# XR-8115

**High IQ** Battery Management System AFE

...*the analog plus company*™

## FEATURES

- 10-Bit Analog-to-Digital Converter
- Reversible Coulomb Counter
- 8-Bit Digital-to-Analog Converter with Buffered Output
- Wakeup Timer
- Interrupt Control
- 5V Regulator
- Charge/Discharge Detection
- Can Measure Battery Current and Voltage, $\Delta T$

## APPLICATIONS

- Battery Management Systems
- Fuel Gauges
- Battery Charger Control

## GENERAL DESCRIPTION

The EXAR Intelligent Battery Management System monitors critical battery parameters to produce a highly accurate state of charge indication and to control slave charging systems. It is compatible with lead acid, Ni-cd, Ni-MH, & Li-Ion technologies.

By providing charger control, fuel gauge display drivers, and both a digital and analog interface, the XR-8100 allows both the OEM and user maximum flexibility and performance. The combination of these features makes it the most comprehensive and flexible system in the market today.

The XR-8115 AFE incorporates all system peripheral cells, in conjunction with the XR-8101, to complete a comprehensive battery management system.

## ORDERING INFORMATION

| Part No. | Package | Operating Temperature Range |
|---|---|---|
| XR-8115BIQ | 44 Lead Plastic QFP (14 mm X 14 mm) | -40°C to +85°C |

**T⬦M**™

EXAR Corporation, 48720 Kato Road, Fremont, CA 94538 ◆ (510) 668-7000 ◆ FAX (510) 668-7017
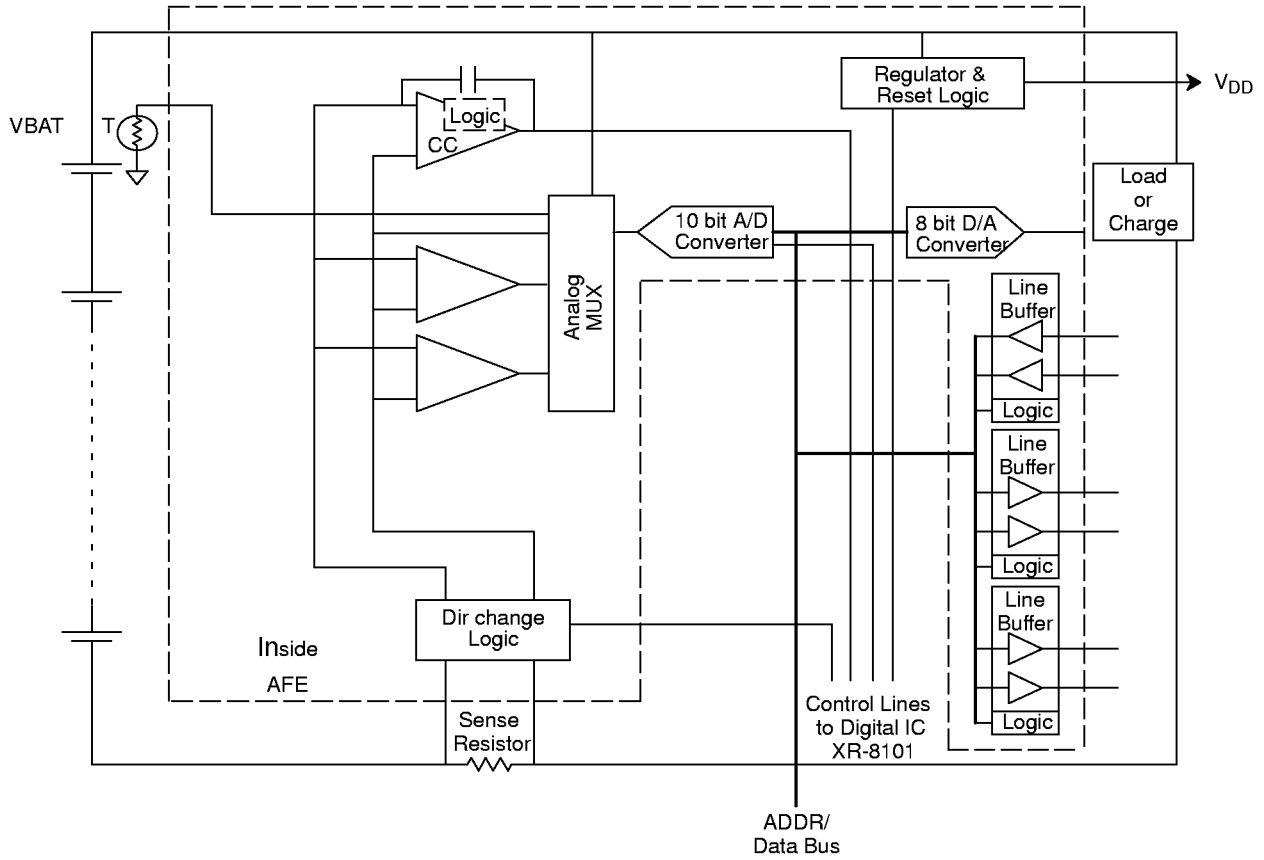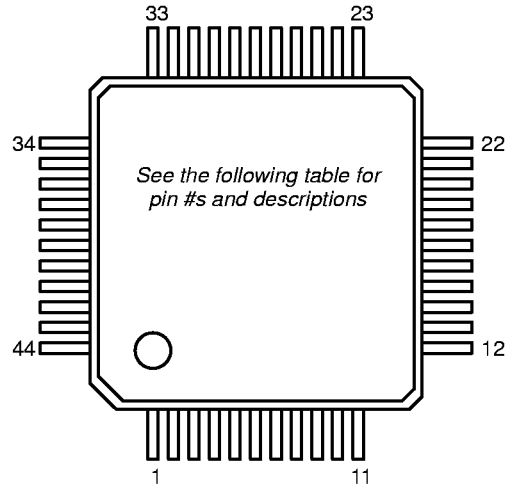
**Figure 1. Intelligent Smart Battery Management System AFE**

