MTA11200B

TRUEGAUGE™ Intelligent Battery Management I.C.

FEATURES

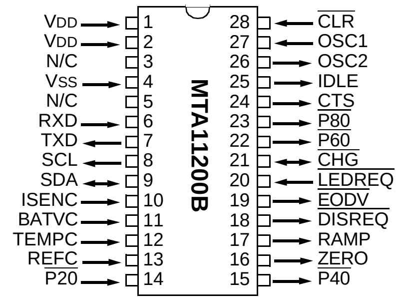
- Digitally integrates battery charge and discharge current to provide an accurate state of charge indication (< 3% error).
- Operates with NiCd, NiMH, or Lead Acid battery packs containing as few as three cells
- Provides real-time battery data via a single-wire interface
  - Remaining capacity in percentage
  - Total Capacity in mA-Hr
  - Battery Voltage
  - Battery Temperature
  - Battery Current
- -ΔV, ΔT/dt, or maximum voltage fast charge termination
- Provides three overcharge protection mechanisms:
  - Elapsed time fast charge termination
  - Over and Under Temperature protection
  - Over-Voltage protection
- Automatically measures and updates the total capacity of the battery
- Automatic battery conditioning requests at regular intervals based on usage
- Wake-up on current sense without need for extra pin

BENEFITS

- Provides accurate, real-time battery capacity information
- Extends battery life through automatic, regular conditioning cycles
- Logs battery activity like a “flight recorder”
- Permits use of an inexpensive current source for battery charging
- Allows rapid and reliable battery recharging with multiple backup safety mechanisms
- Avoids errors due to battery noise, variations in load current, and deep discharge situations
- Provides total capacity data to help detect imminent battery failure
- Assists in efficient power management

PACKAGE TYPE

PDIP, SOIC



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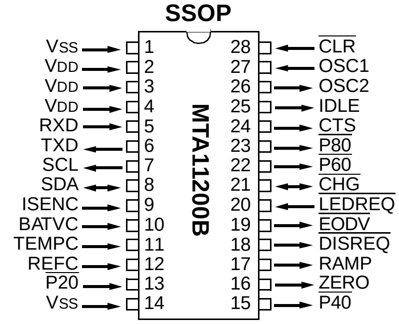

DESCRIPTION

The MTA11200B is the heart of a simple, low-cost, yet fully featured solution to battery monitoring and charging. It is designed to operate with either nickel cadmium, nickel-metal hydride, or lead acid battery packs.

By digitally integrating battery charge and discharge current the MTA11200B accurately determines the battery's state of charge. The battery's total capacity is automatically measured and factored into the state of charge calculation. Thus, an accurate indication of percentage of battery capacity remaining is determined.

Automatic total capacity measurement occurs during battery conditioning cycles when the battery is cycled from full charge to full discharge. The MTA11200B requests conditioning cycles at regular intervals based on battery usage to extend battery life. Additionally, the MTA11200B continually monitors battery condition and can output the following battery parameters via RS-232 1-wire interface or optional 3-wire bi-directional serial link: remaining capacity, total capacity, voltage, current, temperature, error flag, etc.

The MTA11200B is a 28-pin low power CMOS integrated circuit. Combined with a few simple external components, a complete battery maintenance system can be realized.

APPLICATIONS

The MTA11200B is ideally suited for use in portable computers, portable video equipment, cellular phones, and other products relying on rechargeable battery technology. The MTA11200B excels in applications where an accurate "fuel gauge" is desired to prevent interruption in use or data loss due to insufficient battery power.

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1.0 PIN DESCRIPTIONS

Pin Name	Type	Description
TXD	Output	RS-232 transmit data 9600,N,8,1. The MTA11200B transmits command responses and measured battery data to a host via this pin
RXD	Input	and data from a host via this pin. This pin can be a no-connect if the MTA11200B is operating in the transmit only (broadcast) mode
CTS	Output	RS-232 clear to send output. The MTA11200B signals that it is ready to receive a command from the host via this pin. This pin can be a no-connect if the MTA11200B is operating in the transmit only mode
SCL	OC-Output	I^2C™ format serial clock to an external Serial EEPROM
SDA	Input/Output	I^2C format serial data to and from external Serial EEPROM
REFC	Input	Reference voltage comparator sense input
BATVC	Input	Battery Voltage comparator sense input
TEMPC	Input	Temperature comparator sense input
ISENC	Input	Charge and Discharge Current comparator sense input
ZERO	Output	Comparator offset compensation control
RAMP	Output	A/D voltage ramp control
$\overline{\text{DISREQ}}$	OC-Output	Discharge request output for external charger/discharger control. Active low when battery discharge cycle is requested. Inactive tristated
$\overline{\text{EODV}}$ / $\overline{\text{P0}}$	OC-Output	Battery at End Of Discharge Voltage output, active low, inactive tristated. This pin can be configured to indicate between 0% - 20% capacity through the B options (Section 5.2.1 through Section 5.2.4)
$\overline{\text{CHG}}$	Input/Output	Charge request output and host or charger present input. When in output mode, fast charge request is active low when capacity is less than value stored in EEPROM. Inactive tristate. In input mode charger present is indicated when input is high. A 100K pull down is required. Externally pulled high to command ON (as opposed to STANDBY) mode The $\overline{\text{CHG}}$ pin automatically becomes an input when it is sampled every 1.75 seconds. If, when sampled, the $\overline{\text{CHG}}$ pin is found to be high, TrueGauge will be forced to an ON state. If it is sampled low, no action is taken, and TrueGauge enters the standby state. When in output mode, fast charge request is indicated by an active low $\overline{\text{CHG}}$ pin
$\overline{\text{LEDREQ}}$	Input	LED request switch input for momentary contact switch. Enables LED outputs for ~1.75 seconds when input goes low
$\overline{\text{P20}}$	OC-Output	Battery >20% full, LED drive, active low, inactive tristated
$\overline{\text{P40}}$	OC-Output	Battery >40% full, LED drive, active low, inactive tristated
$\overline{\text{P60}}$	OC-Output	Battery >60% full, LED drive, active low, inactive tristated
$\overline{\text{P80}}$	OC-Output	Battery >80% full, LED drive, active low, inactive tristated
IDLE	Output	Standby mode output, shuts down external circuits, active high
OSC2	Output	4.0 MHz ceramic or crystal oscillator output
OSC1	Input	4.0 MHz ceramic or crystal oscillator input
$\overline{\text{CLR}}$	Input	Power on reset input
V_{DD}	Pwr	
Vss	Gnd	

I^2C is a Trademark of Philips Corporation.

2.0 OVERVIEW

The MTA11200B determines the state of charge of a battery by integrating all the current going into and out of a NiCd, NiMH, or Lead Acid rechargeable battery pack. Compensation factors which adjust for battery non-linearity and environmental conditions are continuously applied to the state of charge calculation. The MTA11200B also performs the charge controller function of a battery charging system. It can directly control a “dumb” current source charging supply to provide both a high current fast charge and a long term maintenance (trickle) charge. The battery’s state of charge is communicated by the MTA11200B’s four LED outputs and by a 9600 baud RS-232 serial link. Additionally, battery voltage, current, temperature, measured total capacity, and history information are available via the RS-232 link.

System control parameters that are stored in an external EEPROM allow the operation of the MTA11200B to be customized for use with a wide variety of battery types and sizes. There are approximately 35 programmable system parameters stored in 128 bytes of external EEPROM. These parameters are listed alphabetically and described in detail in Section 5.0.

2.1 STANDBY State

The MTA11200B has two states of operation:

- ON state
- low power STANDBY state

The MTA11200B enters the STANDBY state when it senses that the battery is not connected to any external equipment (via the $\overline{\text{CHG}}$ pin) and therefore is not in use. In this low power state, the battery voltage, temperature, and current flow are measured at 138 second intervals. The MTA11200B compensates for battery self-discharge by adjusting the state of charge indication based upon the temperature and the battery’s available charge. The self-discharge compensation factors are highly programmable and allow the MTA11200B to accurately compute the decay in the battery’s available charge for a wide variety of different battery types. In this STANDBY state, the battery’s charge state can be communicated via the four LED outputs. The MTA11200B’s RS-232 link is disabled when in the STANDBY state to conserve power.

2.2 ON State

Exiting the STANDBY state and entering the ON state occurs when a connection to external equipment is detected. This indicates that the battery is in use or is being charged. The ON state is entered when the $\overline{\text{CHG}}$ pin is sampled at a high level. The CHG pin is sampled at a 1.75 second rate and the MTA11200B can be easily forced into the ON mode when the battery’s host equipment is powered up or when the battery is connected to a charger. Battery voltage, temperature, and current flow are sampled at 1.75 second intervals in this state.

2.3 Monitoring and Charging System

The MTA11200B is designed as the main controller I.C. in a battery monitoring and charging system. Additionally, a few other components are required to implement an entire system. A Serial EEPROM that uses standard I^2C interface is required. Control parameters that customize the MTA11200B for a particular battery type and application are stored in the Serial EEPROM. Additionally, the actual battery capacity that is measured by the MTA11200B is routinely updated and stored in the EEPROM. The analog-to-digital conversion technique used by the MTA11200B is a timed voltage ramp system that uses an external quad comparator. This combination provides highly accurate conversions across a wide dynamic range of input levels. For example, the current measurement range is typically 5000:1 for charge or discharge current.

3.0 FUNCTIONAL DESCRIPTION

3.1 Charge State Indicator

The MTA11200B indicates the present state of charge in percentage relative to a full (100%) charge. The total capacity of the battery pack is measured and used as the reference value for calculating the present state of charge. The total capacity is obtained by numerically integrating discharge current only, over a complete discharge cycle. A separate numerical integration is performed using both charge and discharge currents. The result of this integration in relation to the measured capacity determines the present state of charge of the battery.

3.1.1 MEASURED BATTERY CAPACITY

Total battery capacity is automatically determined by measuring and integrating the total discharge current delivered by the battery during any uninterrupted (by charge current) and complete discharge cycle. This helps maintain the accuracy of the charge state indication over the life of the battery.

An automatic capacity measurement cycle begins when the battery is charged to its 100% capacity point. This occurs when fast charging is terminated by the MTA11200B's internal charge controller. Additionally, if the MTA11200B receives a Start Capacity Measurement command, it allows the discharge measurement cycle to begin by defining the present state of the battery as the 100% capacity point.

Now, integration of the discharge current begins when measurable discharge current flows from the battery. The MTA11200B may enter the STANDBY state and not cause the measurement cycle to abort. However, a complete and uninterrupted discharge cycle must occur following the start of discharge. If, after the start of discharge, the battery discharge current is reduced to zero, or if charge current is detected, the measurement cycle will be aborted.

If the discharge cycle continues until the battery reaches the programmed (in EEPROM) End Of Discharge Voltage ($\overline{\text{EODV}}$), the capacity measurement cycle is completed. This measured battery capacity replaces the value previously stored in EEPROM at location MEACAP and becomes the new basis for the charge state calculation. From this point forward the MTA11200B will integrate all charge and discharge current and calculate battery self-discharge rates in relation to the stored measured capacity.

Long term accuracy of the state of charge calculation is maintained by regularly referencing known battery capacity points. When the fast charge termination point is detected, the state of charge indicator will be adjusted to indicate 100% capacity remaining. When the battery voltage reaches the end of discharge voltage point during discharge, the state of charge indicator will be adjusted to 0% if necessary. Additionally, the indicated battery capacity is restricted to a 0% to 100% range.

3.1.2 NOMINAL BATTERY CAPACITY

The MTA11200B reserves storage space for the battery's nominal (rated) capacity in the EEPROM at address NOMCAP. The MTA11200B does not use this value for any calculations. It is included so that a smart host may query the MTA11200B for the measured battery capacity and the nominal battery capacity. The host can then alert the user of impending battery "wear out" or failure.

3.1.3 COMPENSATION FACTORS

The MTA11200B applies several compensation factors to the state of charge calculation. Compensation is required to maintain an accurate state of charge indication due to battery non-linearity and changing environmental conditions. These compensation factors are stored as lookup tables in the EEPROM.

When the battery is being charged, the charge current is integrated and the state of charge indication is calculated. However, since battery charging is not a 100% efficient operation, compensation is applied to the state of charge calculation. Charge efficiency is adjusted based upon the battery's present state of charge and it's temperature. Since most charging sources charge at a fixed rate, a separate compensation table for charge rate versus charge efficiency is not included. The compensation required for this rate is usually factored into the programmable temperature compensation versus charge efficiency table in EEPROM.

Self-discharge compensation occurs when the MTA11200B is in the STANDBY state. The MTA11200B measures the temperature once every 138 seconds and applies self-discharge compensation based on the temperature and the battery's state of charge. The self-discharge compensation factors are stored in a lookup table SDFT (31-0) in EEPROM.

Accuracy is improved by not applying compensation factors to the state of charge calculation when the battery is discharging. The MTA11200B maintains accuracy by avoiding the cumulative application of compensation factors to both the measured capacity discharge cycle and subsequent discharges. Since the measured capacity is based upon an actual measured discharge cycle that typically occurs during actual use in the host equipment, the discharge rate is automatically factored into the state of charge calculation.

3.2 Charge Controller

The MTA11200B can control the complete charging regimen for several popular types of rechargeable batteries. Nickel Metal Hydride (NiMH), Nickel Cadmium (NiCd), and Lead Acid (Pb) batteries are all supported. The internal charge controller is designed to interface via a single wire to a “dumb” constant current source, thus forming a complete charging system. Two modes of charging are provided, a high current fast charge mode and a low current maintenance (or trickle) charge mode. Several “fail-safe” backup mechanisms are provided to ensure that the fast charge mode is not allowed to continue indefinitely. Fail-safe mechanisms for maintenance charge mode are also included to allow termination of all charging if the battery voltage or temperature is out of range.

3.2.1 FAST CHARGE

The fast charge mode is designed to allow high current rapid charging of a battery pack. Several techniques for fast charge termination are supported. They are:

- negative delta voltage (-ΔV)
- rate of change in temperature with respect to time (dT/dt)
- absolute voltage

Typically, -ΔV termination is used with NiCd batteries, dT/dt is used with NiMH batteries, and voltage detection is used with lead acid (Pb) batteries. The MTA11200B uses one of these principal fast charge termination methods based upon the data in EEPROM location BATINFO. BATINFO is read immediately following a power on reset or during execution of a reset command.

The MTA11200B will request fast charging via the $\overline{\text{CHG}}$ pin when the battery’s state of charge is less than the percentage value programmed in EEPROM location TONCHG. Once fast charging begins, TONCHG has no effect. Fast charging will continue until the programmable limit for the selected principal fast charge method is reached or exceeded. Fast charging can also terminate if any one of the fast charge fail-safe limits are exceeded. Maintenance charge mode will always be entered after the fast charge mode terminates. Additionally, the LED outputs $\overline{\text{P20}}$, $\overline{\text{P40}}$, $\overline{\text{P60}}$ and $\overline{\text{P80}}$ are always enabled and indicating the battery state of charge when the MTA11200B is requesting fast charge and the battery is receiving fast charge current, regardless of the state of the $\overline{\text{LEDREQ}}$ input pin.

3.2.2 FAIL-SAFE MECHANISMS

The MTA11200B provides several programmable fail-safe mechanisms. Temperature limits for both over-temperature and under-temperature are stored in EEPROM locations MAXTFC and MINTFC respectively. Fast charging will not be allowed if the battery temperature exceeds the over-temperature limit or is less than the under-temperature limit. Fast charging will begin or resume when the temperature falls within these limits.

Overvoltage and under-voltage protection is also provided by the MTA11200B. The charge request is terminated if the battery voltage exceeds the value stored in EEPROM address MAXTV. Fast charge is prevented when battery voltage is less than the value stored in EEPROM location $\overline{\text{EODV}}$.

A fast charge timer provides additional protection by limiting the amount of time that the fast charge mode may be active during any one charging cycle. This timer runs anytime fast charge mode is active. If the timer value exceeds the maximum fast charge time limit programmed in EEPROM at address OVTIM, the state of charge indication is set to 100%, the timer is turned off and is reset, and fast charge mode is terminated.

3.2.3 MAINTENANCE CHARGE MODE

The maintenance charge mode allows the battery to continue charging and remain at or near a 100% state of charge during periods of discharge inactivity. The amount of current provided to the battery is determined by the external “dumb” current source. Fail-safe limits for battery over-temperature (MAXTMC) and under-temperature (MINTMC), as well as battery overvoltage (MAXTV), can all suspend maintenance mode charging. Maintenance charging can resume when battery conditions fall back within the fail-safe limits.

3.2.4 EXTERNAL CHARGE CURRENT SOURCE CONTROL

The charge rate is controlled by the $\overline{\text{CHG}}$ pin. The $\overline{\text{CHG}}$ pin is driven high when the MTA11200B is requesting maintenance (trickle) charge current. When driven low fast charge current is requested.

The $\overline{\text{CHG}}$ pin is also used to force the MTA11200B into the ON state. This pin is sampled (i.e., becomes an input) once every 1.75 seconds. If the $\overline{\text{CHG}}$ pin is sampled high, then the MTA11200B is forced into the ON state. If it is sampled low, then no action is taken and the MTA11200B enters the standby state.

3.2.5 ΔV FAST CHARGE TERMINATION

The MTA11200B’s proprietary -ΔV algorithm makes extensive use of filtering, signal processing techniques, and heuristics to avoid premature charge termination and to retain high sensitivity. The -ΔV termination threshold is programmable and is stored in EEPROM at location NDV.

