

*R-Box*TM

Low cost portable data logger with 16-bit ADCs, DACs, High Voltage Drivers, Relays, Opto-couplers with Custom Enclosure



Technical Manual



1950 5th Street, Davis, CA 95616, USA

Tel: 530-758-0180

Fax: 530-758-0181

Email: sales@tern.com

<http://www.tern.com>

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1950 5th Street, Davis, CA 95616, USA
Tel: 530-758-0180 Fax: 530-758-0181
Email: sales@tern.com <http://www.tern.com>

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Temperature readings for controllers are based on the results of limited sample tests; they are provided for design reference use only.

Chapter 1: Introduction

1.1 Functional Description

Boxed in an extruded aluminum enclosure of 4.0x3.2 inches, the **R-Box™(RB)** is designed as a low cost, portable data logger, or industrial embedded controller. It integrates 16-bit ADCs, 16-bit DACs, 4-20 mA drivers, RS232/485, Relays, Opto-couplers, and CompactFlash for mass local data storage.

The **RB** is based on a high performance C/C++ programmable 186 CPU with a 16-bit external bus supporting fast execution times through 16-bit Flash and 16-bit battery-backed SRAM. For longer life time supply, two CPU chips, either the AMD186ER or RDC R1100, can be used.

A 16-bit ADC (ADS8344, TI) provides 8 single-ended or 4 differential analog inputs with 65536 counts of resolution at up to 10 KHz sample rate. The analog inputs can be hardware configured for variable input voltage range, default 0-10V. A 16-bit DAC(LTC2600) provides 8 analog output voltages (0-5V). Two of the DAC outputs can be buffered with 4-20 mA drivers. The 4-20 mA drivers can be powered by local or remote positive voltage, up to 30V.

A 50-pin CompactFlash receptacle can be installed to allow access to mass storage CompactFlash cards (up to 2GB). Users can easily add mass data storage to their embedded application. C/C++ programmable software packages with file system libraries are available.

Three internal timer/counters can be used to count or time external events, or to generate non-repetitive or variable-duty-cycle waveforms as PWM outputs. A serial real time clock (DS1337, Dallas) is a clock/calendar with two time-of-day alarms. Three RS232 serial ports are available: A Dual UART (SCC2692) and a single CPU internal UART(default as DEBUG port). All UARTs have deep FIFOs to minimize the potential of receiver overrun or to reduce interrupt overhead. One UART can be buffered by RS232 (as default) or RS485. 20+ TTL I/O lines are free to use, including multifunctional CPU's PIO lines, and TTL I/Os from the Dual UART SCC2692.

Seven high voltage sink drivers are installed, capable of sinking 350 mA at 50V per line, and they can directly drive solenoids, relays, or lights. Four opto-couplers providing opto-isolation with both positive and negative inputs to the headers. Two solid-state relays (PS7241, NEC) with GaAs LED on the input side and MODFET on the output side designed for AC or DC line switching. Two mechanical Reed Relays provide reliable, fast switching contacts with a specification of 200 V, maximum 1 Amp carry current, 0.5 Amp switching, and 100 million times operation. Optional high efficient Switching Regulator (LM2575) provides a shutdown feature(VOFF). It can enter μ A poweroff mode and can be woken up by active-low signal from the on-board RTC or external signal. The poweroff mode allows the **RB** to operate in a remote location for a long period using only battery power. The **RB** uses 8.5V to 12V DC power supply with default linear regulator, or up to 30V DC with switching regulator without generating excessive heat. The **RB** is designed to fit in an aluminum enclosure. All signals on two 20x2 pin headers are accessible outside of the enclosure. The user can use W40 (40 field removable screw terminals) to access all I/O signals. Use one W40P on the front end, one W40S on the back end.