## PIN CONFIGURATION



**44 Lead PQFP (14 mm x 14 mm)**

## PIN DESCRIPTION

| Pin # | Symbol | Type | Description |
|---|---|---|---|
| 1 | TXBUFFI | I | Transmit Buffer Input |
| 2 | TXBUFFO | O | Transmit Buffer Output |
| 3 | RDN | I | Read Not Toggle Pin |
| 4 | WRN | I | Write Not Toggle Pin |
| 5 | A10 | I | Register Address Line |
| 6 | A9 | I | Register Address Line |
| 7 | A8 | I | Register Address Line |
| 8 | N/C | | No Connection |
| 9 | WAKEUPN | O | Interrupt to $\mu$P |
| 10 | CNT1 | O | 5V Digital Logic Charger Control Outputs |
| 11 | N/C | | No Connection |
| 12 | CNT0 | O | 5V Digital Logic Charger Control Outputs |
| 13 | CFILT | | External Filter Cap |
| 14 | RSNS-GND | I | Reference for Current Sense Resistor |
| 15 | RSNS | I | Current Sense Resistor |
| 16 | EXT1 | I | A/D Input 1:1 |
| 17 | EXTD | I | A/D Input 1:1 |
| 18 | AFG0 | O | 8-bit D/A Output - Used to Indicate Capacity 0-5 VDC in 16 Steps; Used to Control Charger in 0-255 Steps |
| 19 | TST0 | O | Test Pin (Normally Left Floating by User) |
| 20 | GND | I | System Analog Ground |