3.2.6 dT/dT FAST CHARGE TERMINATION

The MTA11200B’s dT/dt algorithm is designed to use an external thermistor to detect the rapid rise in temperature that rechargeable batteries exhibit when full charge is reached. The MTA11200B measures the battery temperature and calculates the rate temperature rise with respect to time and compares this value to the programmed DTDT threshold stored in EEPROM. When fast charging begins the measured dT/dt rate is allowed to exceed the programmed DTDT threshold for three minutes without causing a fast charge termination. Thereafter, the MTA11200B will terminate fast charge mode if the measured dT/dt rate meets or exceeds DTDT and the dT/dt rate is increasing.

3.2.7 VOLTAGE DETECTION FAST CHARGE TERMINATION

When programmed for voltage detection fast charge termination, which is typically used with lead acid batteries, the MTA11200B will terminate fast charge mode when the battery voltage meets or exceeds the limit programmed in EEPROM location LAFCV. This should not be confused with the MTA11200B fail-safe over-voltage mechanism that will remove all charge current requests if a maximum voltage limit (MAXTV) is exceeded. The MAXTV limit is a backup mechanism for fast charge termination and is always enabled. The LAFCV is a primary charge termination limit and is only active when voltage detection fast charge termination is enabled.

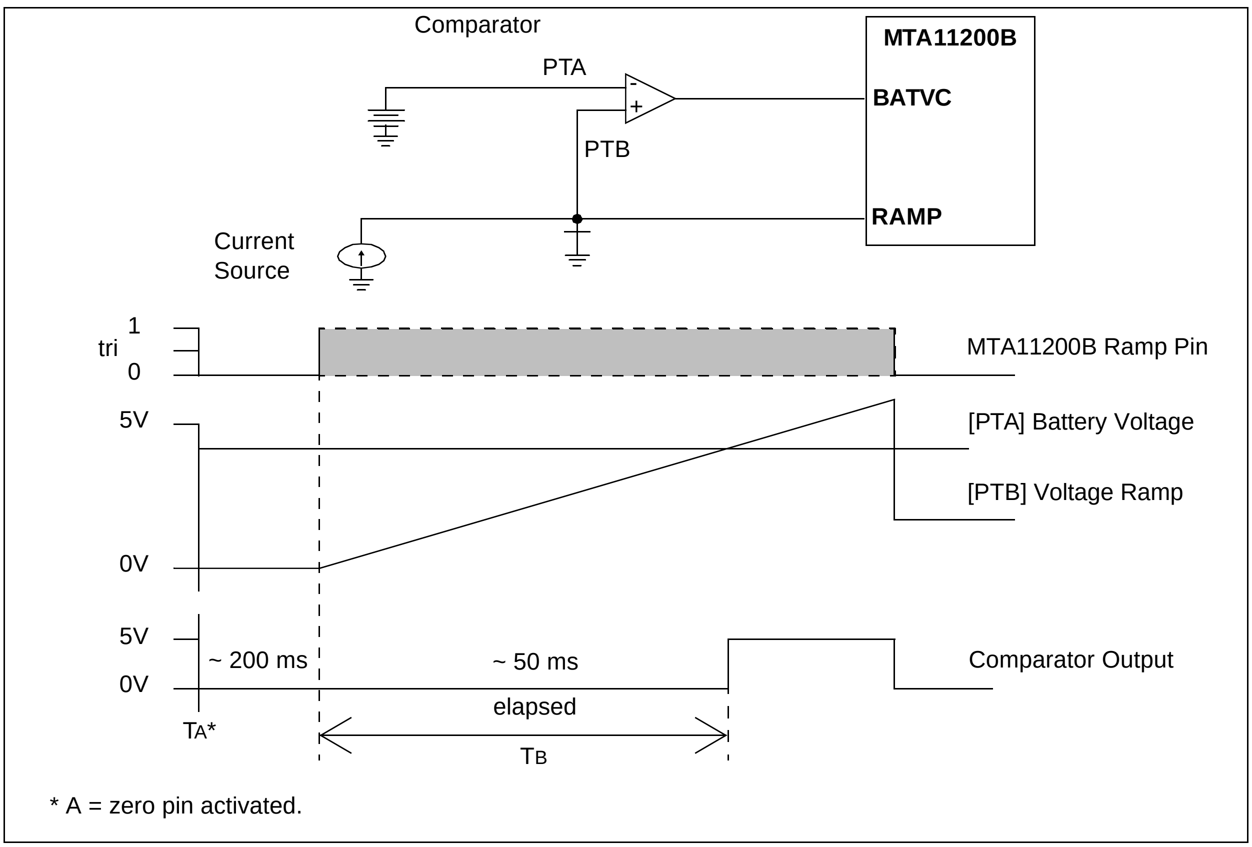
3.3 A/D Conversion

The MTA11200B uses a highly accurate timing system to control a timed voltage ramp analog-to-digital converter. Battery current, voltage and temperature are sampled every 1.75 seconds when the battery is in use.

Each measurement cycle begins by performing a comparator offset correction procedure. First the ZERO pin is driven high. Approximately 200 ms later an internal timer begins counting and the RAMP pin is driven from a low to a tristated condition. Next, the MTA11200B monitors the ISENC, and REFC inputs for a state change from low to high. The elapsed time until the state change occurs is recorded for both inputs. The total duration of this offset correction measurement is constant and takes approximately 650 ms.

The measurement cycle continues and A/D conversion starts when the ZERO pin is driven to a low state. An internal timer begins counting and the RAMP pin is driven from a low to a tristated condition. Next, the MTA11200B monitors the BATVC, ISENC, TEMPC, and REFC inputs for a state change from low to high. The elapsed time until state change occurs is recorded for each input. The duration of this measurement cycle is constant and takes approximately 650 ms. These elapsed time measurements form the basis for the A/D conversions. Figure 3-1 illustrates this form of analog-to-digital conversion.

FIGURE 3-1: A/D CONVERSION PRINCIPLE



3.3.1 A/D CALIBRATION

Calibration factors for each A/D input are stored in the Serial EEPROM. These factors compensate for component tolerances and drift for the external circuits. Typically, the calibration factors are determined and programmed into the Serial EEPROM once the external circuits are connected to the MTA11200B (i.e., at board assembly). After calibration, the MTA11200B based system is ready for use. Normally, it is then mated to a battery pack.

An “A/D Reference Point” is set during the calibration process. It allows the MTA11200B to adjust for variations in the external voltage ramp over time and temperature. The elapsed time value for the REFC input is stored in the EEPROM when the Set A/D Reference Point command is received. Typically, this command is only used once in the life of the TrueGauge system and usually occurs as the first step in the calibration process. During normal operation, the elapsed time values for the BATVC. ISENC, and TEMPC inputs are compensated for the difference in the present value of REFC and the stored “A/D Reference Point” value for REFC. Note, since the REFC input is used for drift compensation of the external voltage ramp, the other input of the comparator is kept at a constant voltage potential.

Gain values for battery current, voltage, and temperature inputs are stored in the EEPROM.

Offset correction factors are also stored for the BATVC and TEMPC inputs. The offset measurement that occurs when the ZERO pin is driven high determines the “zero” point for the ISENC input and eliminates the need for an offset correction factor for this input.

Typically, the voltage, current, and temperature gain factors in EEPROM are set equal to one prior to performing a calibration procedure. Also, the offset factors for voltage and temperature calculations are usually set to zero. Next, two known values of current (usually 0 mA and -1000 mA) are applied and the measured values reported by the MTA11200B are recorded. A current gain correction factor is then calculated from the known values of current versus the reported values. This correction factor is then written into the EEPROM.

Correction factors for voltage and temperature measurement are determined in a similar manner. Additionally, offset factors for voltage and temperature are required to ensure that the zero temperature point and the zero voltage point are correct.

During normal operation the MTA11200B uses all of these calibration factors to accurately compute the physical quantities of voltage, current, and temperature from the elapsed time measurements.

3.4 Communication

The MTA11200B communicates battery status information via a 9600 baud RS-232 serial link. It can operate as a transmit only device via a single wire connected to the TXD pin and a ground return. Or, bidirectional communication can occur via a three wire interface that uses the TXD, RXD, and CTS pins. Utilizing the three wire bidirectional mode during initial system calibration, and then switching to the single wire transmit only mode when the device is mated to a battery pack provides both a flexible and low cost battery monitoring solution.

A data broadcast mode is provided that is especially useful when a single wire interface is desired. The MTA11200B will transmit battery status data spontaneously when broadcast mode is enabled by setting the system parameter BRDINTVL to a nonzero value. BRDINTVL sets the interval between these data broadcasts. The amount of data that is sent during the broadcast can either be a single byte that indicates the battery’s state of charge in percent, or a 16-byte data packet that gives complete information about the battery. The system parameter REPMODE controls the amount of data that is broadcast.

Alternately, the three wire interface method uses a CTS handshake protocol that allows a host device to poll the MTA11200B for battery status data. Additionally, several commands are available that can be sent to the MTA11200B that allow the host to access the system control parameters stored in the EEPROM and perform other control functions.

3.4.1 DATA FORMAT

The following data format is broadcast by the MTA11200B when transmitting data to the host. This 9600 baud 8,N,1 RS-232 serial data format utilizes a 10-bit data frame that consists of 8-bits of message data and two control bits. All data to and from the MTA11200B is binary coded.

Data Frame Format:

Bit	Description
1	Start Bit (always 1)
2	Message Data Bit0, lsb
3	Message Data Bit1
4	Message Data Bit2
5	Message Data Bit3
6	Message Data Bit4
7	Message Data Bit5
8	Message Data Bit6
9	Message Data Bit7, msb
10	Stop Bit (always 0)

3.4.2 BATTERY PARAMETER DATA PACKET

When transmitting the complete set of battery status information, the MTA11200B will transmit the following 16-byte data packet:

Byte(1) = Battery Voltage in mV (lsb)

Byte(2) = Battery Voltage in mV (msb)

Byte(3) = Battery Temperature in ∞C (lsb)

Byte(4) = Battery Temperature in ∞C (msb) (signed)

Byte(5) = Battery Current magnitude in mA (lsb)

Byte(6) = Battery Current magnitude in mA (msb)

Byte(7) = Battery State of Charge in %

Byte(8) = Battery Error Byte

Byte(9) = Battery Capacity in mA-hr (lsb)

Byte(10) = Battery Capacity in mA-hr (msb)

Byte(11) = Reserved

Byte(12) = Reserved

Byte(13) = Battery Status Byte

Byte(14) = Measured dT/dt rate*

Byte(15) = Reserved

Byte(16) = Reserved

To translate the battery data into physical quantities apply the following equations and decodes.

Battery Voltage in volts =

[{Byte(2) * 256} + Byte(1)] / 1000

Battery Temperature in °C =

[Byte(3) / 256] + Byte(4)

Battery Current in Amps =

[Byte(5) + {256 * Byte(6)}] / 1000

Battery Capacity in Amp-hours =

[Byte(9) + {256 *Byte(10)}] / 1000

Measured dT/dt rate in degrees Celsius per minute =

Byte(14) / 32

Note: *Byte(14) of the data packet is only valid when the MTA11200B is configured to use dT/dt fast charge termination, otherwise this byte is undefined (Section 5.1.1)

Battery Error Byte:

Bit	Description
0	Fast Charge Time Out Error, 1 = true, 0 = false
1	Low Temperature Error, 1 = true, 0 = false
2	High Temperature Error, 1 = true, 0 = false
3	Reserved
4	Overvoltage Error, 1 = true, 0 = false
7,6,5	0,0,1 = SOC below Low Battery Alarm (Low BAT) Limit (Section 5.1.13)
7,6,5	0,1,0 = SOC below Critical Battery Alarm (CRITBAT) Limit (Section 5.1.5)
7,6,5	0,1,1 = SOC below Battery Shutdown Alarm (SHUTDN) Limit (Section 5.1.29)
7,6,5	1,0,0 = SOC below EODV Limit (Section 5.1.7)

SOC = Indicated Battery State of Charge in percent

Battery Status Byte:

Bit	Description
0	Sign of Current, 1= Charging, 0 = Discharging
1	Reserved
2	Reserved
3	Reserved
4	Charge Current Request, 1 = turn on current, 0 = turn off current
5	Capacity Measurement Request, 1 = true, 0 = false
6	Capacity Measurement in Progress, 1 = true, 0 = false
7	Fast Charge Request, 1 = Fast charge, 0 = maintenance charge

4.0 COMMANDS

Command	Code, Data	Units
Read EEPROM byte	F0,XX	XX= Address
Write EEPROM byte	F1,XX,YY	XX= Address YY= Data
Send State of Charge (SOC)	F2	Percentage
Send Firmware Revision	F3	Rev. Number (Hex)
Send Battery Data	F4	16 bytes, mixed data types (see text)
reserved	F5	n/a
reserved	F6	n/a
Execute Self-test	F7	n/a
Start Capacity Measurement Cycle	F8	n/a
Clear Battery Errors	F9	n/a
Initialize EEPROM	FA,XX,...,XX	128 bytes
Reset	FB	n/a
Set A/D Reference Point	FC	n/a
Toggle EEPROM Lock	FD	n/a
High Speed Read EEPROM	FE	128 bytes
Force Capacity to 100%	FF	n/a

4.1 Read EEPROM Code: F0h,XXh

This command reads one Serial EEPROM byte at the specified address. Upon receiving this command, the MTA11200B issues a read command to the Serial EEPROM via the I^2C bus. The Serial EEPROM responds with the data at the specified address. The MTA11200B receives the serial EEPROM's response and in turn transmits this data in RS-232 format on the TXD pin.

4.2 Write EEPROM Code: F0h,XXh

This command writes one byte of data to the Serial EEPROM at the specified address. Then a read of the EEPROM address is performed and the read data is transmitted back to the host. This adds additional security to the write operation by allowing the host to quickly verify that the data was written correctly.

When the WRITE EEPROM command is received the MTA11200B issues a write command to the Serial EEPROM on its I^2C bus port (SCL and SDA). The MTA11200B then issues a read command to the Serial EEPROM via the I^2C bus. When the Serial EEPROM responds with the data at the specified address the MTA11200B forwards the serial EEPROM's response to the host by transmitting this data in RS-232 format on the TXD pin.

4.3 Send State Of Charge Code: F2h

The MTA11200B will transmit a single byte that indicates the battery's internal state of charge in response to the Send State of Charge command. This byte is limited to the range from 0 to 64h inclusive and indicates from 0% to 100% state of charge.

4.4 Send Firmware Revision Code: F3h

In response to this command the MTA11200B will transmit a single byte that indicates the internal firmware version and revision. The most significant four bits of this byte represent the version number and the least significant four bits indicate the revision status.

> **Note:** There is no predefined correlation between the firmware version and the MTA11200B revision status as physically marked on the I.C.

4.5 Send Battery Data Code Code: F4h

The MTA11200B transmits a 16-byte data packet in response to this command. This data provides complete information about the present status of the battery. The data packet is defined as follows:

Byte (n)	Battery Data
1	Voltage LSB
2	Voltage MSB
3	Temperature LSB
4	Temperature MSB
5	Current LSB
6	Current MSB
7	State of Charge
8	Error Byte
9	Measured Total Capacity Byte1
10	Measured Total Capacity Byte2
11	Reserved
12	Reserved
13	Flag Byte
14	Measured dT/dt
15	Reserved
16	Reserved

4.6 Start Capacity Measurement Cycle Code: F8h

This command forces the initiation of a battery capacity measurement sequence in the MTA11200B controller. First the internal discharge count register is cleared. Next, the MTA11200B will total all discharge current until the programmed End Of Discharge Voltage ($\overline{\text{EODV}}$) is reached or the discharge is aborted (i.e., charge current is detected or current goes to zero). If the discharge is aborted then this capacity measurement cycle is abandoned. Otherwise, the measured total capacity is copied to the internal total capacity register and is also written to system parameter MEACAP in the EEPROM.

4.7 Clear Battery Errors Code: F9h

This command clears the error bits in the Battery Error Byte. The Time-out Error, Under-temperature Error, Over-temperature Error, and Overvoltage bits are all reset to zero. Additionally, if an error bit was set prior to receipt of the Clear Battery Errors command the associated error counter in EEPROM will be incremented when the error bit is reset. For example, if a Clear Battery Errors command is executed when the Over-temperature error bit in the Battery Error Byte is set then the Over-temperature error bit in the Battery Error byte will be reset and the error counter HITERRS in EEPROM will be incremented.

4.8 Initialize EEPROM Code: FAh

This command is used to initialize the MTA11200B system parameters in external EEPROM. The MTA11200B accepts 128 bytes of data that will be written sequentially into the EEPROM starting at location “0”. The MTA11200B suspends all operations while receiving this data and writing it to the EEPROM. This allows the EEPROM data to be initialized at a much faster rate than using the single-byte Write EEPROM command.

4.9 Reset Code: FBh

This command initiates a power up reset sequence in the MTA11200B controller. First, all internal registers and operating parameters are cleared. Next, the present state of charge is reset to zero percent and the total battery capacity is read from location MEACAP in EEPROM and normal operation begins. This command has the effect of driving the $\overline{\text{CLR}}$ pin from low to high.

4.10 Set A/D Reference Code: FCh

This Set A/D Reference command causes the MTA11200B to measure and record a reference point for the A/D converter. The MTA11200B maintains the high accuracy of the A/D by using this reference point to compensate for drift in the A/D circuits over time and temperature. This command is usually issued only once during the normal operating life of the battery monitoring system. It is normally issued as the first step of the A/D calibration process.

The MTA11200B measures the amount of time that elapses from when it tristates the RAMP pin until the REFC pin goes to a high state. When the Set A/D command is issued this value is then stored as the A/D reference point in EEPROM at location REFVAL. Subsequently, during each conversion cycle the stored value is compared with the measured amount of time and all A/D measurements are compensated accordingly.

4.11 Reserved Commands Code: (Fxh)

Command codes F5h and F6h are reserved and should not be sent to the MTA11200B. Unpredictable operation may result if the MTA11200B receives one or more reserved command codes.

