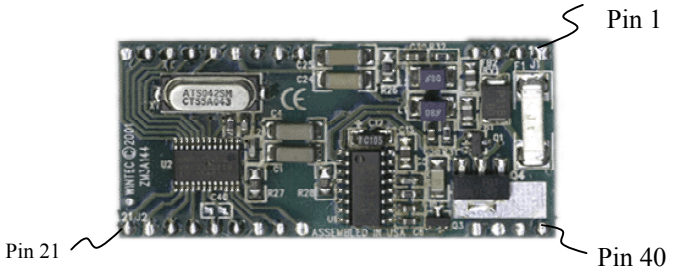
A/ Repeat last command
The A/ command instructs the modem to repeat the last command line. A command line termination character is not required for the execution of this command (that is, the command is executed as soon as the slash is typed).

+++ Return to command state (escape sequence)
The escape sequence is used to force the modem back to local command state from on-line state. Do not type any other commands or make entries before or after the escape sequence for a period equal to the guard time set in register S12 (default is one second).

SLM2456/33/14/03 DIP Modem Pin Diagram

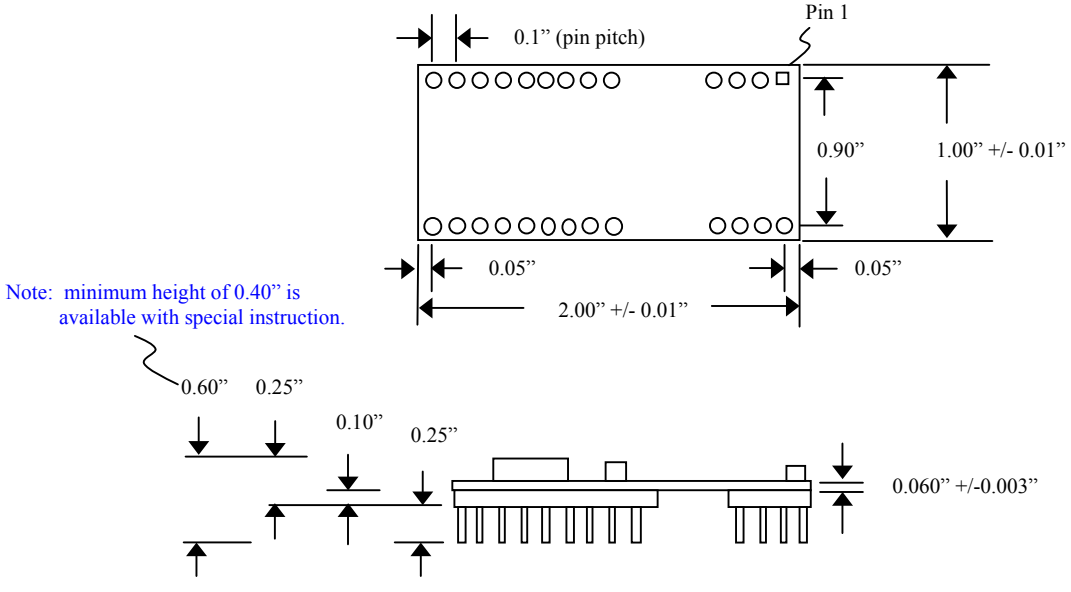


(Serial Mode / Parallel Mode)



Physical Dimensions:

The physical dimension of Wintec's SLM2456/33/14/03 DIP modem is 2"x 1"x 0.35" (excluding the height of DIP pin). The detail drawing is shown below.

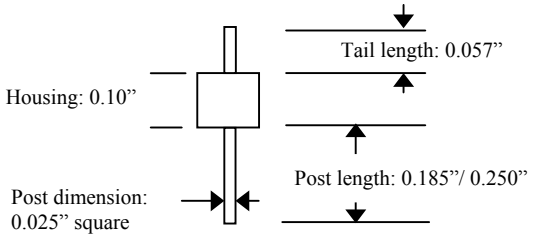


Modem Header Specification:

(A). Pin Header Specification:

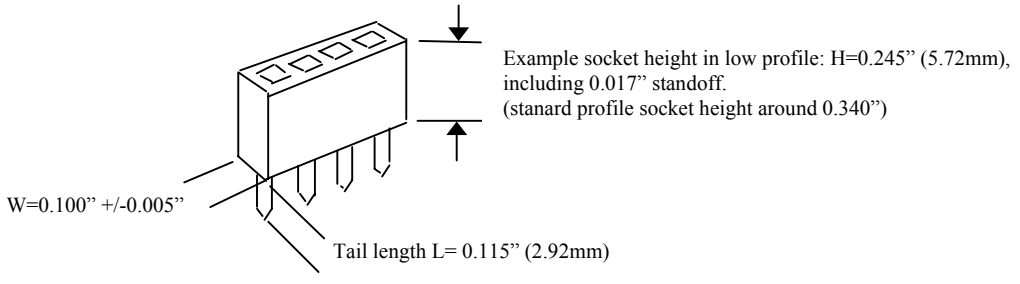
1. Pin Coating: 3-6 micro-inch gold flash (30 micro-inch gold plating is also available)
2. Post dimension: 0.025" per side, square pin
3. Two post lengths are available:
   - Post length: 0.185" for low profile socket (mate height ranges from 0.245" to 0.200" including standoff)
   - Post length: 0.250" for standard socket (mate height ranges from 0.340" to 0.245" including standoff)
   - For other different lengths are also available per customer's request.
4. Housing insulator: 0.10"
5. Tail length: 0.057"
6. Pin pitch: 0.1"

(B). Pin Header Drawing:



(C) Socket:

The mate (socket, receptacle) for DIP pin is a single-in-line socket strip with 0.100" (2.54mm) centered to match with 0.025" (0.64mm) square mating posts.



Evaluation Board

A companion evaluation board is available for customers to evaluate the functionality of DIP modem and the AT command set used in the Si2456/33/14/03 ISOmodem chipset. It is extremely helpful for customers to start with the evaluation board.

SLM24xx DIP modem and companion evaluation board