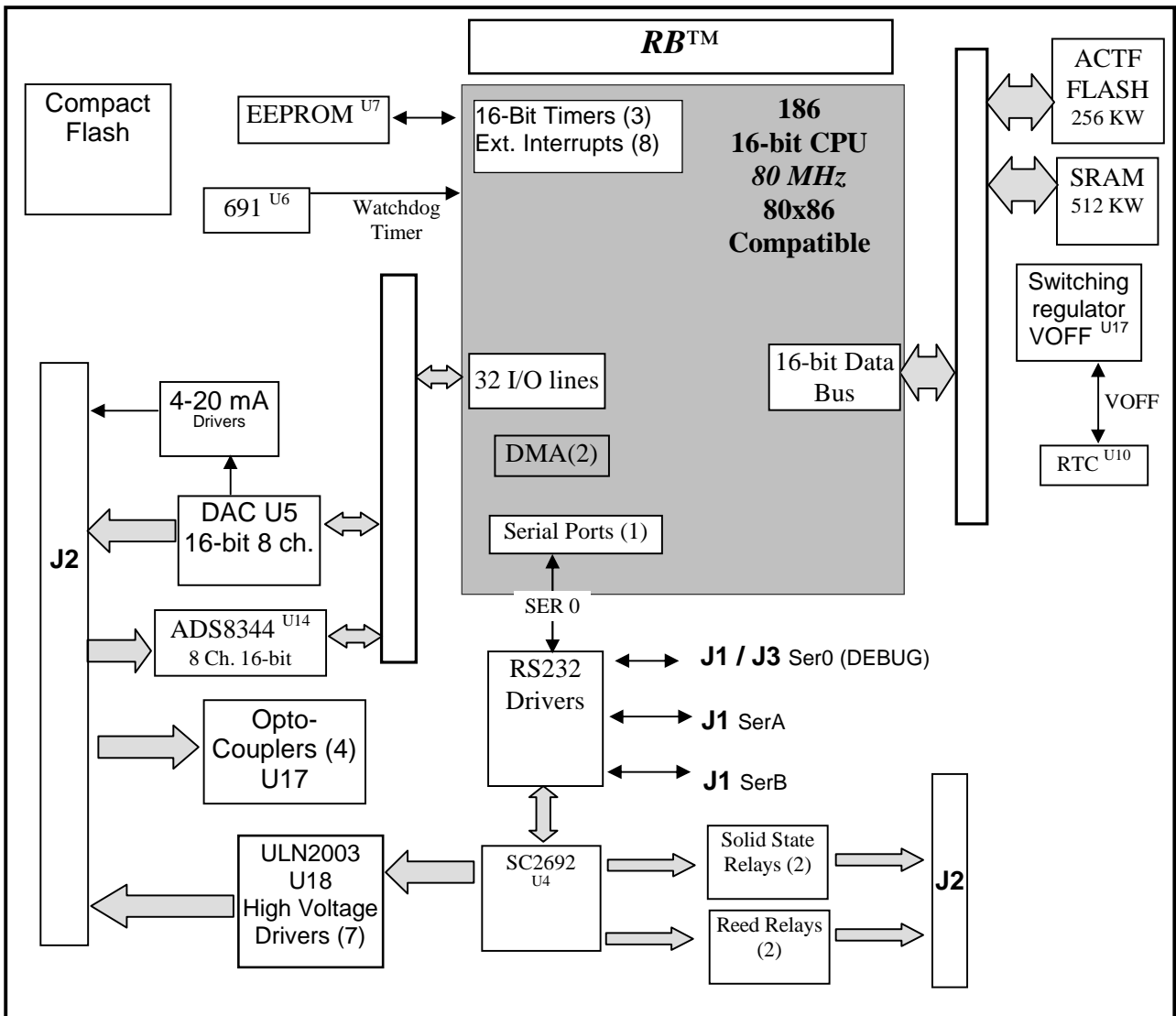


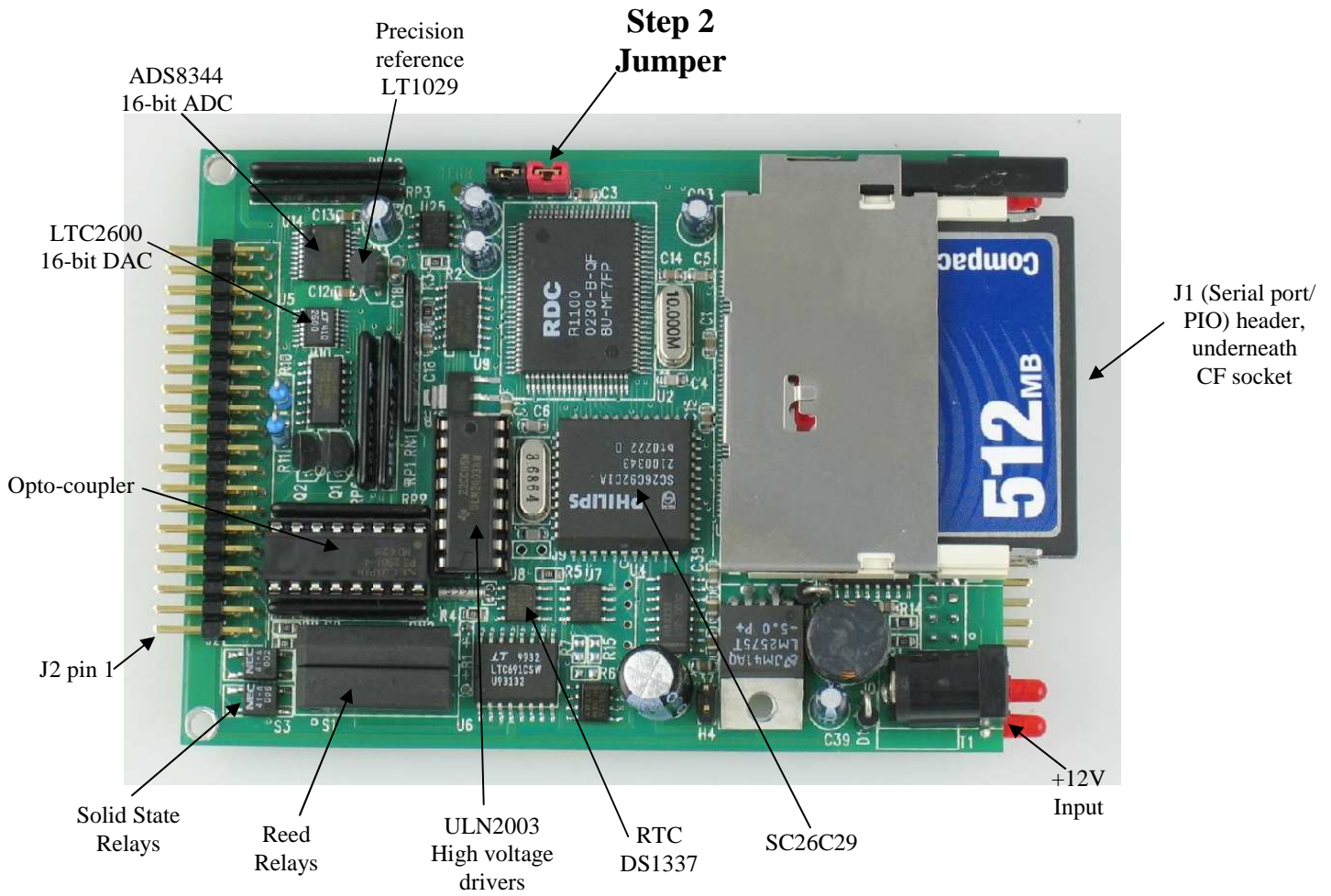
Figure 1.1 Functional block diagram of the RB

Features:

- * 3.0 x 3.6", 50 µA standby, 160 mA, 9-24V DC power
- * Complete C/C++ programmable environment
- * 8 16-bit ADC with analog inputs, 0-10V
- * 8 16-bit DAC (0-5V), two 4-20 mA outputs
- * Up to 2GB CompactFlash with FAT file system support
- * 80/40 MHz 186 CPU with 256 KW Flash, 256 KW SRAM
- * 20+ TTLs, 7 Solenoid drivers, 4 Relays, 4 Opto-couplers
- * 3 RS-232 serial ports, one can be RS232/485/422
- * 3 16-bit timer/counters, PWM output, RTC, EE
- * Aluminum box with field removable screw terminals

1.2 Physical Description

Below shows the physical description of the RB.



1.3 Programming Overview

An “ACTF Boot Loader” resides in the top protected sector of the 256KW on-board flash chip (29F400). At power-on/reset, the ACTF Utility will check the STEP 2 jumper (J3 pins 1&3, or H1 pins 1&2). If the STEP 2 jumper is installed, the “jump address” located in the on-board serial EEPROM will be read out and the CPU will jump to that address for immediate execution. A DEBUG kernel (already pre-programmed at the factory) can be downloaded and programmed into the flash starting at address 0xFA000. Using the ACTF Utility, the “GFA000 <enter>” command will set the jump address to 0xFA000. The command will also run the DEBUG kernel, preparing the RB for communication with the Paradigm C/C++ IDE for downloading and debugging applications. The following diagrams show the procedure for programming the RB. Steps include preparing the RB for debugging, debugging the RB, standalone field test, and production.