4.12 Unspecified Commands

Command codes not in the range of F0h to FFh are unspecified. The MTA11200B will completely ignore command codes that are not within the range F0h to FFh.

4.13 High Speed EEPROM Read Code: FEh

This command reads 128 Serial EEPROM bytes starting with address “0”. Upon receiving this command the MTA11200B enters a loop that reads a byte from the Serial EEPROM and transmits this data in RS-232 format on the TRANSMIT pin. The loop continues until all 128 bytes have been read and transmitted. Note that in response to this command the data is transmitted spontaneously and cannot delayed or interrupted.

4.14 Toggle EEPROM Lock Code: FDh

This command toggles the MTA11200B’s internal EEPROM Lock bit. The MTA11200B responds by transmitting the new state of the EEPROM Lock where 00 indicates locked and AA indicates unlocked. When locked all writes to the EEPROM are disabled except for writes to EEPROM addresses 20h through 2Fh.

4.15 Force 100% Capacity Indication Code: FFh

This command forces the percent capacity indication to be set to 100% to force the MTA11200B to behave as if the battery is fully charged.

This command is provided to aid manufacturing testability of end products.

4.16 Perform Self-test Code: F7h

This command causes the MTA11200B to initiate a self-test sequence. Upon completion of the self-test sequence a single byte will be transmitted to indicate a test pass (AAh) or fail (any non-AAh data). Two checks of external circuits are included in the self test sequence. The state of RAMP pin is tested at 1 ms and 500 ms after the RAMP pin is driven from a low to tristate by the MTA11200B. The RAMP pin must be low at the 1 ms sample point and high at the 500 ms sample point for this test to pass. If these conditions are not satisfied the MTA11200B will return a 01H code indicating an A/D ramp failure.

Next, the LED outputs $\overline{\text{P20}}$, $\overline{\text{P40}}$, $\overline{\text{P60}}$, and $\overline{\text{P80}}$ are individually driven low in sequence starting with $\overline{\text{P20}}$ for a period of 125 ms each.

5.0 CONFIGURATION PARAMETERS

The MTA11200B is designed to work in conjunction with an external Serial EEPROM that stores configuration parameters for the MTA11200B. The MTA11200B communicates with the Serial EEPROM via the SCL and SDA pins. Standard I^2C bus communication protocol is used.

The parameters that are stored in Serial EEPROM are variables that control the MTA11200B's mode of operation and variables that describe the characteristics of the battery that the TrueGauge is monitoring. These system parameters range from single-byte values to four-byte values. All multi-byte system parameters are stored in little endian (low byte first) format.

All bytes and bits declared as reserved must be programmed to a value of zero (0).

TABLE 5-1: SYSTEM PARAMETER STORAGE MAP FOR SERIAL EEPROM

Addr (hex)	Parameter	Addr (hex)	Parameter	Addr (hex)	Parameter	Addr (hex)	Parameter
0	REVID	20	TCC -lb	40	CESC(0)	60	SDFT(0) lb
1	BATINFO	21	TCC-hb	41	CESC(1)	61	SDFT(0) hb
2	NOMCAP- lb	22	TOERRS	42	CESC(2)	62	SDFT(1) lb
3	NOMCAP - lmb	23	LOTERRS	43	CESC(3)	63	SDFT(1) hb
4	NOMCAP - hmb	24	HITERRS	44	CESC(4)	64	SDFT(2) b
5	NOMCAP - hb	25	HIVERRS	45	CESC(5)	65	SDFT(2) hb
6	reserved	26	reserved	46	CESC(6)	66	SDFT(3) b
7	reserved	27	reserved	47	CESC(7)	67	SDFT(3) hb
8	MAXTFC	28	reserved	48	CESC(8)	68	SDFT(4) b
9	MINTFC	29	reserved	49	CESC(9)	69	SDFT(4) hb
0A	MAXTMC	2A	reserved	4A	CESC(10)	6A	SDFT(5) b
0B	MINTMC	2B	reserved	4B	CESC(11)	6B	SDFT(5) hb
0C	reserved	2C	MEACAP - lb	4C	CESC(12)	6C	SDFT(6) b
0D	MAXTV	2D	MEACAP - lmb	4D	CESC(13)	6D	SDFT(6) hb
0E	reserved	2E	MEACAP - hmb	4E	CESC(14)	6E	SDFT(7) b
0F	reserved	2F	MEACAP - hb	4F	CESC(15)	6F	SDFT(7) hb
10	TONCHG	30	REFVAL - lb	50	CEFT(0)	70	SDFT(8) b
11	CCCR	31	REFVAL - hb	51	CEFT(1)	71	SDFT(8) hb
12	USER	32	VSC -lb	52	CEFT(2)	72	SDFT(9) b
13	USER	33	VSC - hb	53	CEFT(3)	73	SDFT(9) hb
14	USER	34	VOC - lb	54	CEFT(4)	74	SDFT(10) b
15	USER	35	VOC - hb	55	CEFT(5)	75	SDFT(10) hb
16	DTDT	36	ISC - lb	56	CEFT(6)	76	SDFT(11) b
17	OVTIM - lb	37	ISC - hb	57	CEFT(7)	77	SDFT(11) hb
18	OVTIM - hb	38	TSC - lb	58	CEFT(8)	78	SDFT(12) b
19	EODV	39	TSC - hb	59	CEFT(9)	79	SDFT(12) hb
1A	NDV	3A	TOC - lb	5A	CEFT(10)	7A	SDFT(13) b
1B	LOWBAT	3B	TOC - hb	5B	CEFT(11)	7B	SDFT(13) hb
1C	CRITBAT	3C	reserved	5C	CEFT(12)	7C	SDFT(14) hb
1D	SHUTDN	3D	reserved				
1E	REPMODE	3E	LAFCV-lb				
1F	REPINTRVL	3F	LAFCV-hb				

5.1 Configuration Parameters (listed in alphabetical order)

5.1.1 BATINFO

Battery Information Byte

EEPROM Address	1h
Allowable Range	Number of cells = 0 to 15
Typical Value	N/A
Stored Value	(See below)

The battery information byte specifies the number of series connected cells in the battery pack and the fast charge termination technique being used. Parallel connected cells should only be counted as one cell.

Stored Value:

Bits 7-4: Number of cells in the battery pack (0-15)

Bits 3-2: Reserved (unused)

Bit1: Voltage Limit Fast Charge Termination,
1 = enabled, 0 = disabled

Bit0: Fast Charge Termination Technique,
1= dT/dt, 0 = -ΔV

Bits 0 and 1 are mutually exclusive. If voltage limit fast charge termination is enabled then bit0 is ignored and -ΔV or dT/dt termination is disabled.

5.1.2 CCCR

Charge Cycles between Capacity Measurement Requests

EEPROM Address	11h
Allowable Range	0 to 255
Typical Value	5 to 25
Stored Value	Number of Charge Cycles

The charge cycles between capacity measurement requests parameter specifies the number of full or partial charge cycles that occur before the MTA11200B will issue a request for a battery capacity measurement cycle.

This request is indicated in the flag byte of the battery parameter's data packet. An internal counter is incremented each time fast charge mode is terminated by exceeding any of the following limits:

- dT/dt
- -ΔV
- absolute voltage

If a capacity measurement cycle successfully completes, then this internal charge cycle counter will be reset to zero.

5.1.3 CESC(0 15)

Charge Efficiency vs. State of Charge

EEPROM Addresses	40h through 4Fh
Allowable Range	0 to 99.6%
Typical Value	N/A
Stored Value	% Efficiency) * 25.6

The charge efficiency versus state of charge table is a sixteen-byte lookup table. These compensation parameters adjust for the less than 100% charge acceptance efficiency that batteries display when charging. This table contains charge efficiency factors for the ranges of percent capacity from 0% to 3% and 90% to 100%, in 1% increments. The capacity range from 4% to 89% is compensated with a single factor. Each entry in the table specifies charge efficiency as a fraction of 256. A value of 128 (07Fh) indicates 50% charge efficiency whereas a value of (0ECh) indicates 92.2% charge efficiency.

TABLE 5-2: CHARGE EFFICIENCY VS STATE OF CHARGE COMPENSATION

Addr	Parameter	Definition
40h	CESC(0)	Chg eff. for chg state 0%
41h	CESC(1)	Chg eff. for chg state 1%
42h	CESC(2	Chg eff. for chg state 2%
43h	CESC(3)	Chg eff. for chg state 3%
44h	CESC(4)	Chg eff. for chg state 4% to 89%
45h	CESC(5)	Chg eff. for chg state 90%
46h	CESC(6)	Chg eff. for chg state 91%
47h	CESC(7)	Chg eff. for chg state 92%
48h	CESC(8)	Chg eff. for chg state 93%
49h	CESC(9)	Chg eff. for chg state 94%
4Ah	CESC(10)	Chg eff. for chg state 95%
4Bh	CESC(11)	Chg eff. for chg state 96%
4Ch	CESC(12)	Chg eff. for chg state 97%
4Dh	CESC(13)	Chg eff. for chg state 98%
4Eh	CESC(14)	Chg eff. for chg state 99%
4Fh	CESC(15)	Chg eff. for chg state 100%

5.1.4 CEFT(0-15)

Charge Efficiency versus Temperature

EEPROM Addresses	50h through 5Fh
Allowable Range	0 to 100%
Typical Value	N/A
Stored Value	(% Efficiency) * 2.56

The charge efficiency versus temperature table is a sixteen-byte lookup table. These compensation parameters adjust for the decrease in charge acceptance efficiency that batteries typically exhibit as their temperature increases. This table stores compensation factors for a temperature range of 0°C to 60°C, in 4°C increments. Each entry in the table specifies charge efficiency as a fraction of 256, which indicates 100% charge efficiency. For example, a value of 128 (07Fh) indicates 50% charge efficiency and a value of 253 (0FDh) indicates 98.8% charge efficiency.

TABLE 5-3: CHARGE EFFICIENCY VS CHARGE STATE COMPENSATION TABLE

Addr	Parameter	Definition
50h	CEFT(0)	Chg eff. for temperature 0°C
51h	CEFT(1)	Chg eff. for temperature 4°C
52h	CEFT(2)	Chg eff. for temperature 8°C
53h	CEFT(3)	Chg eff. for temperature 12°C
54h	CEFT(4)	Chg eff. for temperature 16°C
55h	CEFT(5)	Chg eff. for temperature 20°C
56h	CEFT(6)	Chg eff. for temperature 24°C
57h	CEFT(7)	Chg eff. for temperature 28°C
58h	CEFT(8)	Chg eff. for temperature 32°C
59h	CEFT(9)	Chg eff. for temperature 36°C
5Ah	CEFT(10)	Chg eff. for temperature 40°C
5Bh	CEFT(11)	Chg eff. for temperature 44°C
5Ch	CEFT(12)	Chg eff. for temperature 48°C
5Dh	CEFT(13)	Chg eff. for temperature 52°C
5Eh	CEFT(14)	Chg eff. for temperature 56°C
5Fh	CEFT(15)	Chg eff. for temperature 60°C

5.1.5 CRITBAT

Critical Battery Level

EEPROM Address	1Ch
Allowable Range	SHUTDN < CRITBAT < LOWBAT
Typical Value	3%
Stored Value	Integer limit in %

A bit in the FLAGBYTE portion of the battery parameter data packet is set when the battery state of charge is less than the CRITBAT limit. The MTA11200B will indicate a critical battery level and mask off a low battery level indication in response to state of charge falling below this limit. Conversely, the critical level indication will be cleared and the low battery level alarm will be unmasked when the state of charge exceeds the CRITBAT limit. The programmed value of this parameter must be between the limits set for the SHUTDN and LOWBAT parameters.

5.1.6 DTDT

Delta Temperature Delta Time

EEPROM Address	16h
Allowable Range	0 to 7.97 °C/minute
Typical Value	0.5 to 1.0 °C/minute
Stored Value	(°C/minute) * 32

This parameter specifies the rate of change in temperature in degrees Celsius over a one minute interval that will terminate a fast charge request. For example, to set a 0.625 °C/minute rate termination limit the DTDT stored value would be 0.625 *32 = 20.

5.1.7 EODV

End of Discharge Voltage

EEPROM Address	19h
Allowable Range	0 to 65.28 Volts
Typical Value	Pb (1.7V to 1.8V) * (# of cells)
Stored Value	(Limit in Volts) / 0.256

The End Of Discharge Voltage parameter specifies the battery voltage when the battery is at 0% capacity. It is the value indicated by EODV is multiplied by 256 mV to obtain the specified end of discharge voltage for the battery. This parameter establishes an end point for the battery state of charge calculation. It also prevents the MTA11200B from requesting fast charge when the battery voltage is less than EODV. A typical value for both NiCd and NiMH battery packs is calculated by multiplying 1.05V times the number of cells in the battery pack. This formula assumes that the cells are electrically connected in a series fashion.

5.1.8 HITERRS

Over Temperature Errors

EEPROM Address	24h
Allowable Range	0 to 255
Typical Value	0
Stored Value	Number of Errors

This parameter is incremented each time an Over Temperature Error, as defined by the MAXTFC or MAXTMC parameters, occurs and is acknowledged by a host via the RS-232 link. This error counter will be incremented immediately after the host issues a clear battery errors command if an over temperature error has occurred.

5.1.9 HIVERRS

Over Voltage Errors

EEPROM Address	25h
Allowable Range	0 to 255
Typical Value	0
Stored Value	Number of Errors

This parameter is incremented each time an Over Voltage Error, as defined by the MAXTV parameter, occurs and is acknowledged by the host. This error counter will be incremented immediately after the host issues a clear battery errors command if an over voltage error has occurred.

5.1.10 ISC

Current Slope Correction

EEPROM Address	36h (lsb) and 37h (msb)
Allowable Range	0 to 65535
Typical Value	256 (100h)
Stored Value	Current Gain * 256

The Current Slope Correction factor provides a fixed gain that is applied to the A/D conversion calculation of the battery current. Gain factors from 1/256 to 255 are available. This factor is normally determined when the A/D converter is calibrated. A value of 100h corresponds to a gain of 1.0.

5.1.11 LAFCV

Lead Acid Fast Charge Cutoff Voltage

EEPROM Address	3Eh (lsb) and 3Fh (msb)
Allowable Range	0 to 65.28V
Typical Value	Pb (2.5V to 2.7V) * number of cells
Stored Value	Volts / 1000

The Lead Acid Fast Charge Cutoff Voltage applies when voltage limit fast charge termination is specified by parameter BATINFO. This is a sixteen-bit (two-byte) value that indicates the termination voltage in 1 mV increments. A value of 13450 (348A HEX) specifies a 13.340V termination limit.

Voltage limit termination is generally the preferred method of fast charge termination used with lead acid batteries.

5.1.12 LOTERRS

Under Temperature Errors

EEPROM Address	23h
Allowable Range	0 to 255
Typical Value	0
Stored Value	Numbers of Errors

This parameter is incremented each time an Under Temperature Error, as defined by the MINTFC or MINTMC parameters, occurs and is acknowledged by the host. This error counter will be incremented immediately after the host issues a clear battery errors command if an under-temperature error occurs.

5.1.13 LOWBAT

Low Battery Warning Level

EEPROM Address	1Bh
Allowable Range	CRITBAT < LOWBAT <100%
Typical Value	5%
Stored Value	Integer limit in %

A bit in the ERRORBYTE portion of the battery parameter data packet is set when the battery state of charge is less than the LOWBAT limit. This alarm sets the appropriate bit in ERRORBYTE. No other action by the MTA11200B is taken in response to the alarm. The value of this parameter must be greater than the CRITBAT limit and less than 100%.

5.1.14 MAXTFC

Maximum Temperature for Fast Charge

EEPROM Address	8h
Allowable Range	0 to 255°C
Typical Value	40°C to 50°C
Stored Value	Integer limit in °C

Maximum Temperature for Fast Charge specifies the maximum temperature limit for fast charging. If the temperature exceeds this limit fast charging will be terminated. MAXTFC is an 8-bit (1-byte) value that indicates the temperature limit value in 1°C increments. For example, a value of 40 (28h) equals a 40°C over temperature fast charge termination limit.

5.1.15 MAXTMC

Maximum Temperature for Maintenance Charge

EEPROM Address	0Ah
Allowable Range	0 to 255°C
Typical Value	50°C to 60°C
Stored Value	Integer limit in °C

Maximum Temperature for Maintenance Charge specifies the maximum temperature limit for maintenance charging. If the temperature exceeds this limit all charging will be terminated. MAXTFC is an 8-bit (1-byte) value that indicates the temperature limit value in 1°C increments. For example, a value of 50 (32h) equals a 50°C over temperature charge termination limit.

5.1.16 MAXTV

Maximum Terminal Voltage

EEPROM Address	0Dh
Allowable Range	0 to 65.28 Volts
Typical Value	NiCd (1.5V to 1.7V) * (number of cells) NiMH (1.5V to 1.7V) * (number of cells) Pb (2.8V to 3.0V) * (number of cells)
Stored Value	(Limit in Volts) / 0.256

Maximum Terminal Voltage specifies the maximum voltage allowed during charging. If the battery voltage exceeds this value then all charge requests, both fast and maintenance charging will be terminated and the $\overline{\text{CHG}}$ pin will be driven low.

The actual terminal voltage is obtained by multiplying the value stored in MAXTV by 256 mV.

5.1.17 MEACAP

Measured Battery Capacity

EEPROM Address	2Ch (lsb) through 2Fh (msb)
Allowable Range	0 to 2,087,831 mA-hr
Typical Value	Nominal Battery Capacity
Stored Value	(Capacity in mA-hr)*(2057.14)

This parameter is updated with the measured capacity of the battery each time a manual or automatic battery capacity calibration is performed by the MTA11200B. A four-byte value is stored that indicates the measured capacity in mA-Sec /1.75.