# XR-8115

EXAR

## PIN DESCRIPTION (CONT'D)

| Pin # | Symbol | Type | Description |
|---|---|---|---|
| 21 | RINT | I | External Resistor for Coulomb Counter |
| 22 | VBATZ | I | Output to Zener Shifted VBatt |
| 23 | CINT | O | External Cap for Coulomb Counter |
| 24 | N/C | | No Connection |
| 25 | COFFZ | I | Zener Shifted VBatt for Cutoff Circuit |
| 26 | VBAT | I | Battery Pack Maximum Voltage Potential (Top of Cell Stack) |
| 27 | VBASE | O | Base Drive for External V Regulator PNP |
| 28 | $V_{DD}$ | I | Analog $V_{DD}$ Input Regulated Supply |
| 29 | $DV_{DD}$ | I | Digital $V_{DD}$ Input to Digital Circuitry and Source for uP |
| 30 | RSTN | O | Reset Signal to uP (Inverted from Pin 31) |
| 31 | RST | O | Reset Signal to uP |
| 32 | D0 | I/O | Register Data Lines |
| 33 | D1 | I/O | Register Data Lines |
| 34 | D2 | I/O | Register Data Lines |
| 35 | D3 | I/O | Register Data Lines |
| 36 | D4 | I/O | Register Data Lines |
| 37 | EN-TSTOP | I | Test Pin (Normally Grounded by User) |
| 38 | RCIN | I | External Cap for 2kHz osc |
| 39 | DGND | I | System Digital Ground |
| 40 | N/C | | No Connection |
| 41 | CLKIN | I | System Clock ($\leq$ 4MHz) |
| 42 | RXBUFFO | O | Receive Buffer Output |
| 43 | RXBUFFIH | I | Receive Buffer Input High Voltage Range |
| 44 | RXBUFFIL | I | Receive Buffer Input 5V Range |

Rev. 1.01

4

## ELECTRICAL CHARACTERISTICS

Test Conditions: $V_{BAT}$ = 8V to 18V, $T_A$=25°C

| Symbol | Parameter | Min. | Typ. | Max. | Units | Conditions |
|---|---|---|---|---|---|---|
| **DC Electrical Characteristics** | | | | | | |
| $I_{BAT}$ | Battery Current | | 1.3 | | mA | Awake |
| | | | 130 | | μA | Sleep |
| $V_{BAT}$ | Battery Voltage | 3.6 | | 25 | V | |
| $V_{DD}$ | Regulated Supply Voltage | 5.1 | 5.25 | 5.4 | V | |
| $I_{DD}$ | Supply Current Sourcing | | | 15 | mA | |
| $V_{BAT}RES$ | A/D VBAT Measurement Resolution | | 20 | | mV | |
| $V_{BAT}MAX$ | A/D VBAT Measurement Range | 3.6 | | 20 | V | |
| $V_{BATZ}RES$ | VBATZ Measurement Resolution | | 10 | | mV | |
| $V_{BATZ}MAX$ | VBATZ Measurement Range | 10 | | 20 | V | 10V Zener |
| $DAC_{MAX}$ | DAC Full-Scale Output | 5.0 | 5.1 | 5.2 | V | $V_{BAT}$ > 5.3 V |
| $DAC_{RES}$ | DAC Resolution | | 20 | | mV | 8 Bit Mode |
| $DAC_{DNL}$ | DAC DNL | | | 1 | LSB | |
| $I_{AD}MAX$ | A/D Current Measurement Range | 0 | | ±16 | A | 0.025Ω Sense Resistor |
| $I_{AD}RES$ | A/D Current Measurement Resolution | | ±16 | | mA | 0.025Ω Sense Resistor |
| $I_{AD}MAX_{LOW}$ | A/D Low Current Measurement Range | 0 | | -820 | mA | 0.025Ω Sense Resistor |
| $I_{AD}RES_{LOW}$ | A/D Low Current Measurement Resolution | | -820 | -1640 | μA | 0.025Ω Sense Resistor |
| $AD_{DNL}$ | A/D DNL | | 0.2 | | LSB | |
| $AD_{INL}$ | A/D INL | | 0.7 | | LSB | |
| $I_{CC}MAX$ | C.C. Current Measurement Range[1] | 0 | | ±16 | A | 0.025Ω Sense Resistor |
| $I_{CC}RES$ | C.C. Current Measurement Resolution[1] | | ±1 | | mA | 0.025Ω Sense Resistor, 10 sec. Auto-zero |
| $I_{MATC}$ | Charge/Discharge Matching (A/D or C.C)[1] | | 0.5% | 1.0% | | |
| $T_{RES}$ | Temperature Measurement Resolution | | 0.5 | | °C | 2 Stacked External Diodes or Internal Diodes |
| $I_{SENS}$ | Charge/Discharge Detect | | 280 | | mA | 0.025Ω Sense Resistor |
| PORUP | Power-On Reset Trip | | 4.8 | | V | $V_{DD}$ Rising |
| PORDWN | Power-On Reset Trip | | 4.0 | | V | $V_{DD}$ Falling |
| RXBUFFHI | High Voltage Receive Buffer Input | | | 25 | V | |
| **AC Electrical Characteristics** | | | | | | |
| $I_{CC}BW$ | C.C. Current Measurement Bandwidth[1] | | 1 | | MHz | |
| CLK | System Clock | | | 4 | MHz | |
| RCOSC | RC Oscillator | 1.8 | 2 | 2.2 | kHz | |