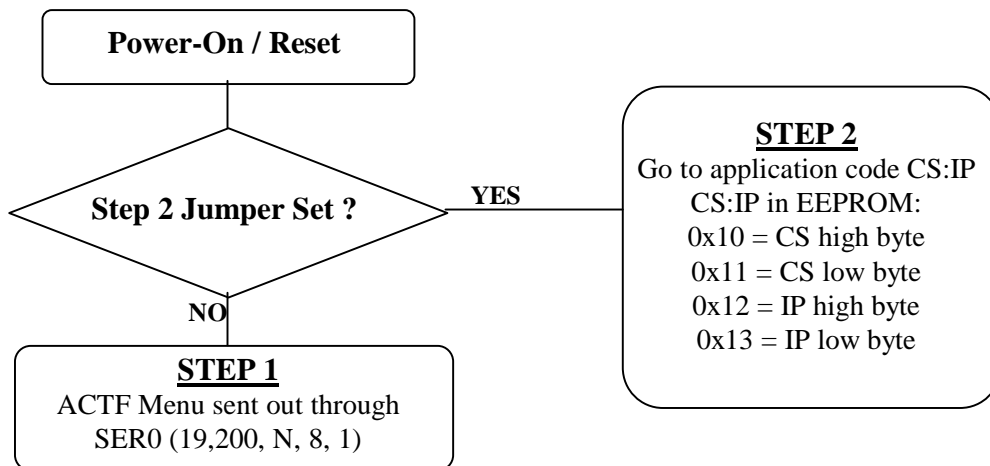


Figure 1.2 Flow Chart of ACTF Operation

By default, the DEBUG kernel has been loaded into the ACTF flash at the factory for your convenience. You may proceed directly to STEP 1: Debugging.

Preparation for Debugging:

This had already been done at the factory! You may proceed to STEP 1: Debugging. This step is only required if you have completed STEP 3 and would like to return to STEP 1.

- Connect the RB (SER0, H2) to PC (COMx) via serial debug cable provided with the EV-P/DV-P. Using the Windows “Hyper Terminal”, create a serial link based on 19,200, 8 bits, 1 stop, no parity.
- Power on the RB WITHOUT the STEP 2 jumper installed (J3 pins 1&3 or H1 pins 1&2). The ACTF text MENU should be sent out via serial port to “Hyper Terminal”.
- Use the “D <enter>” command to initiate download. Select Transfer -> Send File, and select \tern\186\rom\re\l_debug.hex. Use the “G04000 <enter>” command to execute this script.
- Select Transfer -> Send File to select \tern\186\rom\re\re80_115.hex (based on the default 80MHz board). This is the debug kernel. Use the “GFA000 <enter>” command to set jump address and execute the debug kernel. The LED will blink twice and remain on. With the 40MHz board, use “re40_115.hex”.
- Set the STEP 2 jumper (J2 pins 38 & 40). The RB is now ready to communicate with the Paradigm C/C++ IDE for debugging and application development.

Step 1: Debugging:

- Launch the Paradigm C/C++ IDE. Select File -> Open. Chose the project file \tern\186\samples\rb\rb.ide.
- Use samples within the “rb.ide” project to create application. Download, run, and debug application.

Step 2: Standalone Field Test:

- After completing STEP 1, by default, your application resides in the battery-backed SRAM starting at address 0x08000.
- Remove STEP 2 jumper and setup Hyper Terminal link with ST. (Open Windows “Hyper Terminal” program. Set for 19,200, 8 bits, 1 stop, no parity).
- At power-on, ACTF menu will be sent to Hyper Terminal. Use the “G08000 <enter>” command to execute application. Set STEP 2 jumper (J3 pins 1&3 or H1 pins 1&2). At every power-on/reset, application at 0x08000 will execute.
- Complete STANDALONE FIELD TEST. If return to STEP 1 is required, remove STEP 2 jumper and use the “GFA000 <enter>” command to run debug kernel to prepare to setup for communication with Paradigm C/C++ IDE.

Step 3: Production:

The DV-P Kit is required for this step. If you do not have the DV-P Kit, visit <http://tern.com/devkit.htm> for upgrade details.

- Refer to Section 3.3 of the ACTF technical manual, found in the \tern_docs\manuals directory. Here you will find details on generating an ACTF downloadable HEX file based upon you application.
- Remove the STEP 2 jumper and create serial link using Hyper Terminal (19,200, N, 8, 1). At power-on/reset, you will see the ACTF menu at Hyper Terminal. Use the “D <enter>” command to initiate download process. Select Transfers -> Send File, and select \tern\186\rom\re\l_29f40r.hex.
- This file will erase the flash and prepare the flash to accept ACTF downloadable application HEX file. Use the “G04000 <enter>” command to run script. Flash will be ready for application.
- Select Transfer -> Send File to select your ACTF downloadable application HEX file. Upon completion, use the “G80000 <enter>” command to execute application. This command also sets the jump address to point you application in flash. Set STEP 2 jumper (J3 pins 1&3 or H1 pins 1&2). At power-on/reset application will execute.