5.1.18 MINTFC

Minimum Temperature for Fast Charge

EEPROM Address	9h
Allowable Range	0 to 255 °C
Typical Value	10°C
Stored Value	Integer limit in °C

Minimum Temperature for Fast Charge specifies the minimum temperature limit for fast charging. If the temperature is below this limit fast charging will be terminated. MINTFC is an 8-bit (1-byte) value that indicates the temperature limit value in 1°C increments. For example, a value of 10 (0Ah) equals a 10°C under temperature fast charge termination limit.

5.1.19 MINTMC

Minimum Temperature for Maintenance Charge

EEPROM Address	0Bh
Allowable Range	0 to 255 °C
Typical Value	0°C
Stored Value	Integer limit in °C

Minimum Temperature for Maintenance Charge specifies the minimum temperature limit for maintenance charging. If the temperature is below this limit all charge requests will be terminated. MINTMC is an 8-bit (1-byte) value that indicates the temperature limit value in 1°C increments. For example, a value of 5 equals a 5°C under temperature charge termination limit.

5.1.20 NDV

Negative Delta Voltage Threshold

EEPROM Address	1Ah
Allowable Range	0 to 255 mV
Typical Value	NiCd (2mV to 4mV) * (number of cells) NiMH (1mV to 2mV) * (number of cells) Pb n/a
Stored Value	Limit in mV

The Negative Delta Voltage Threshold specifies the amount of voltage decay that is required for termination of a fast charge cycle. This voltage decay is referenced from the peak voltage obtained during the fast charge cycle. ΔV termination must be enabled in the BATINFO parameter for this threshold voltage to control fast charge termination.

5.1.21 NOMCAP

Nominal Battery Capacity

EEPROM Address	2h(lsb) through 5h(msb)
Allowable Range	0 to 2,087,831 mA-hr
Typical Value	Nominal Battery Capacity
Stored Value	(Capacity in mA-hr) *(2057.14)

This parameter is a storage location for saving the rated capacity of the battery pack. With this information a smart host can determine if the battery has reached end of life or is malfunctioning by comparing the rated capacity with the measured capacity. A 4-byte value is stored that indicates the rated capacity in mA-Sec/75. This value is not used by the MTA11200B for any capacity calculations or error detection.

5.1.22 OVTIM

Override Timer

EEPROM Address	17h(lsb) and 18h(msb)
Allowable Range	0 to 57342 seconds
Typical Value	1.5 * (Nom. capacity mA-hr * 3600sec/hr) /Fast chg rate mA
Stored Value	(Limit in seconds) / 1.75

The override timer specifies the maximum amount of time that a fast charge cycle is allowed to be active. If a fast charge cycle exceeds this time limit a time-out error is logged. The time limit is calculated by multiplying the value of OVTIM by 1.75 seconds.

5.1.23 5.23 REFVAL

A/D Reference Value

EEPROM Address	30h(lsb) and 31h(msb)
Allowable Range	0 to 64535
Typical Value	N/A
Stored Value	Reference level

This location is where the MTA11200B stores the A/D reference value that is set during the A/D calibration procedure.

5.1.24 REPMODE

Reporting Mode

EEPROM Address	1Eh
Allowable Range	N/A
Typical Value	N/A
Stored Value	(See below)

Reporting Mode defines the amount of data broadcast by the MTA11200B when broadcasting is enabled as well as the type of data output on the LED drive pins $\overline{P20}$, $\overline{P40}$, $\overline{P60}$, and $\overline{P80}$. REPMODE is defined as follows:

Bits 7 Broadcast data select, 1 = send entire 16-byte battery parameter packet. 0 = send only the single byte percent capacity indication.

Bit 6-1: Reserved (program to 0)

Bit 0 LED mode select, 1 = LED outputs are BCD code 0 through 10 that represents 0 percent to 100 percent remaining battery capacity in 10% increments, 0 = LED outputs represent discrete >20%, >40%, >60%, and >80% levels.

5.1.25 REPINTRVL

Report Interval

EEPROM Address	1Fh
Allowable Range	0 to 222.25 seconds
Typical Value	5.25 to 31.5 sec
Stored Value	(Interval in seconds) / 1.75

The report interval byte specifies the interval between battery data broadcasts on the RS-232 link. The time between data broadcasts from the MTA11200B will be 1.75 seconds times the value contained in REPINTRVL. If a polling scheme of communication is desired then REPINTRVL can be set to zero and will battery data broadcasting will be disabled.

5.1.26 RESERVED

Reserved Locations

EEPROM Address	Various
Allowable Range	0
Typical Value	0
Stored Value	0

All location listed as RESERVED are not presently used by the MTA11200B. They are however reserved for future versions or revisions of the TrueGauge family. These locations must be initially programmed to a value of zero. EEPROM locations defined as USER are provided for general purpose data storage.

5.1.27 REVID

EEPROM Revision Identification

EEPROM Address	0h
Allowable Range	0 to 255
Typical Value	N/A
Stored Value	Revision

This location allows a revision identifier to accompany the system parameter EEPROM data set. When a set of system parameters are defined for use with a particular battery and/or system an identifier can be allocated and stored at location REVID. This allows unique data sets to be identified. This REVID location is provided as a convenience feature only and not used by the MTA11200B for any control or monitoring functions.

5.1.28 SDFT(0-15)

Self-discharge as a Function of Temperature

EEPROM Address	60h through 7Fh
Allowable Range	0 65535
Typical Value	N/A
Stored Value	K

The self-discharge versus temperature lookup table provides the factor K, that is used in the self-discharge compensation calculation:

Compensated SOC = SOC - (SOC * [K / 2^{24}])

SOC (State Of Charge)

The battery state of charge is decreased once every 138 seconds when battery is idle and this calculation is applied. The compensation factors cover the temperature range of 0°C up to 60°C in 4°C increments. For temperatures in excess of 60°C, the 60°C compensation factor is applied. Similarly, for temperatures below 0°C the 0°C factor is used.

TABLE 5-4: SELF-DISCHARGE VS TEMPERATURE COMPENSATION TABLE

Addr	Parameter	Definition
61h, 60h	SDFT(0)	Self-dischg const. for 0°C
63h, 62h	SDFT(1)	Self-dischg const. for 4°C
65h, 64h	SDFT(2)	Self-dischg const. for 8°C
67h, 66h	SDFT(3)	Self-dischg const. for 12°C
69h, 68h	SDFT(4)	Self-dischg const. for 16°C
6Bh, 6Ah	SDFT(5)	Self-dischg const. for 20°C
6Dh, 6Ch	SDFT(6)	Self-dischg const. for 24°C
6Fh, 6Eh	SDFT(7)	Self-dischg const. for 28°C
71h, 70h	SDFT(8)	Self-dischg const. for 32°C
73h, 72h	SDFT(9)	Self-dischg const. for 36°C
75h, 74h	SDFT(10)	Self-dischg const. for 40°C
77h, 76h	SDFT(11)	Self-dischg const. for 44°C
79h, 78h	SDFT(12)	Self-dischg const. for 48°C
7Bh, 7Ah	SDFT(13)	Self-dischg const. for 52°C
7Dh, 7Ch	SDFT(14)	Self-dischg const. for 54°C
7Fh, 7Eh	SDFT(15)	Self-dischg const. for 60°C

5.1.29 SHUTDN

Shutdown Alarm Limit

EEPROM Address	1Dh
Allowable Range	0 < SHUTDN < CRITBAT
Typical Value	1%
Stored Value	Integer limit in %

A bit in the FLAGBYTE portion of the battery parameter data packet is set when the battery state of charge is less than the SHUTDN limit. This alarm sets the appropriate bit in FLAGBYTE. The MTA11200B will mask off a battery critical level indication in response to this alarm. The alarm will be cleared and the critical level alarm will be unmasked when the state of charge exceeds the SHUTDN level. The value of this parameter must be between 0 and the CRITBAT limit.

5.1.30 TCC

Total Charge Cycle Counter

EEPROM Address	20h (lsb) and 21h (msb)
Allowable Range	0 to 65535
Typical Value	0 (initial)
Stored Value	Number of charge cycles

This parameter is incremented each time a charge cycle is terminated by exceeding a dT/dt, -ΔV or absolute voltage limit threshold.

5.1.31 TOC

Temperature Offset Correction Factor

EEPROM Address	3Ah (lsb) and 3Bh (msb)
Allowable Range	-32766 (80h) to 32767 (7Fh)
Typical Value	0
Stored Value	Voltage offset in °C / 256

The Temperature Offset Correction factor provides a fixed value that is added to the A/D conversion calculation of the Temperature. There are Offset factors from (-32766/256) to (32767/256) °C available. This factor is normally determined when the A/D converter is calibrated.

5.1.32 TOERRS

Time-out Errors Counter

EEPROM Address	22h
Allowable Range	0 to 255
Typical Value	0
Stored Value	Number of Errors

This parameter is incremented each time a Time Out Error, as defined by the OVTIM parameter, occurs. This error counter will be incremented when the error is acknowledged when the host issues a Clear Battery Errors Command.

5.1.33 TONCHG

Fast Charge Turn On Threshold

EEPROM Address	10h
Allowable Range	0 to 100
Typical Value	90% to 96%
Stored Value	Threshold in %

This parameter controls the point at which the charge controller will enter fast charge mode.

5.1.34 TSC

Temperature Slope Correction

EEPROM Address	38h (lsb) and 39h (msb)
Allowable Range	0 to 65535
Typical Value	256 (100h)
Stored Value	Temperature Gain * 256

The Temperature Slope Correction factor provides a fixed gain that is applied to the A/D conversion calculation of the battery temperature. Gain factors from 1/256 to (255+255/256) are available. This factor is normally determined when the A/D converter is calibrated.

5.1.35 USER

User Storage

EEPROM Address	12h through 15h
Allowable Range	N/A
Typical Value	N/A
Stored Value	N/A

These locations are not used by the MTA11200B and will not be used by future versions. They are available to the user for general purpose data storage.

5.1.36 VOC

Voltage Offset Correction

EEPROM Address	34h (lsb) and 35h (msb)
Allowable Range	-32768 (80h) to 32767 (7Fh)
Typical Value	0
Stored Value	Voltage offset in mV

The Voltage Offset Correction factor provides a fixed value that is added to the A/D conversion calculation of the battery voltage. Offset factors from -32768 mV to 32767 mV are available. This factor is normally determined when the A/D converter is calibrated.

5.1.37 VSC

Voltage Slope Correction

EEPROM Address	32h (lsb) and 33h (msb)
Allowable Range	0 to 65535
Typical Value	256 (100h)
Stored Value	Voltage Gain * 256

The Voltage Slope Correction factor provides a fixed gain that is applied to the A/D conversion calculation of the battery voltage. Gain factors from 1/256 to (255+255/256) are available. This factor is normally determined when the A/D converter is calibrated.

5.2 ENHANCEMENTS

Several new configuration parameters have been added to the MTA11200B. Many of these options are individual bit settings which are stored in the OPTB register. Not using B options allows the MTA11200B to be compatible with older MTA11200 designs.

5.2.1 BOPT

B-Options

EEPROM Address	06h
Allowable Range	N/A
Typical Value	N/A
Stored Value	0

5.2.1.1 BIT0: FAST CHARGE TERMINATION

The choices for this option are listed below:

- Does not affect percent capacity gauge
- Forces percent capacity gauge to 100%

The default selection will force the capacity to 100% when the fast charge termination is reached. Some battery types may achieve the fast charge termination before 100% capacity is reached, requiring a slower rate to achieve full capacity. Therefore, this alternative option is provided.

5.2.1.2 BIT1: PRIMARY FAST CHARGE TERMINATION METHOD

The choices for this option are listed below:

- Stop fast charge when gauge at 100% or dT/dt defect
- Stop fast charge on dT/dt detect

The default selection will terminate fast charge on a valid dT/dt detect only. In the event of a battery which must not receive any overcharge, the option may be selected to terminate fast charge on reaching 100% capacity. This option should only be used in the presence of a trickle charge, to ensure that untapped capacity be utilized.

5.2.1.3 BIT2: NEGATIVE DELTA VOLTAGE CONTROL OPTION

The choices for this option are listed below:

- Use current monitor to prevent false -dV detects
- Use voltage monitor to prevent false -dV detects

In the event that a load is engaged while a battery is charging, a corresponding drop in battery voltage may cause a false -dV trip. Therefore, the new default current monitor option is intended to provide protection against this false fast charge termination. The voltage method is retained to provide backward compatibility with previous revisions.

5.2.1.4 BIT3: WAKE UP FROM STANDBY IF CURRENT LEVEL REACHED

The choices for this option are listed below:

- Enable wake up
- Disable wake up

The default selection will enable this wake up on current sense. This option eliminates the need to pull up the $\overline{\text{CHG}}$ pin on TrueGauge. A separate scroll bar allows the user to input a desired value of wake up current in milliamps. This parameter is named IWAKE.

5.2.1.5 BIT4: $\overline{\text{EODV}}$ PIN FUNCTION

The choices for this option are listed below:

- $\overline{\text{EODV}}$ pin indicates between 0%-20% charge, P0#
- $\overline{\text{EODV}}$ pin indicates voltage below $\overline{\text{EODV}}$ limit

The default selection maintains the current TrueGauge function which sets the $\overline{\text{EODV}}$ pin low when the battery voltage goes below the present $\overline{\text{EODV}}$ level. The new selection turns the $\overline{\text{EODV}}$ pin into a fifth LED output to indicate battery capacity from 0% to 19%. This output will be activated with a button push, the same as the other four LED outputs.

5.2.2 IWAKE

Walk-up Current Threshold

EEPROM Address	0Ch
Allowable Range	0 to 255 mA
Typical Value	100 mA
Stored Value	Wake up current level

If, when TrueGauge wakes up to take measurements, the absolute value of the measurement current is greater than the IWAKE value, TrueGauge will stay awake until the current is reduced below IWAKE, or until the $\overline{\text{CHG}}$ pin is pulled up. This value is associated with Section 5.2.1.4.

5.2.3 STBYIDZ

EEPROM Address	0Eh
Allowable Range	0 to 255 mA
Typical Value	3 mA
Stored Value	Standby current level

If, while in sleep mode, the TrueGauge A/D reports a current measurement whose absolute value is less than the value in STBYIDZ, the measurement will be viewed as zero. This prevents large inaccuracies in battery capacity from accumulating during periods of battery storage. To use the 3 mA default, 1% tolerance resistors must be used in the REFC and ISENC circuits. A suggested rule of thumb is to set STBYIDZ to half of the application's minimum current consumption value.

5.2.4 DIMON

Current Monitor -dV Detector Threshold

EEPROM Address	07h
Allowable Range	0 to 255 mA
Typical Value	30 mA
Stored Value	Current monitor level

If the absolute value of a charge current fluctuation exceeds the value in DIMON, the -dV algorithm will restart. A period of 29.75 seconds must pass before a valid -dV condition can terminate fast charge. This value is associated with Section 5.2.1.3.

6.0 POWER ON RESET

The MTA11200B incorporates an on-chip Power On Reset Timer which provides internal chip reset. An internal timer begins counting when a logic high level is detected on $\overline{CLR}$. The MTA11200B remains in the reset state while this timer is running or anytime $\overline{CLR}$ is low. The timer expires 18 mS (typical) after $\overline{CLR}$ goes high. Then the MTA11200B emerges from the reset condition and the remaining battery capacity is set to 0%.

In order to ensure proper power-on reset when a battery provides the V_{DD} power source, an external voltage level detector or “brown-out” circuit is recommended. This prevents $\overline{CLR}$ from reaching a valid logic high level when V_{DD} less than V_{DD} minimum, which can occur while the battery is in storage for long periods and its voltage is very slowly decaying to zero.

The voltage level detector or brown out circuit should ensure that $\overline{CLR}$ is held low anytime V_{DD} is less than the minimum operational V_{DD} level for the MTA11200B and any external I.C.’s. This will prevent erroneous operation and inaccurate capacity gauging.

7.0 APPLICATION EXAMPLE

An example of a MTA11200B-based battery monitoring and charging system is shown in the following schematic (Document number 11200DTS).

This example system provides battery state of charge information via the TXD output and the display LEDs. In normal operation, only three connections are required between the host and the battery subsystem. LOAD+ provides the charge and discharge current path and LOAD- is the system ground. TXD allows the host to receive battery status data in real time and connects to a receiver in the host. If the battery charging source is included in the host system then an additional connection, to $\overline{CHG}$, can be used.

To connect to an external charging source (e.g., stand alone charger) only 3 connections between the charger and the battery system are required.

In this case the connection to the $\overline{CHG}$ is needed and the TXD connection usually is not needed. Again, LOAD+ provides the charge and discharge current path and LOAD- is the system ground.

Additionally, the $\overline{DISREQ}$ output can control a discharge circuit within the charger (or host for that matter) to instruct the charger to fully discharge (to $\overline{EODV}$) the battery.

The external A/D components and the Serial EEPROM are routinely powered down to reduce power consumption when the MTA11200B is in the STANDBY state. The IDLE pin controls a transistor that switches the power bus to these circuits. The Serial EEPROM, comparators, current source, and their associated pull-up resistors and bias resistors are powered by this secondary power bus.

The MTA11200B, voltage regulator (U4), and dropout voltage detector are always powered up as long as there is sufficient battery power. The voltage regulator protects the entire system from the battery voltage. It also provides the voltage that the A/D is referenced to.

The voltage detector forces the entire battery monitor system to shut down if the battery voltage falls below the operational limits of the I.C.'s in the system. This is added insurance against data corruption for both transmitted and stored data.