***Note***
[1] *"C.C" refers to Coulomb Counter*

## ABSOLUTE MAXIMUM RATINGS

$V_{DD}$ . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5.5 VDC

$V_{BATT}$ . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 25 VDC

Storage Temperature . . . . . . . . . . . . . -65°C to +150°C

Operating Temperature . . . . . . . . . . . . -40°C to +85°C

## FEATURE DESCRIPTIONS

### A/D Converter

The A/D converter is a 10 bit monotonic SAR converter with both DNL and INL better than 1 LSB. An 8-to-1 analog mux at the converter's input allows the A/D to read the following:

    a) Charge or discharge current through one of 2 gain channels.

    b) Battery voltage through 2 different dividers (used for dV/dT end-of-charge sensing, and regulator shut-down - see "5V Supply Regulator").

    c) Changes in temperature through a unity-gain input for external diodes, or from an internal diode (diodes are used for dT/dt end-of-charge sensing). Bias current for the external diode(s) is supplied at the pin.

    d) Ground potential for A/D offset testing.

    e) There is also an auxiliary unity-gain input.

The A/D output is read in two 5-bit sets (high set and low set). Speed of the A/D is software controllable ("fast" or "slow") to give greater flexibility with clock frequency.

### D/A Converter

The D/A converter is an 8 bit monotonic converter with better than 1 LSB DNL. Full scale output is 5.1V typical. The output is buffered, and can drive loads of 48kΩ typical. It can be used for 4 or 8 bit analog indication of fuel gauge value, or as a static charger control for I-COMM level 2 and 3 chargers (chargers who's output voltage is adjustable).

### 5 Volt Supply Regulator

An on-board voltage regulator supplies a regulated 5V from the battery voltage, and requires an external pass transistor and capacitor. This regulated supply is available for off-chip use (such as the battery management microprocessor), and can source 15mA. When battery voltage is low enough, the regulator can be shut down (regulated 5V supply falls to 0V), eliminating almost all current drain. Regulator is prevented from shutting down at higher battery voltages (shut down threshold can be controlled by an external zener). Regulator will automatically power up again when battery voltage rises above a power up threshold.

### Power-On Reset

A voltage level sensing circuit monitors the regulated 5V supply. If this supply falls below a minimum operating voltage, a RST signal immediately tells other circuitry (such as the microprocessor) that $V_{DD}$ is too low. The opposite polarity is also available on another pin, RSTN. For $V_{DD}$ rising, RST and RSTN will hold their reset states for 2 seconds after $V_{DD}$ rises above the threshold.

### Interrupt

An interrupt (WAKEUPN) is supplied to external circuitry (like a microprocessor) to inform it that one of four events has taken place. These events are :

    a) A "bucket" of coulombs (either charge or discharge) has gone by (see "Coulomb Counter").

    b) Charge current or discharge current has passed a certain threshold (see "Charge/Discharge Detect")

    c) The timer has timed out (see "Timer").

    d) Communication has taken place on the RXBUFI pin (see "Communications").