There is no ROM socket on the RB. The user’s application program must reside in the SRAM (starting at address of 0x08000 by default based on \tern\186\config\186.cfg) for debugging in STEP 1, reside in the battery-backed SRAM for standalone field testing in STEP 2, and finally be programmed into the on-board flash for a complete product. For production, the user must produce an ACTF-downloadable HEX file for the application based on the DV-P Kit. From the ACTF Utility, use the command “G80000 <enter>” to point to the user’s application code in the flash. The STEP 2 jumper must installed for every production-version board.

1.4 Minimum Requirements for RB System Development

Minimum Hardware Requirements

- PC or PC-compatible computer with serial COMx port that supports 115,200 baud
- RB controller
- Debug Serial Cable (RS232; DB9 connector for PC COM port and IDE 5x2 connector for controller)
- Center Negative Wall Transformer

Minimum Software Requirements

- TERN EV-P installation CD-ROM and a PC running: Windows 95/98/2000/ME/NT/XP

With the EV-P, you can program and debug the RB in Step One and Step Two, but you cannot run Step Three. To generate an application Flash File and complete a project, the development kit, DV-P, is required. The EV-P kit can be upgraded to the DV-P Kit. See <http://tern.com/devkit.htm> for details.

Chapter 2: Installation

2.1 Software Installation

Please refer to the “software_kit.pdf” technical manual on the TERN installation CD, under tern_docs\manual\software_kit.pdf, for information on installing software.

2.2 Hardware Installation

Overview

- Connect PC-IDE serial cable:
For debugging (STEP 1), place IDE connector on SER0 with red edge of cable on side facing J1 pin 1 (See Fig. 2.1). This DEBUG cable is a 10-pin IDE to DB9 cable, made by TERN.
- Connect wall transformer:
Connect 9V wall transformer to power and plug into power jack using power jack adapter supplied with EV-P/DV-P Kit

Hardware installation consists primarily of connecting the microcontroller to your PC.

2.2.1 Connecting the RB to the PC

The following diagram (Fig 2.1) provides the location of the debug serial port and the power jack. The RB is linked to the PC via a serial cable (DB9-IDE) which is supplied with TERN’s EV-P / DV-P Kits.

The RB communicates through SER0 by default. Install the 5x2 IDC connector on the SER0 J1 pin header. **IMPORTANT:** Note that Ser 0 is in the middle of J1 pin header. The DB9 connector should be connected to one of your PC's COM Ports (COM1 or COM2).

2.2.2 Powering-on the RB

By factory default setting:

- 1) The RED STEP2 Jumper is installed. (Default setting in factory)
- 2) The DEBUG kernel is pre-loaded into the on-board flash starting at address of 0xFA000. (Default setting in factory)
- 3) The EEPROM is set to jump address of 0xFA000. (Default setting in factory)

Connect +9-12V DC to the DC power terminal. The screw terminal at the corner of the board is positive 12V input and the other terminal is GND (see figure for details). A power jack adapter (seen below) is included with the TERN EV-P/DV-P kit. It can be used to connect the output of the power jack adapter and the RB. Note that the output of the power jack adapter is center negative.

The on-board LED should blink twice and remain on, indicating the debug kernel is running and ready to communicate with Paradigm C++ TERN Edition for programming and debugging.