Note:	Although the system schematic shown (Figure 7-1), indicates the MTA11200, the MTA11200B is a direct pin-for-pin substitution.

7.1 Component Selection

7.1.1 CURRENT SENSE RESISTOR

The MTA11200B's programmable features accommodate a wide variety of battery types and load currents. The current sloppe correction factor stored in EEPROM defines the gain factor that the MTA11200B applies to the current measurement. By calibrating this gain factor and selecting the current sense resistor (R6) maximum sensitivity and dynamic range in the current measurement can be achieved.

The maximum discharging current and the maximum charging current expected in normal operation are the parameters that determine the required value of the current sense resistor. The resistor for the example circuit is selected based on the following formula:

Rsense <= 0.5V / Imax

The 0.5V maximum voltage drop limits the power dissipated by the resistor to an acceptable value. It also results in good measurement resolution.

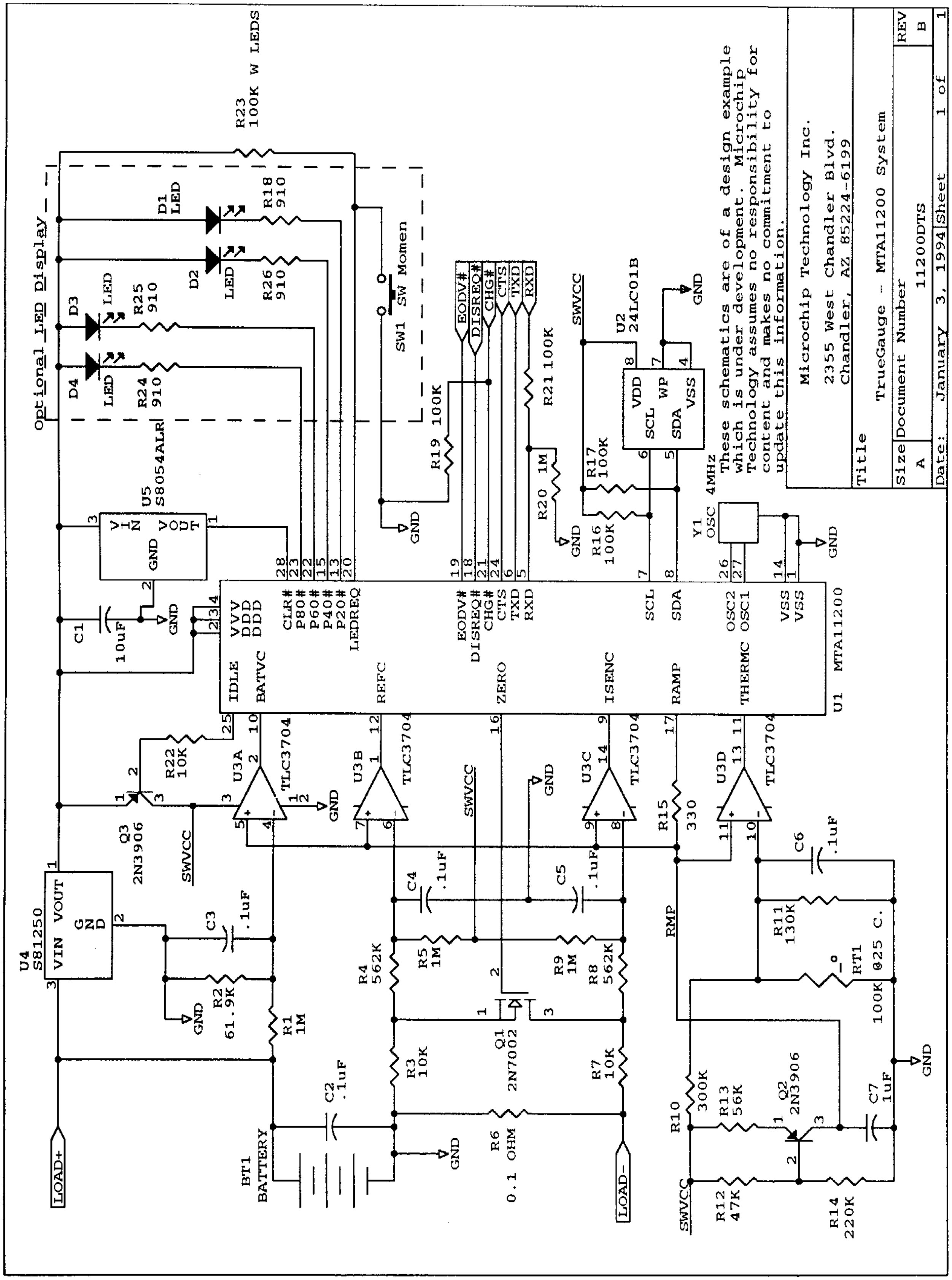
7.1.2 THERMISTOR

A wide variety of linear thermistors can be used in a MTA11200B-based system. The programmable gain and offset factors for thermistor input can be adjusted to obtain accurate temperature readings. The thermistor and it's associated bias resistors should be selected to ensure that voltage swing at the A/D comparator always remains within the range of the voltage ramp.

7.1.3 SERIAL EEPROM

The MTA11200B communicates with a 1Kbit Serial EEPROM organized as 128 bytes x 8-bits via standard I^2C protocol.

FIGURE 7-1: TRUEGAUGE - MTA11200 SYSTEM SCHEMATIC



8.0 DEVELOPMENT SYSTEM

8.1 Features

The MTA11200B development system is a full features design environment to allow the system designer to design, validate and release full production products. The system includes:

- NiCd and NiMH battery packs, complete with MTA11200B intelligent battery management systems attached.
- Stand alone MTA11200B intelligent battery management system ready for customization.
- Charger/discharger control board with PC RS-232 cable and battery interface cable.
- MTA11200B *TrueGauge*™ design software package for Windows® 3.1 operating system.
- International power supply
- Complete documentation

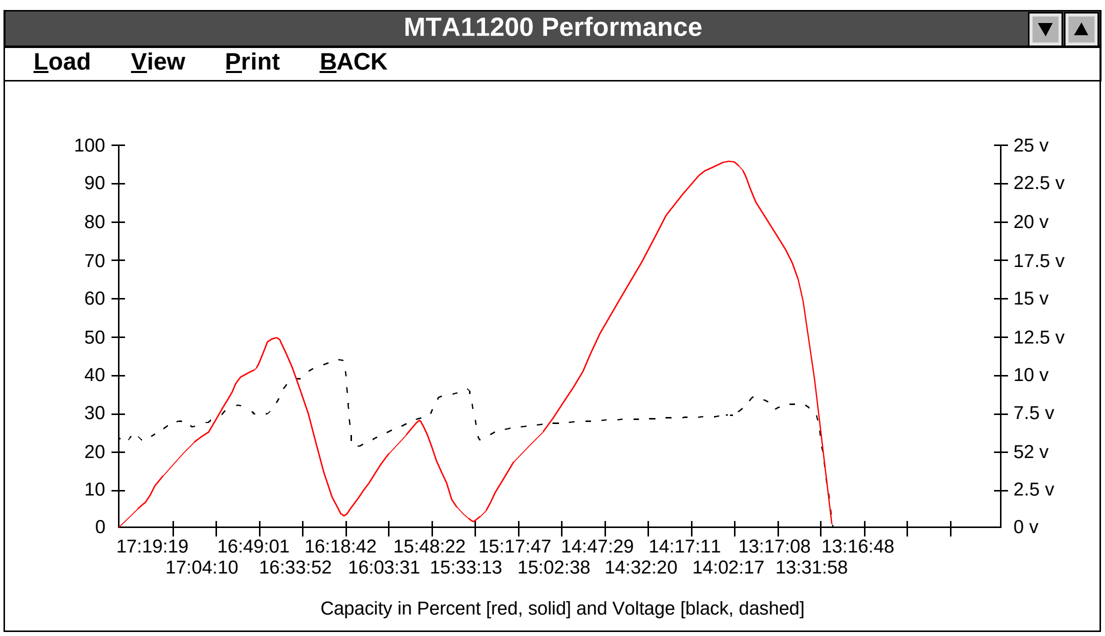
8.2 Function

The MTA11200B development system part number DV114001 has been designed to allow the user to collect real time data from the TrueGauge system and display it in a graphical format. In addition the software can log the data to disk for multiple design comparison or to archive current results for study at a later time. The data displayed can be one of four parameters:

- Voltage
- Capacity
- Temperature
- Current

Voltage and Capacity are displayed concurrently as shown in Figure 8-1. The vertical scale shows capacity in percent between 0.0 (0%) and 1.0 (100%). The voltage per cell is shown on the scale above 1.0 and is in volts. Note that time increases to the left. Temperature is displayed in Figure 8-2 and Current is displayed in Figure 8-3. The graphs read like a strip chart recorder with time increasing to the left.

FIGURE 8-1: TRUEGAUGE VOLTAGE AND CAPACITY vs TIME



TrueGauge is a trademark of Microchip Technology Inc.
Windows is a registered trademark of Microsoft Corporation

FIGURE 8-2: TEMPERATURE vs TIME

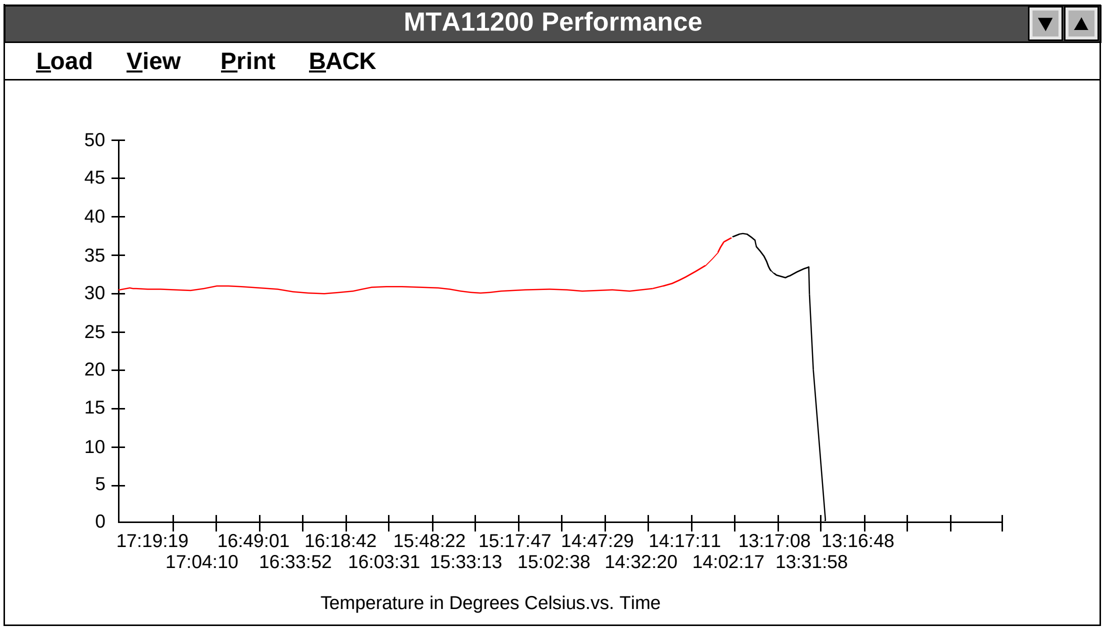
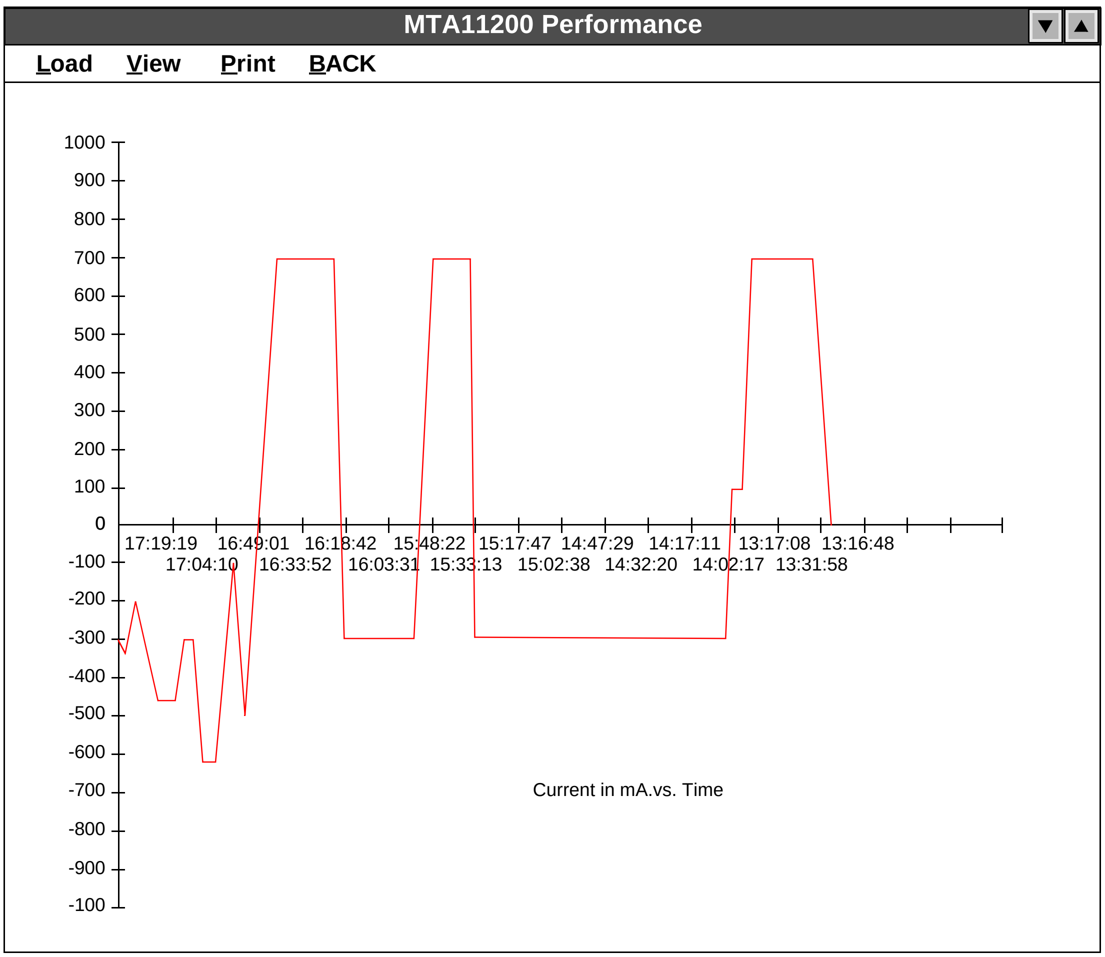
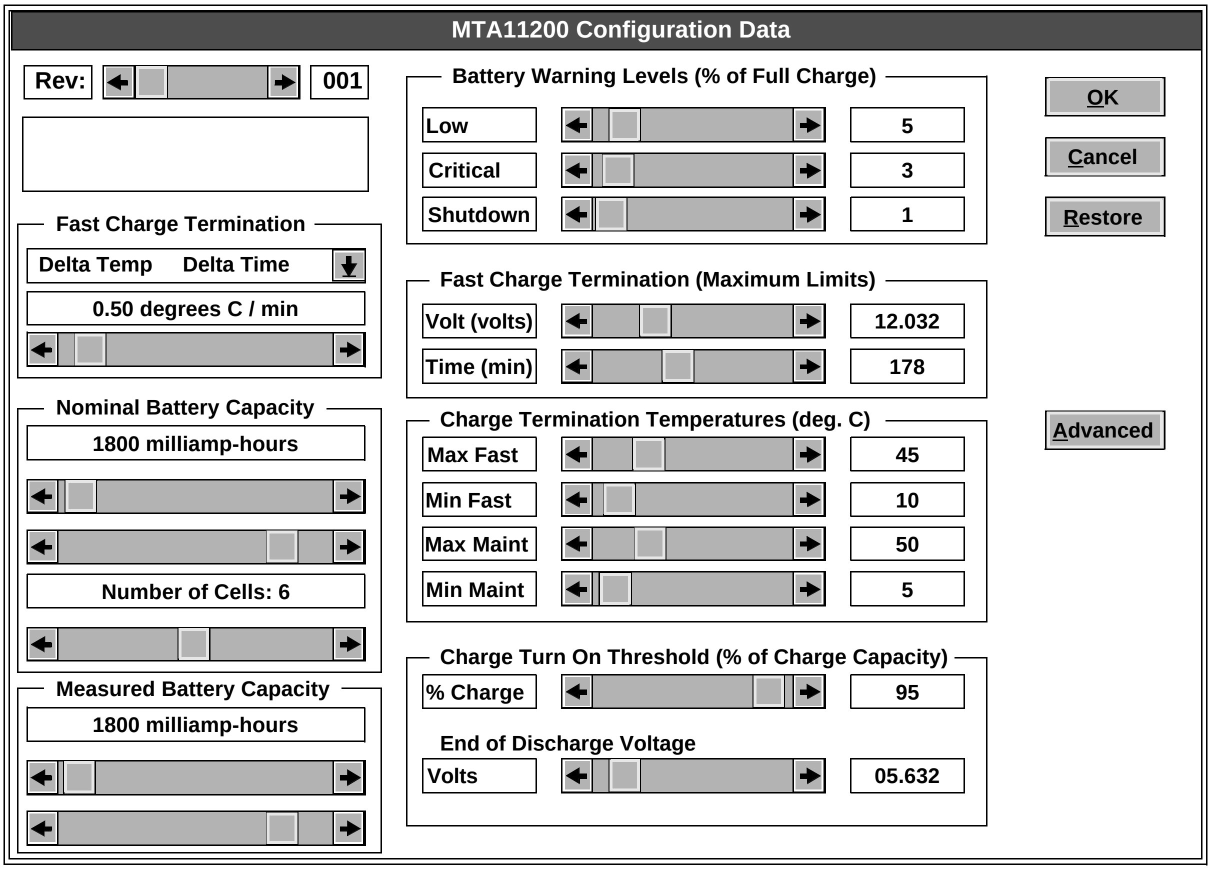


FIGURE 8-3: CURRENT vs TIME



In addition to the display and recording of data the software allows the user to easily configure the system EEPROM. The data contained within the EEPROM is all of the system parameters that control how the MTA11200B operates. To ease in the setup and achiving of this data, the TrueGauge development software has a user friendly configuration panel. This allows the user to easily configure the system for use with their specific battery packs. An example of the control panel to support this operation is shown below in Figure 8-4.