An internal 4 bit register can then be read to inform the user which event(s) has occurred. Each of the 4 interrupts can be individually disabled, causing those events to be ignored.

### Charge/Discharge Detect

Current in both charge and discharge directions is monitored. When this current exceeds a certain threshold, an interrupt event takes place (see "Interrupt"). This circuit runs even when the rest of the chip and battery management system is asleep.

### Timer

A timer is available with three software-selectable times; approximately 4 minutes, 4 seconds and 16mS. When time-out occurs, an interrupt event takes place. These times can be used to wake up a sleeping microprocessor.

The 16mS time will free-run, so that it can be used as an oscillator (to drive a display back-plane).

## Auto-Zero

An auto-zero mode will connect the gain channel inputs to ground, simulating a zero charge/discharge current condition. The coulomb counter's input will also be connected to ground. Both the gain channels and the coulomb counter are intentionally given small offsets, so that as current decreases through the external sense resistor the signal will never clip.

## Coulomb Counter

While charge and discharge current can be measured by the A/D, this current is also monitored by a "coulomb counter", which is really a bi-directional, integrating VCO with a counter. Current causes a voltage to appear on the external sense resistor. This voltage is sensed by the VCO, which produces a triangle wave whose frequency is proportional to the voltage across the sense resistor. A counter counts each period from the VCO. When the counter fills up, it causes an interrupt event (see "Interrupt"). The individual bits of this counter can be monitored at any time, so as to determine intermediate counts.

This is called a "coulomb counter" because ...

$$COUNTS = V \times T \times K$$
$$= I \times R \times T \times K$$
$$= (dQ/dT) \times R \times T \times K$$
$$= dQ \times R \times K$$
$$= (coulombs) \times (a\ constant\ RxK)$$

where:

COUNTS = events counted by the coulomb counter in a period of time T.

V = voltage on the external sense resistor R

K = an arbitrary constant

The bi-directional, integrating VCO is really integrating $RxK \Sigma I(t)\ dt$. This number is the same whether current was small and time was long, or current was high and time was short - it depends only on how many coulombs have gone by, and the multiplying constant RxK.

Since polarity can be changed at the input, both charge and discharge current are monitored by the same circuitry. This gives good agreement between charge and discharge directions because any gain/offset errors are command mode.

Minimum Resolution :

Current levels much below that which the A/D could detect can be monitored with the coulomb counter. In fact, currents which produce sense resistor voltages below the input-referred noise of the circuitry can still be monitored, because the random, bi-directional noise will be integrated out by the VCO.

With no current, there will always be a small offset frequency on the VCO, ensuring that there will be no clipping of the signal as the current through the sense resistor approaches zero. During an auto-zero phase, the microprocessor can count the number of counts in a given time period with no input signal.

Theoretically, the minimum resolution is a function of how long the microprocessor auto-zeros.