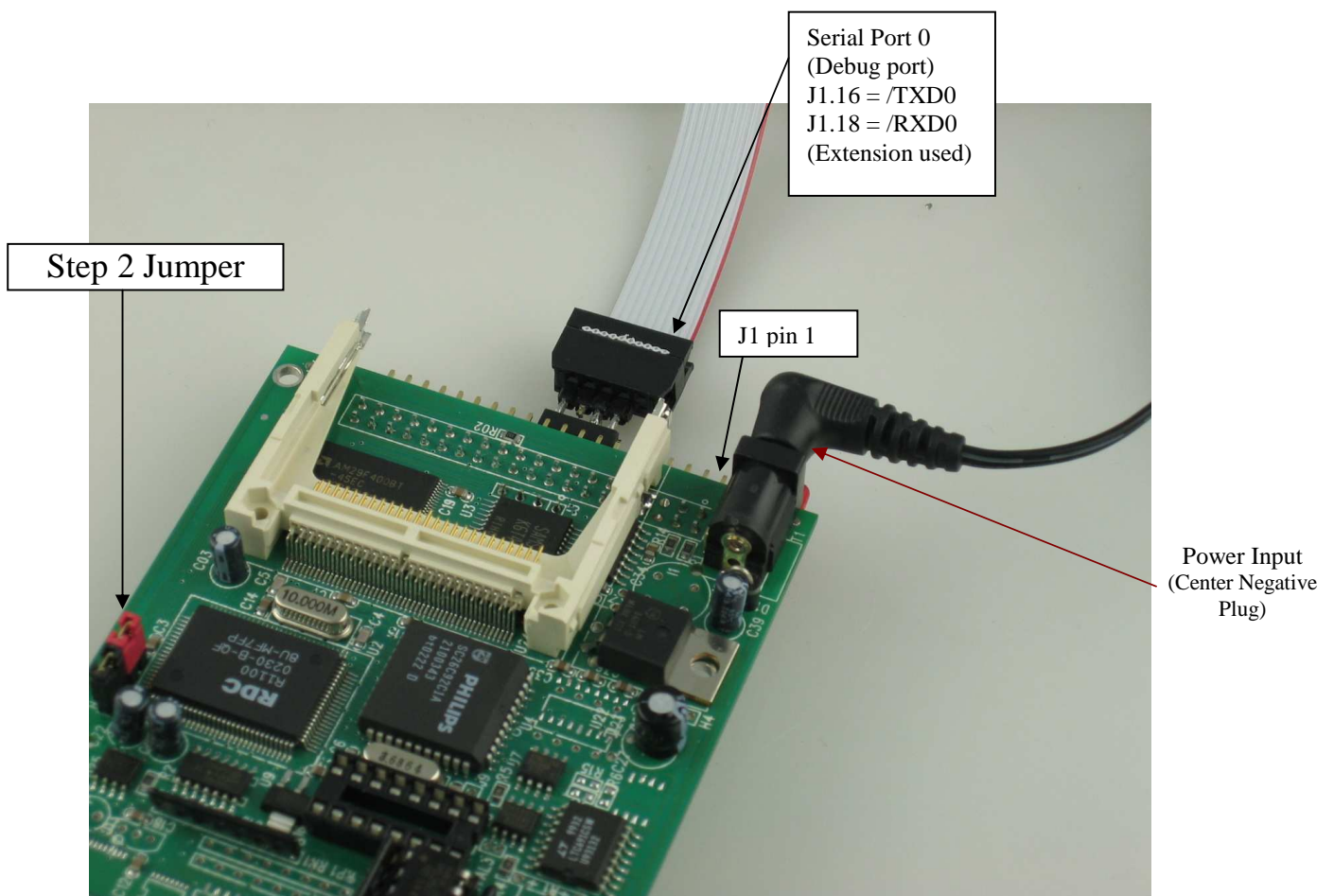


Figure 2.1 Locations of STEP2 Jumper, LED, Power input and DEBUG port

Another option for connecting the Debug cable is through Pin Header J3.

IMPORTANT: Note that when using J3 to connect the Debug cable, the aluminum encasing cannot be used as well due to lack of space.