FIGURE 8-4: CONFIGURATION CONTROL PANEL



9.0 ELECTRICAL CHARACTERISTICS

9.1 Absolute Maximum Ratings †

Ambient temperature under bias .... -55°C to +125°C
Storage temperature .... -65°C to +150°C
Voltage on any pin with respect to Vss (except V_{DD} and $\overline{CLR}$) .... -0.6V to (Vδδ +0.6V)
Voltage on $\overline{CLR}$ pin with respect to Vss .... 0V to +14.0V
Voltage on VDD with respect to Vss .... 0V to +9.5V
Total power dissipation (Note 2) .... 800 mW
Maximum current out of Vss pin .... 150 mA
Maximum current into VDD pin .... 50 mA
Maximum current into input pin .... ± 500 μA
Maximum output current sinked by any I/O or output pin .... 25 mA
Maximum output current sourced by any I/O or output pin .... 20 mA

Note 1: Voltage spikes below Vss at the $\overline{CLR}$ pin, inducing currents greater than 80 mA may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a “low” level to this pin, rather than connecting this pin directly to Vss.

Note 2: Total power dissipation should not exceed 800 mW for the package. The total power dissipation is calculated as follows: $P_{dis} = V_{DD} \times (I_{DD} - \sum I_{OH}) + \sum\{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum(V_{OL} \times I_{OL})$.

† **Notice**: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

10.0 DC CHARACTERISTICS

Characteristic	Sym.	Min.	Typ.	Max.	Units	Conditions
						Standard Operating Conditions (unless otherwise stated). Operating Temperature 0°C < TA < 70°C for commercial. Operating Voltage VDD = 3.0V to 5.5V unless otherwise stated.
Supply Voltage	VDD	3.0		6.25	V	FOSC = DC to 4 MHz
VDD start voltage to guarantee power-on reset	VPOR		VSS		V	
VDD rise rate to guarantee power-on reset	SVDD	0.05(1)			V/MS	
Supply Current	IDD ISTBY(2)		1.8 12	3.3 18	mA µA	FOSC = 4 MHz , VDD = 5.5V STANDBY Mode, FOSC = MHz, VDD = 5.0V
Input Low Voltage $\overline{\text{CLR}}$ (Schmitt trigger) OSC1 (Schmitt trigger) All other Inputs	 VILMC VILOSC VIL			 .15 VDD .3 VDD .2 VDD	 V V V	
Input High Voltage $\overline{\text{CLR}}$ (Schmitt trigger) OSC1 (Schmitt trigger) All other Inputs	 VIHMC VIHOSC VIH	 .85 VDD .7 VDD .45 VDD		 VDD VDD VDD	 V V V	
Input Leakage Current $\overline{\text{CLR}}$ $\overline{\text{CLR}}$ OSC1 (Schmitt trigger) All other Inputs	 IILMCL IILMCH IILMCH IIL	 -5 -1	 0.5 0.5 0.5	 +5 +3 +1	 µA µA µA µA	 VPN = Vss + 0.25V VPN = VDD VSS ≤ VPN ≤ VDD VSS ≤ VPN ≤ VDD
Output Low Voltage All other Outputs	 VOL			 0.6V	 V	 IOL = 1.6 mA, VDD = 4.5V
Output High Voltage All other Outputs	 VOH	 VDD - .7			 V	 IOH =-1.0 mA, VDD = 4.5V

Note 1: These parameters are based on chartacterization and are not tested.

Note 2: The supply current in STANDBY mode is measured with all outputs unconnected and inputs tied to VDD or VSS.