## 44 LEAD PLASTIC QUAD FLAT PACK
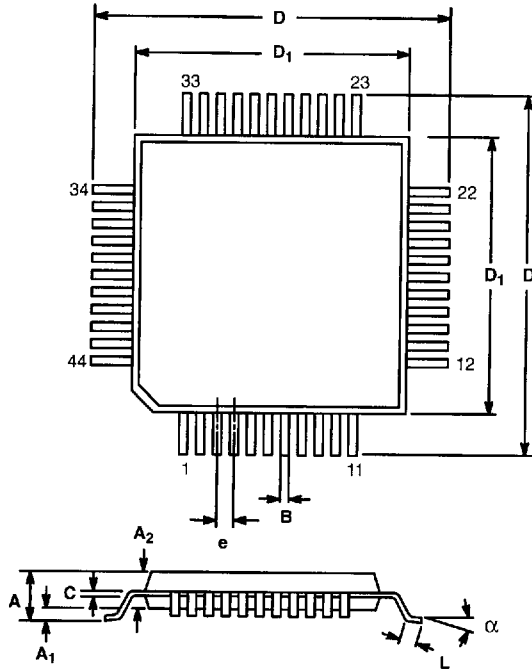## (14 mm x 14 mm QFP)

*Rev. 1.00*
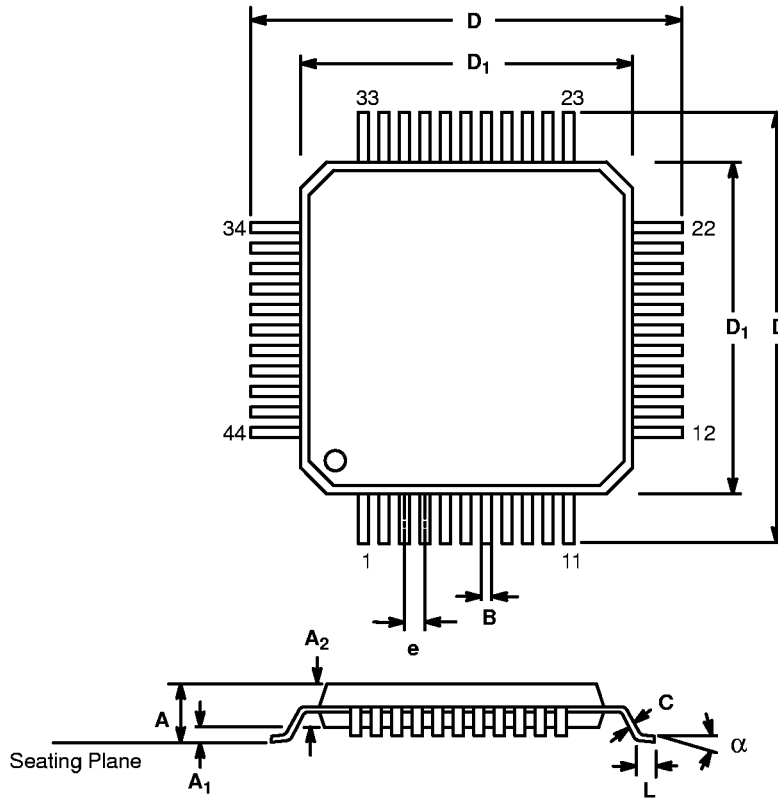


| SYMBOL | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.110 | 0.134 | 2.80 | 3.40 |
| $A_1$ | 0.010 | 0.014 | 0.25 | 0.35 |
| $A_2$ | 0.100 | 0.120 | 2.55 | 3.05 |
| B | 0.014 | 0.020 | 0.35 | 0.50 |
| C | 0.005 | 0.009 | 0.13 | 0.23 |
| D | 0.667 | 0.687 | 16.95 | 17.45 |
| $D_1$ | 0.547 | 0.555 | 13.90 | 14.10 |
| e | 0.039 BSC | | 1.00 BSC | |
| L | 0.026 | 0.37 | 0.65 | 0.95 |
| $\alpha$ | 0° | 7° | 0° | 7° |

*Note: The control dimension is the millimeter column*

## 44 LEAD PLASTIC QUAD FLAT PACK
## (14mm x 14mm PQFP, METRIC)
## Q44



| SYMBOL | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | — | 3.15 | — | 0.124 |
| A₁ | 0.25 | — | 0.01 | — |
| A₂ | 2.6 | 2.8 | 0.102 | 0.110 |
| B | 0.3 | 0.4 | 0.012 | 0.016 |
| C | 0.13 | 0.23 | 0.005 | 0.009 |
| D | 16.95 | 17.45 | 0.667 | 0.687 |
| D₁ | 13.9 | 14.1 | 0.547 | 0.555 |
| e | 1.00 BSC | | 0.039 BSC | |
| L | 0.65 | 1.03 | 0.026 | 0.040 |
| α | 0° | 7° | 0° | 7° |
| Coplanarity = 4 mil max. | | | | |

9

**T⬤M™**

3422618 0007783 49T