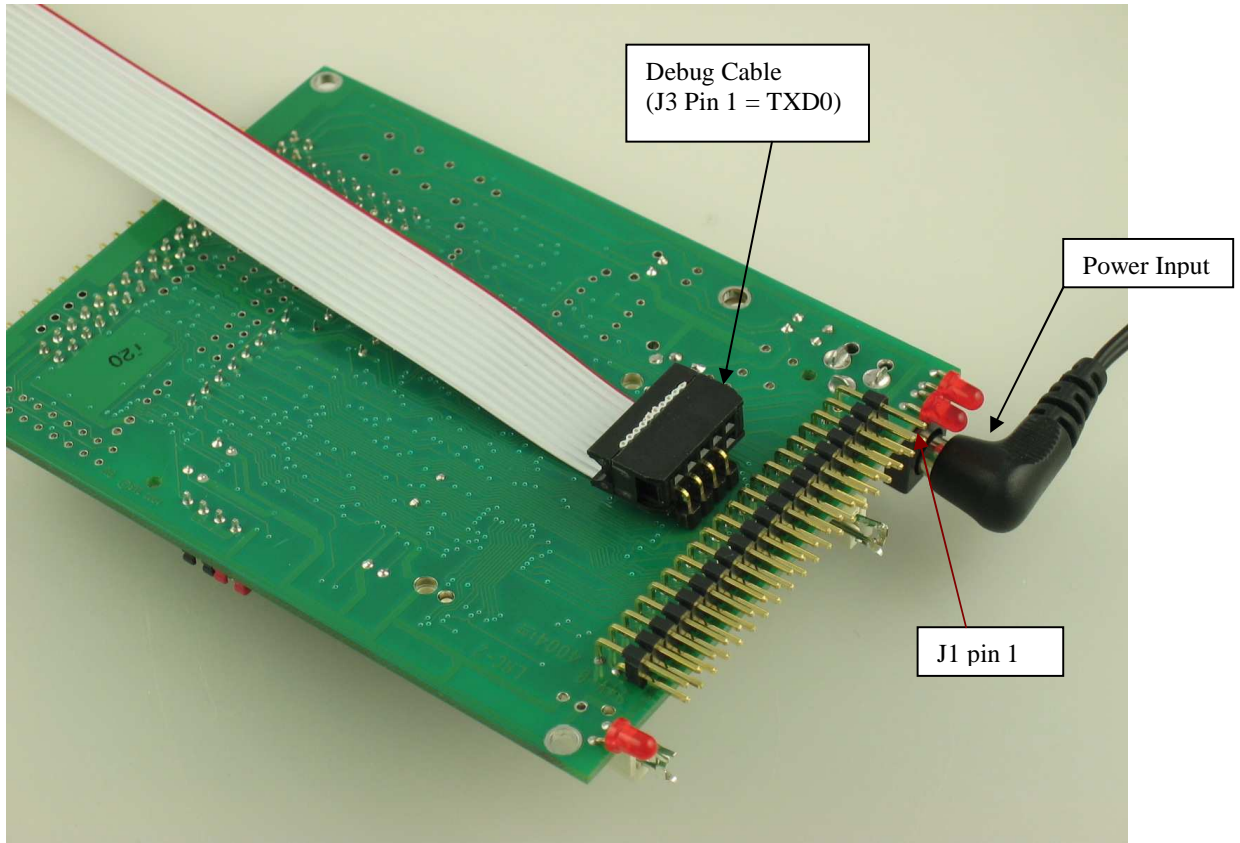


Figure 2.2 Power input and optional DEBUG port J3 (underneath board)

Chapter 3: Hardware

3.1 *Am186ER AND RDC R1100*

The RB is compatible with two different CPUs. Both offer and support the same on-board peripherals as well as the on the CPU itself, aside from a few differences. The Am186ER, from AMD, uses times-four crystal frequency, while the R1100, from RDC, uses times-eight. The RB uses a 10MHz system clock, giving the Am186ER a CPU clock of 40MHz and the R1100 a CPU clock of 80MHz. Both CPUs operate at +3.3V, with lines +5V tolerant. The RDC 1100 supports the same 80C188 microprocessor instruction set as the Am186ER, yet uses an internal RISC core architecture.

3.2 *Am186ER – Introduction*

The Am186ER is based on the industry-standard x86 architecture. The Am186ER controllers are higher-performance, more integrated versions of the 80C188 microprocessors. In addition, the Am186ER has new peripherals. The on-chip system interface logic can minimize total system cost. The Am186ER has one asynchronous serial port, one synchronous serial port, 32 PIOs, a watchdog timer, additional interrupt pins, DMA to and from serial ports, a 16-bit reset configuration register, and enhanced chip-select functionality.

In addition, the Am186ER has 32KB of internal volatile RAM. This provides the user with access to high speed zero wait-state memory. In some instances, users can operate the RB without external SRAM, relying only on the Am186ER's internal RAM.

3.3 *RDC R1100 – Introduction*

The RDC 1100 is based on RISC internal architecture, yet still supports the same 80C188 microprocessor instruction set. It provides faster operation than the Am186ER, allowing it to operate at up to 80MHZ, based a 10MHz system clock and times-eight crystal operation. The RDC R1100 does not offer internal RAM like the Am186ER, so external SRAM is mandatory if using the RDC R1100.

3.4 *Am186ER – Features*

Clock

Due to its integrated clock generation circuitry, the Am186ER microcontroller allows the use of a times-four crystal frequency. The design achieves 40 MHz CPU operation, while using a 10 MHz crystal.

The R1100 offers times-eight crystal frequency, achieving 80MHz operation based on a 10MHz crystal.

The system CLKOUTA signal is default 40 MHz. Neither CLKOUTA nor CLKOUTB signals are routed to headers in the RB.

CLKOUTA remains active during reset and bus hold conditions. The RB initial function `ae_init()`; disables CLKOUTA and CLKOUTB with `clka_en(0)`; and `clkb_en(0)`;

You may use `clka_en(1)`; to enable CLKOUTA.

External Interrupts and Schmitt Trigger Input Buffer

There are six external interrupts: INT0-INT4 and NMI.

/INT0, is used by SC26C92 UART.