10.1 DC Character Graphs

FIGURE 10-1: TYPICAL ISTBY vs VDD AT 25°C

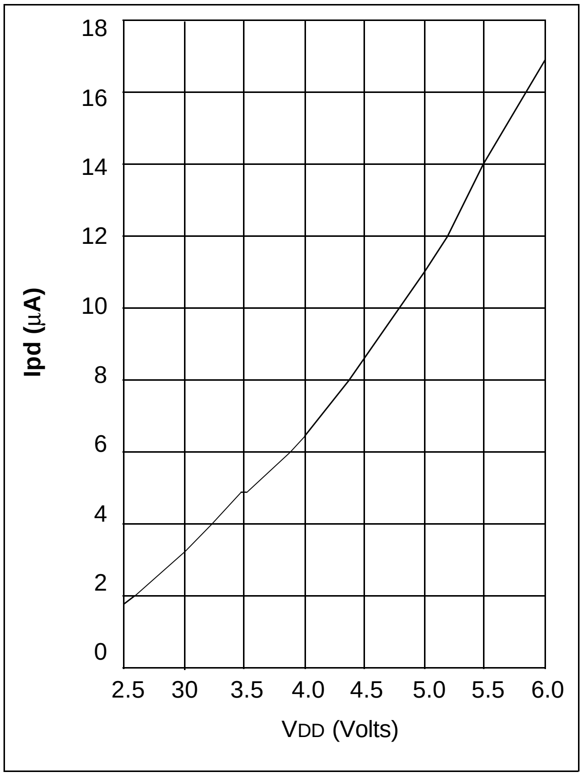


FIGURE 10-2: MAXIMUM ISTBY vs VDD

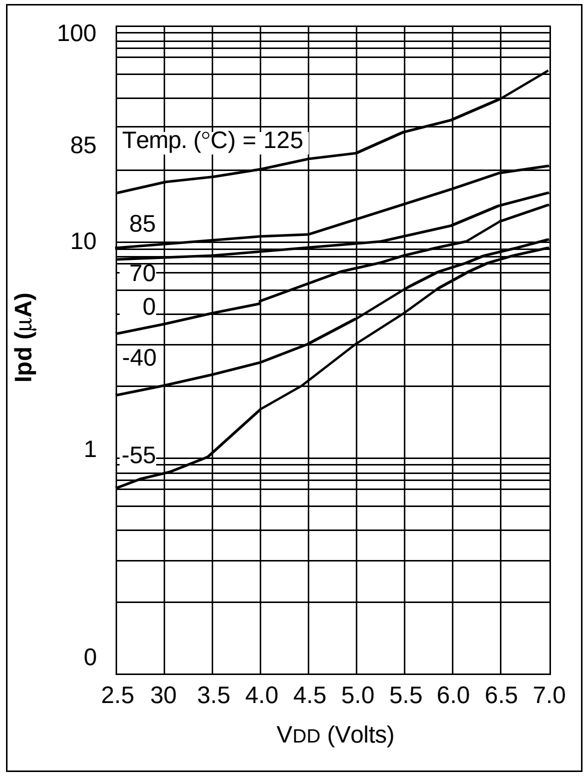


FIGURE 10-3: INPUT THRESHOLD VOLTAGE (V_{TH}) OF INPUT AND I/O PINS vs V_{DD}

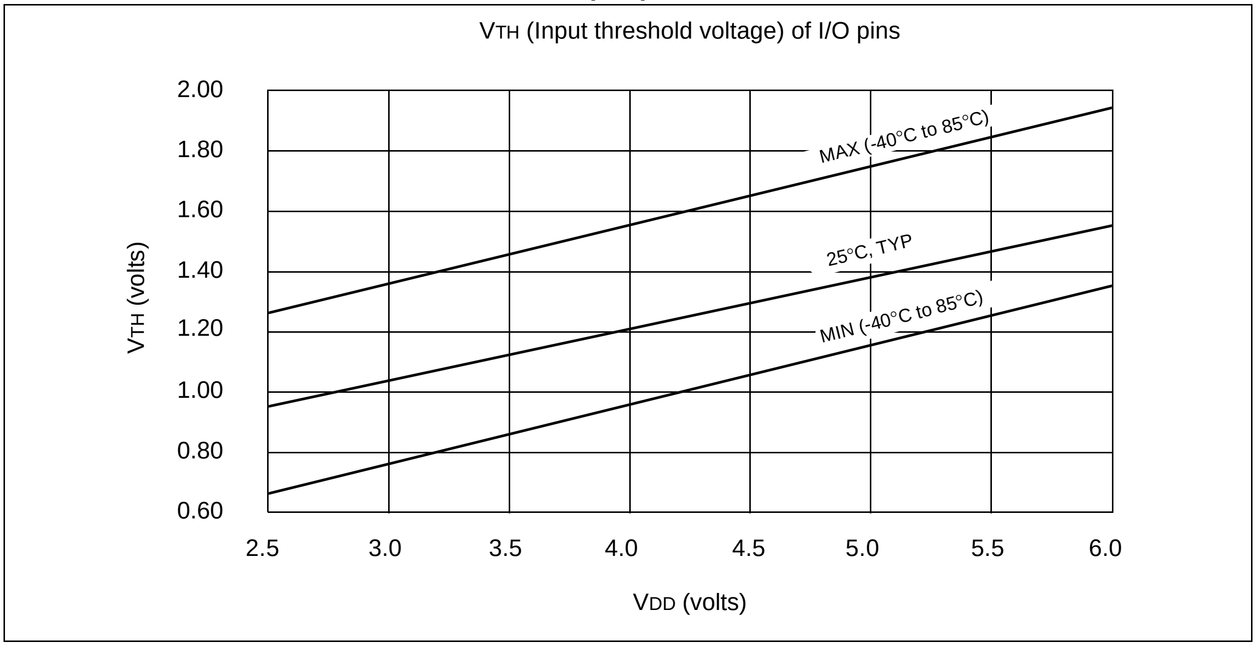


FIGURE 10-4: V_{TH}, V_{IH} OF $\overline{CLR}$ INPUT vs V_{DD}

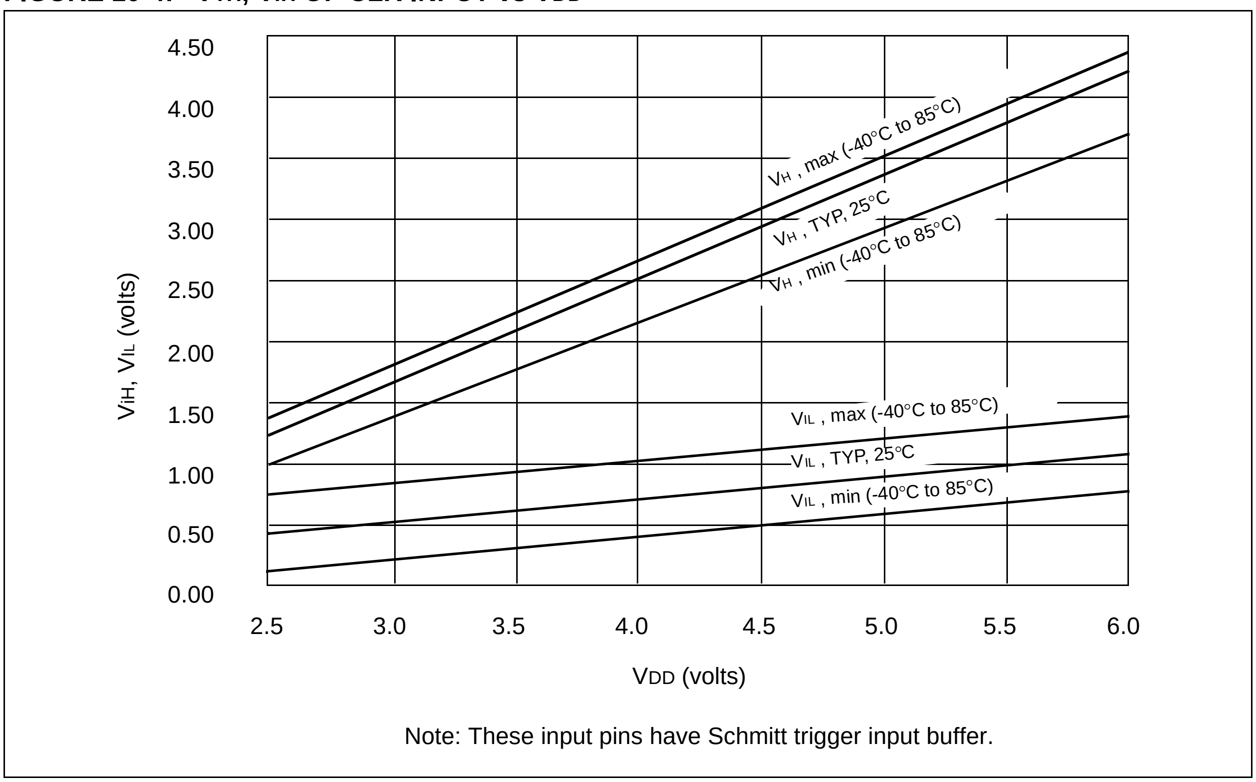


FIGURE 10-5: VTH OF $\overline{\text{CLR}}$ AND OSC1 INPUT vs VDD

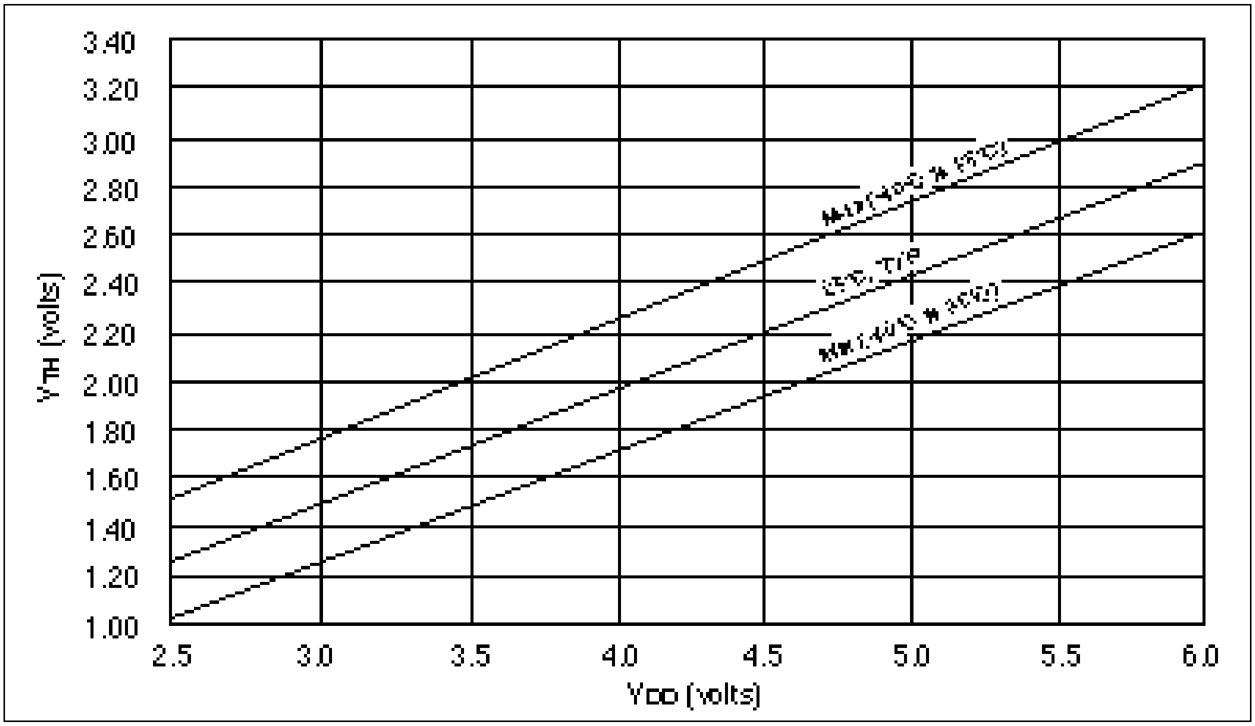


FIGURE 10-6: TRANSCONDUCTANCE (G_M) OF OSCILLATOR vs VDD

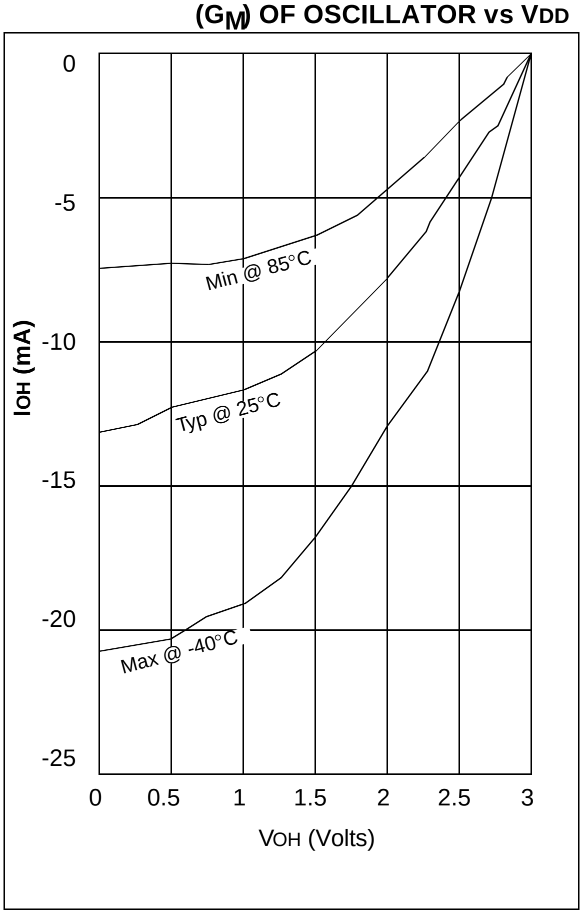


FIGURE 10-7: IOH vs VOH, VDD = 3V

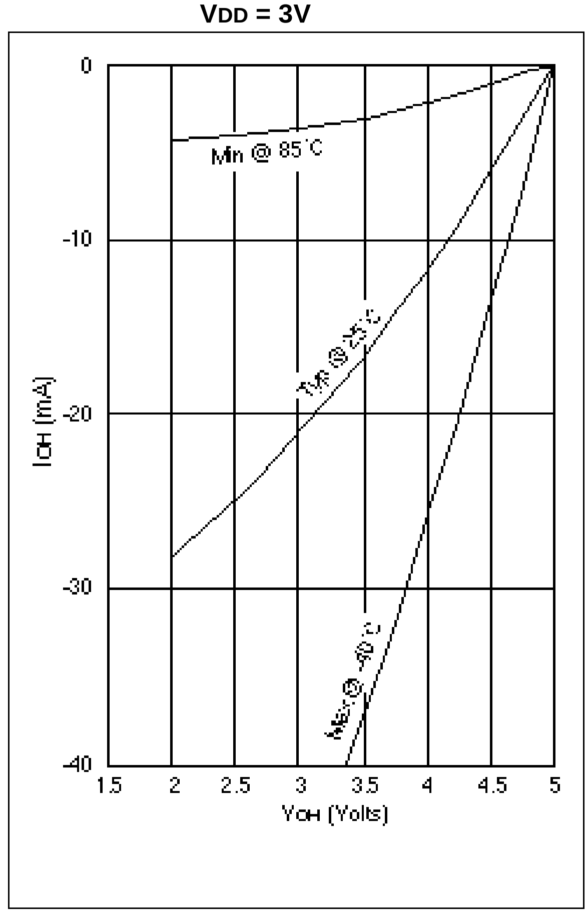


FIGURE 10-8: IOH VS VOH, VDD = 5V

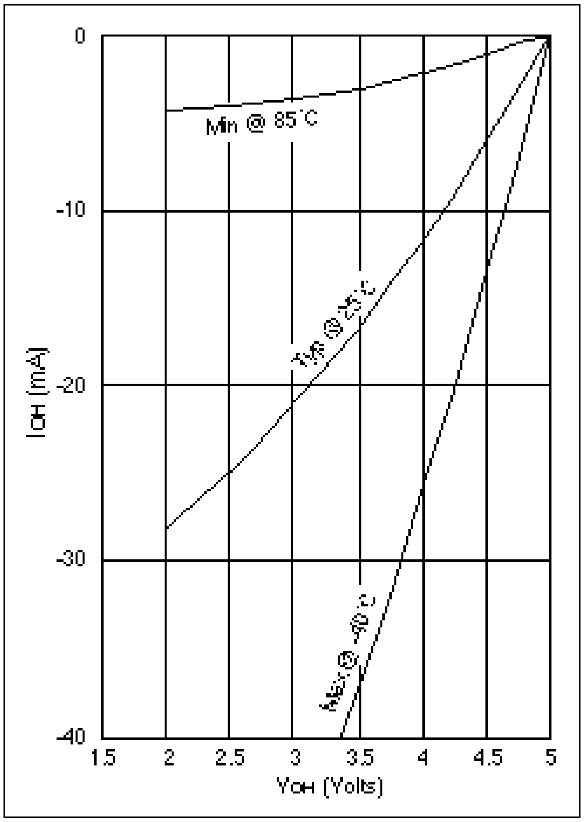


FIGURE 10-9: IOL VS VOL, VDD = 3V

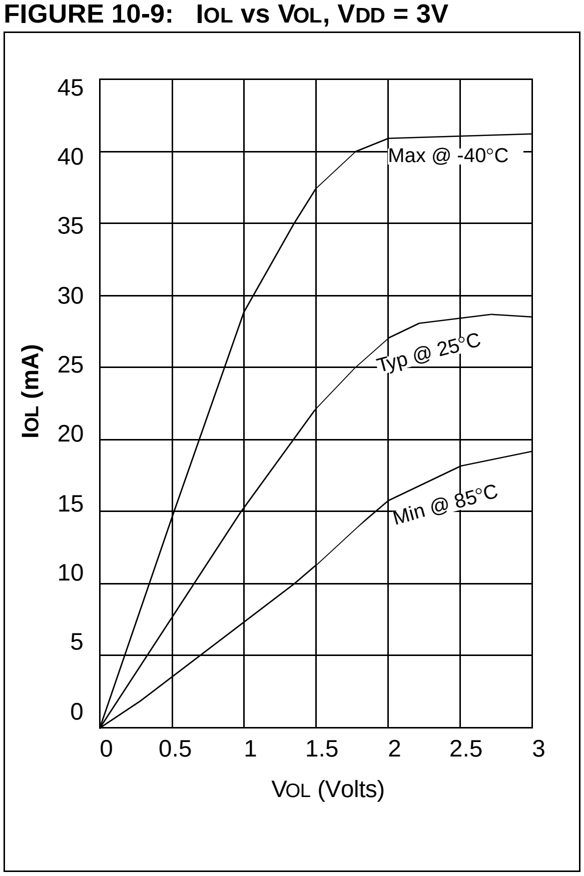


FIGURE 10-10: IOL VS VOL, VDD = 5V

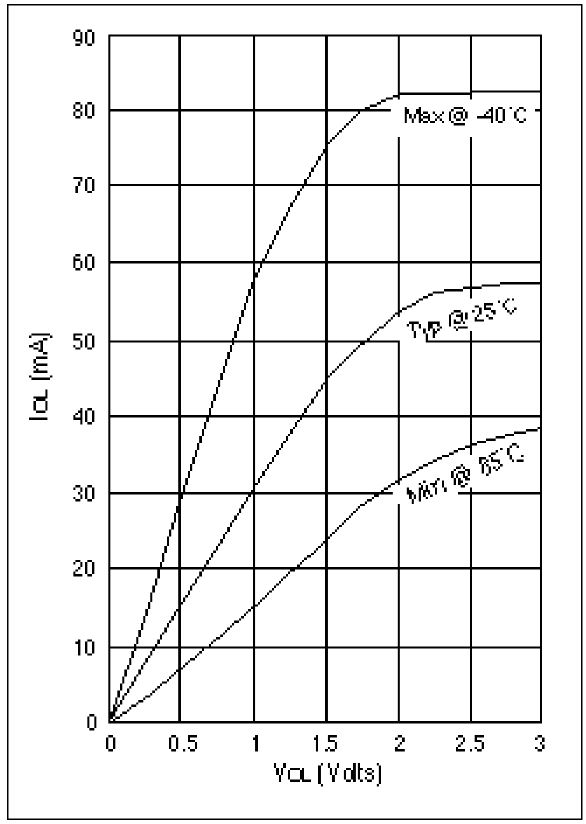


TABLE 10-1: INPUT CAPACITANCE

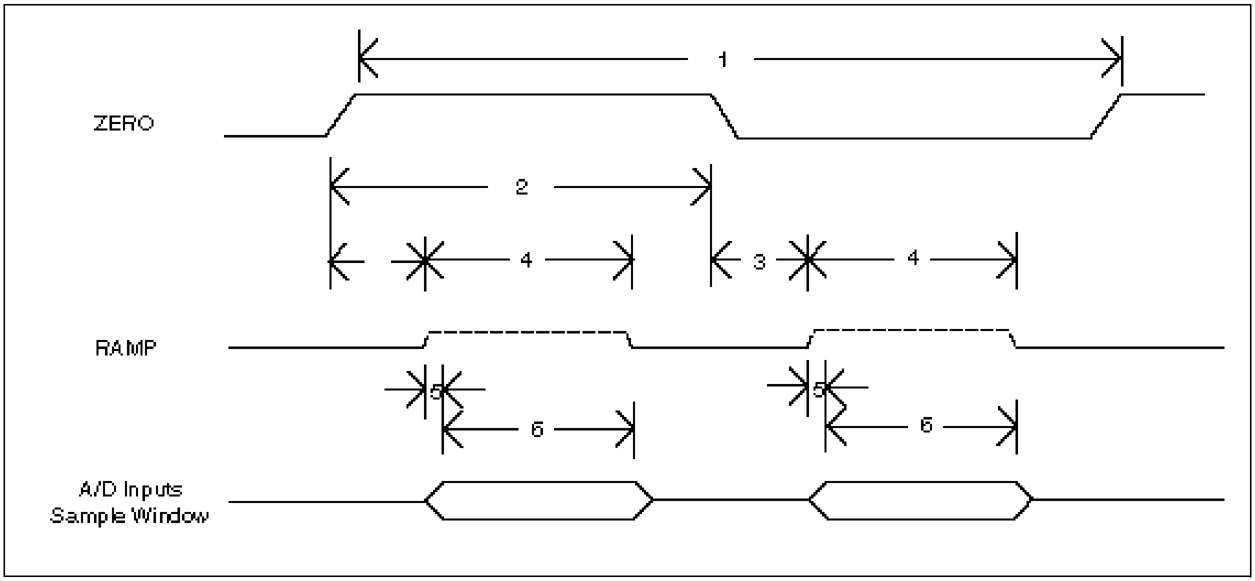
Pin Name	Typical Capacitance (pF) 28L PDIP (600 mil)	Typical Capacitance (pF) 28L SOIC
INPUTS and I/Os	5	4
$\overline{\text{CLR}}$	17	17
OSC1	6	3
OSC2	4	3

11.0 AC CHARACTERISTICS

		Standard Operating Conditions (unless otherwise stated). Operating Temperature 0°C < TA < 70°C for commercial. Operating Voltage VDD = 3.0V to 5.5V unless otherwise stated. Oscillator Frequency = 4 MHz.				
Characteristic	**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Oscillator Frequency	FOSC	DC		4	MHz	
RESET Timing CLR Pulse Width (low)	TMCL	100			ns	
Oscillator Start-up Timer Period	TOST (NOTE 1)	9	18	30	ms	VDD = 5.0V

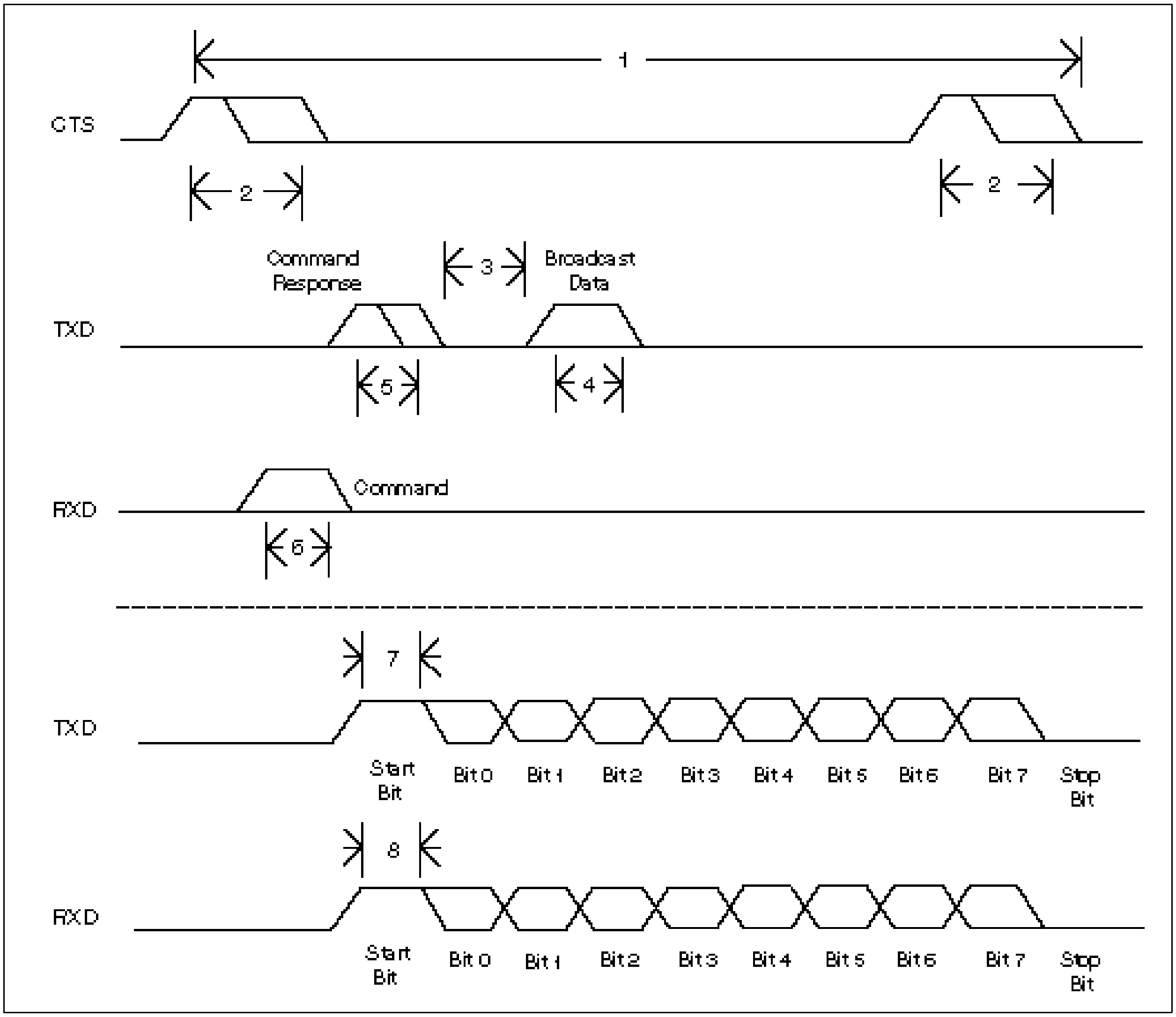
Note 1: These parameters are based on characterization and are not tested.

FIGURE 11-1: A/D TIMING DIAGRAM AND SPECIFICATIONS



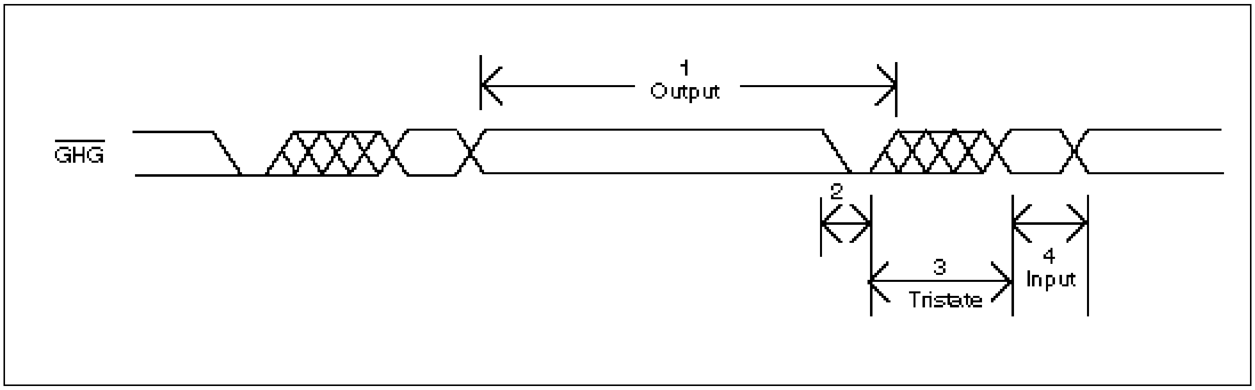
Param. No.	Characteristic	Sym.	Min.	Typ.	Max.	Units	Conditions: Standard Conditions unless otherwise stated
1	ZERO Pulse Period		TP:ZRO	1.65	1.75	1.85	S
2	ZERO Pulse Width		TW:ZRO	840	850	860	ms
3	RAMP Output Delay		TD:RMP		200		ms
4	RAMP Pulse Width		TD:ADI	640	650	660	ms
5	BATVC. REFC, ISENC, TEMPC A/D Input Window Delay Time	TD:ADI			20	µs	
6	BATVC. REFC, ISENC, TEMPC A/D Input Window Width		TDW:ADI	640			µs

FIGURE 11-2: HOST COMMUNICATION TIMING DIAGRAM AND SPECIFICATIONS



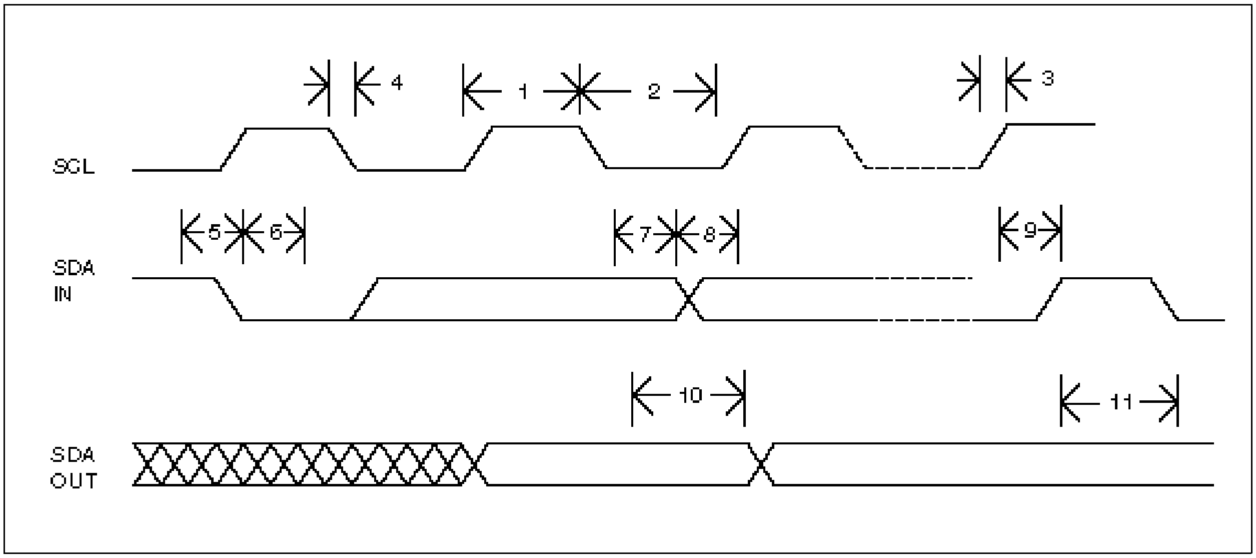
Param. No.	Characteristic	Sym.	Min.	Typ.	Max.	Units	Conditions: Standard Conditions unless otherwise stated
1	CTS Pulse Period	TP:CTS	1.65	1.75	1.85		
2	CTS Pulse Width	TW:CTS	2		12	ms	
3	RXD data to TXD (broadcast) Delay	TD:CTS			1	ms	
4	TXD(broadcast) Data Packet Width	TW:TXD	16.5		17.5	ms	
5	TXD(Cmd Resp.) Data Packet Width	TW:TXC			17.5	ms	
6	RXD Data Packet Width	TW:RX	1			µs	
7	TXD Bit Time	TT:TX	90	100	110	µs	9600 baud
8	RXD Bit Time	TT:RX	60		110	µs	

FIGURE 11-3: CHARGE CONTROL TIMING DIAGRAM AND SPECIFICATIONS



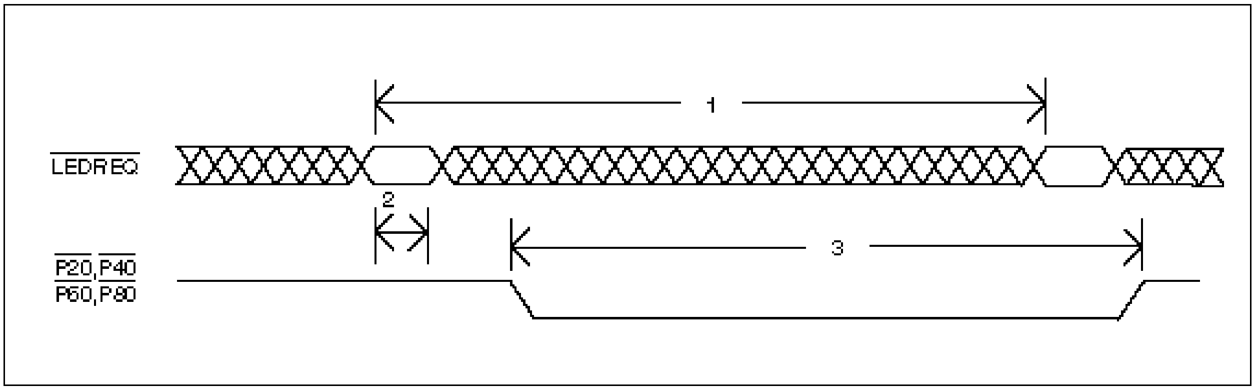
Param. No.	Characteristic	Sym.	Min.	Typ.	Max.	Units	**Conditions:** Standard Conditions unless otherwise stated
1	$\overline{\text{CHG}}$ Output Pulse Period	TP:CRG	1.65	1.75	1.85	s	
2	$\overline{\text{CHG}}$ Output Low (Input Preconditioning) Time	TOL:CRG	1	2	3	µs	
3	$\overline{\text{CHG}}$ Input Setup Time	TIW:CRG	7			µs	
4	$\overline{\text{CHG}}$ Input Window Time	TSU:CRG	1		2	µs	

FIGURE 11-4: I²C BUS TIMING DIAGRAM AND SPECIFICATIONS



Param. No.	Characteristic	Sym.	Min.	Typ.	Max.	Units	Conditions: Standard Conditions unless otherwise stated
1	Clock High TIme		TH:SCL	4.0			µs
2	Clock Low Time		TL:SCL	4.7			µs
3	SCL and SDA Rise Time		TR:SCD			300	µs
4	SCL and SDA Fall Time		TF:SCD			300	µs
5	Start Condition Setup Time	TSU:STA	4.7			µs	
6	Start Condition HOLD Time	THD:STA	4.0			µs	
7	Data Input Hold TIme		THD:DAT	0			µs
8	Data INput Setup Time		TSU:DAT	250			µs
9	Stop COndition Setup Time	TSU:STO	4.7			µs	
10	Output Valid From Clock		TAA	3.5			µs
11	Bus Free Time		TBUF	4.7			µs
	Capacitive Loading		CB			400	pF

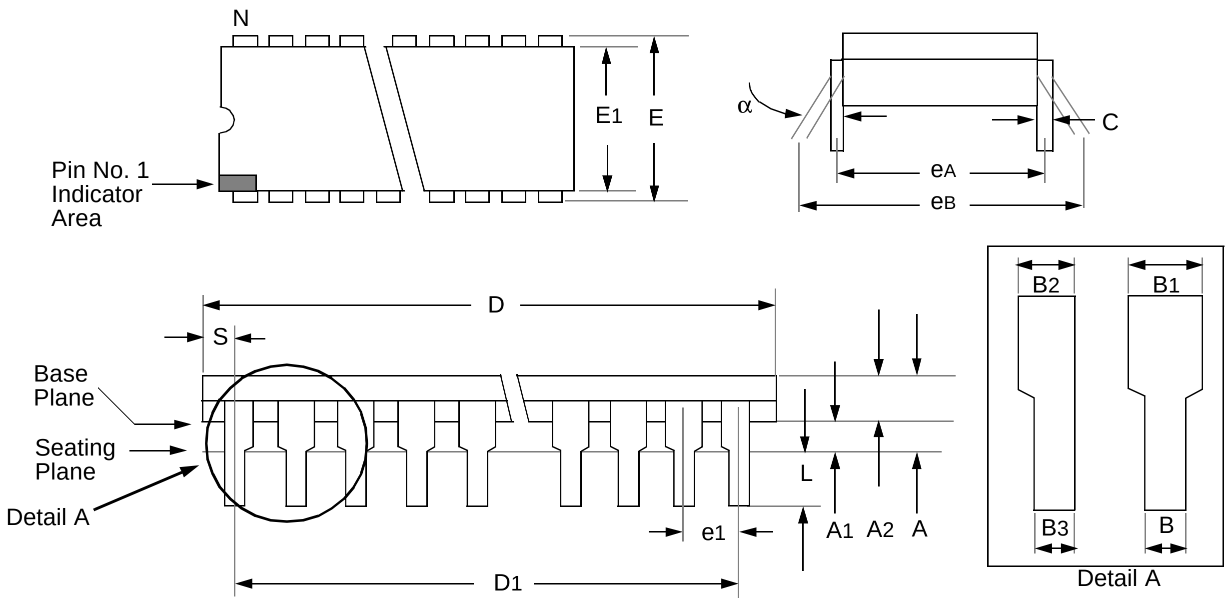
FIGURE 11-5: LED TIMING DIAGRAM AND SPECIFICATIONS



Param. No.	Characteristic	Sym.	Min.	Typ.	Max.	Units	**Conditions:** Standard Conditions unless otherwise stated
1	$\overline{\text{LEDREQ}}$ Input Sample Period	TP:LRQ	1.65	1.75	1.85	S	
2	$\overline{\text{LEDREQ}}$ Input Window		TW:LRQ		1		µs
3	$\overline{\text{P20}}$, $\overline{\text{P40}}$,$\overline{\text{P60}}$, $\overline{\text{P80}}$ Output Pulse Width		TPW:LED	1.65		1.75	S

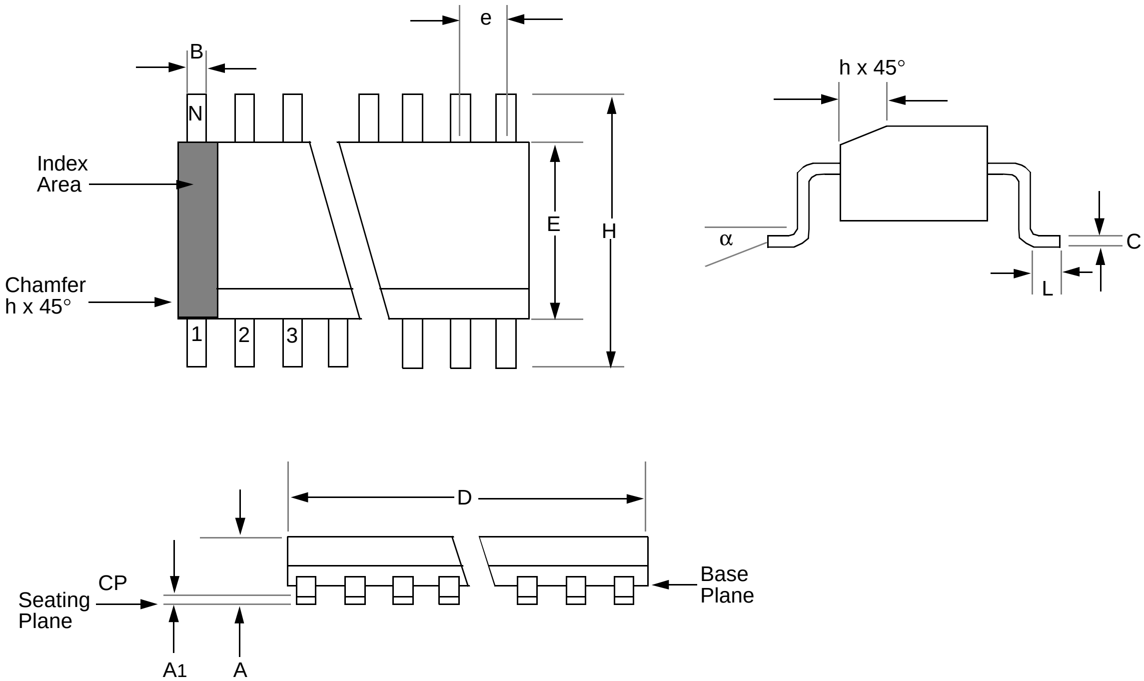
12.0 PACKAGING DIAGRAMS AND DIMENSIONS

12.1 28-Lead Plastic Dual In-Line (300mil)



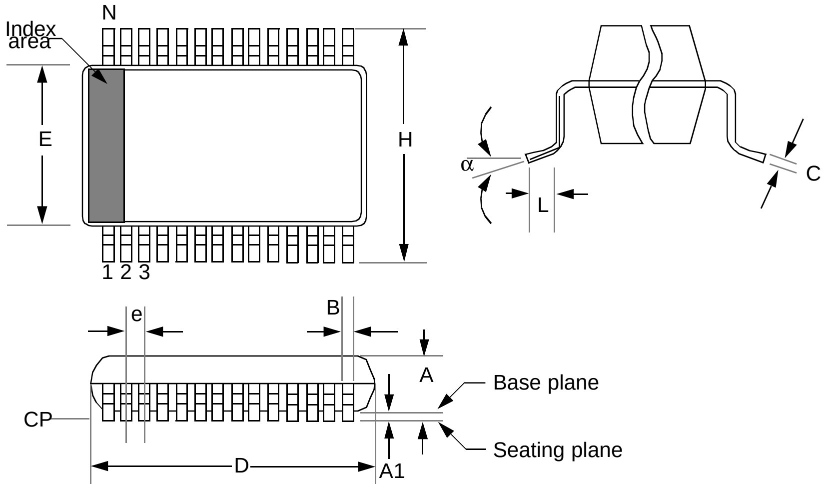
Package Group: Plastic Dual In-Line (PLA)						
	Millimeters			Inches		
Symbol	Min	Max	Notes	Min	Max	Notes
α	0°	10°		0°	10°	
A	3.632	4.572		0.143	0.180	
A1	0.381	–		0.015	–	
A2	3.175	3.556		0.125	0.140	
B	0.4064	0.5588		0.016	0.022	
B1	1.016	1.651	**Typical**	0.040	0.065	**Typical**
B2	0.762	1.016	**4 places**	0.030	0.040	**4 places**
B3	0.2032	0.508	**4 places**	0.008	0.020	**4 places**
C	0.2032	0.3302	**Typical**	0.008	0.013	**Typical**
D	34.163	35.179		1.385	1.395	
D1	33.02	33.02	**Reference**	1.300	1.300	**Reference**
E	7.874	8.382		0.310	0.330	
E1	7.112	7.493		0.280	0.295	
e1	2.54	2.54	**Typical**	0.100	0.100	**Typical**
eA	7.874	7.874	**Reference**	0.310	0.310	**Reference**
eB	8.128	9.652		0.320	0.380	
L	3.175	3.683		0.125	0.145	
N	28	-		28	-	
S	0.5842	1.2192		0.023	0.048	

12.2 28-Lead Plastic Surface Mount (SOIC - Wide, 300 mil Body)



Package Group: Plastic SOIC (SO)						
	Millimeters			Inches		
Symbol	**Min**	**Max**	**Notes**	**Min**	**Max**	**Notes**
α	0°	8°		0°	8°	
A	2.3622	2.6416		0.093	0.104	
A1	0.1016	0.2997		0.004	0.0118	
B	0.3556	0.4826		0.014	0.019	
C	0.2413	0.3175		0.0095	0.0125	
D	17.7038	18.0848		0.697	0.712	
E	7.4168	7.5946		0.292	0.299	
e	1.270	1.270	**Typical**	0.050	0.050	**Typical**
H	10.0076	10.6426		0.394	0.419	
h	0.381	0.762		0.015	0.030	
L	0.4064	1.143		0.016	0.045	
N	28	28		28	28	
CP	–	0.1016		–	0.004	

12.3 28-Lead Plastic Surface Mount (SSOP - 209 mil Body 5.30 mm)



Package Group: Plastic SSOP						
	Millimeters			Inches		
Symbol	Min	Max	Notes	Min	Max	Notes
α	0°	8°		0°	8°	
A	1.730	1.990		0.068	0.078	
A1	0.050	0.210		0.002	0.008	
B	0.250	0.380		0.010	0.015	
C	0.130	0.220		0.005	0.009	
D	10.070	10.330		0.396	0.407	
E	5.200	5.380		0.205	0.212	
e	0.650	0.650	**Reference**	0.026	0.026	**Reference**
H	7.650	7.900		0.301	0.311	
L	0.550	0.950		0.022	0.037	
N	28	28		28	28	
CP	-	0.102		-	0.004	

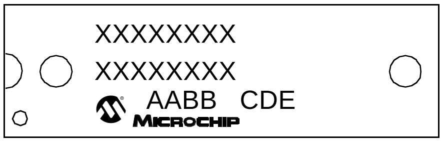
Symbol List for Shrink Small Outline Package Parameters	
Symbol	**Description of Parameters**
α	Angular spacing between min. and max. lead positions measured at the gauge plane
A	Distance between seating plane to highest point of body
A1	Distance between seating plane and base plane
B	Width of terminals
C	Thickness of terminals
D	Largest overall package parameter of length
E	Largest overall package width parameter not including leads
e	Linear spacing of true minimum lead position center line to center line
H	Largest overall package dimension of width
L	Length of terminal for soldering to a substrate
N	Total number of potentially usable lead positions
CP	Seating plane coplanarity

NOTES:

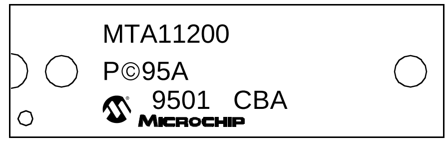
1. Controlling parameter: mm.
2. All packages are gull wing lead form.
3. "D" and "E" are reference datums and do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .015mm .006 package ends and .010" on sides.
4. A .25mm visual index feature must be located within the shaded area to indicate pin 1 position.
5. Terminal numbers are shown for reference.

13.0 PACKAGE MARKING INFORMATION

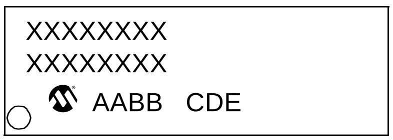
28-Lead PDIP



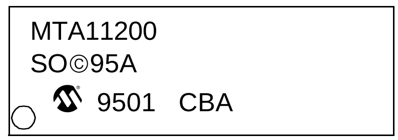
Example



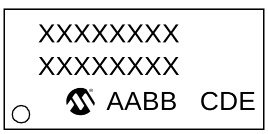
28-Lead SOIC (.300")



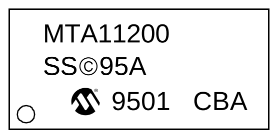
Example



28-Lead SSOP



Example



Legend:	MM...M	Microchip part number information
	AA	Year code (last 2 digits of calendar year)
	BB	Week code (week of January 1 is week '01')
	C	Facility code of the plant at which wafer is manufactured.
		C = Chandler, Arizona, U.S.A.
	D	Mask revision number
	E	Assembly code of the plant or country of origin in which
Note:	In the event the full Microchip part number can not be marked on one line, it will be carried over to the next line.	

SALES AND SUPPORT

To order or to obtain information (e.g., on pricing or delivery), please use the listed part numbers, and refer to the factory or the listed sales offices.

PART NO. -X /XX X

Revision:			
Package:	SO	=	300 mil SOIC (Gull Wing Lead)
	SP	=	28L PDIP (300 mil)
	SS	=	SSOP (209 mil)
Temperature Range:	-	=	0°C to +70°C (T for tape/reel)
Device:	MTA11200B		

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