/INT1, Used by opto-coupler input OT2/OT2-, J2 pins 17-18, free for application use
 INT2, Tied to alarm output of the DS1337 RTC, can be shared with user application
 /INT3, Used by opto-coupler input OT1/OT1-, J2 pins 19-20, free for user application
 /INT4, J1 pin 24, free for application use

NMI, tied 74HC14 inverters to /PFO of MAX691 supervisor chip. (More in Section 3.7)

Five external interrupt inputs, /INT0-1, /INT3-4, and NMI are buffered by Schmitt-trigger inverters (U9, 74HC14) in order to increase noise immunity and transform slowly changing input signals to fast changing and jitter-free signals. As a result of this buffering, these pins are capable of only acting as input.

These buffered external interrupt inputs require a falling edge (HIGH-to-LOW) to generate an interrupt.

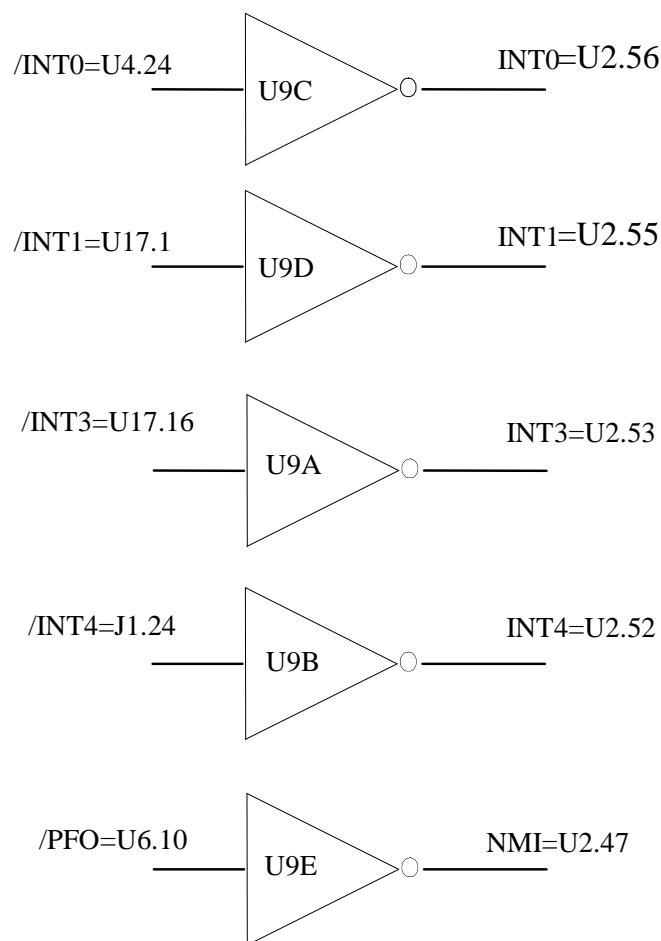


Figure 3.1 External interrupt inputs

Remember that /INT0 is used by the external Dual UART. /INT0 should not be used by application if SERA and SERB are being used.

The RB uses vector interrupt functions to respond to external interrupts. Refer to the Am186ER User's manual for information about interrupt vectors.

Asynchronous Serial Port

The Am186ER and R1100 CPU has one asynchronous serial channel. It supports the following:

- Full-duplex operation
- 7-bit, and 8-bit data transfers
- Odd, even, and no parity
- One or two stop bits
- Error detection
- Hardware flow control
- DMA transfers to and from serial port (Am186ER ONLY)
- Transmit and receive interrupts
- Maximum baud rate of 1/16 of the CPU clock speed
- Independent baud rate generators

The software drivers for the asynch. serial port implement a ring-buffered DMA receiving and ring-buffered interrupt transmitting arrangement. See the sample file *s0_echo.c*

An external SC26C92 UART is located in position U4. For more information about the external Dual UART SC26C92, please refer to the section in this manual on the SC26C92, or the data sheet. From the root directory of the installation CD, \tern_docs\parts\sc26c92.pdf

Note that while the Am186ER supports DMA transfers to and from its asynchronous serial port, the R1100 does not. Despite this difference, the TERN software drivers for the asynchronous serial port support both CPUs.

Timer Control Unit

The timer/counter unit has three 16-bit programmable timers: Timer0, Timer1, and Timer2.

Timer0 and Timer1 are connected to four external pins:

| | | |
|---------------|-------|-------------|
| Timer0 output | = P10 | = J1 pin 28 |
| Timer0 input | = P11 | = J1 pin 25 |
| Timer1 output | = P1 | = J1 pin 27 |
| Timer1 input | = P0 | = J1 pin 29 |

These two timers can be used to count or time external events, or they can generate non-repetitive or variable-duty-cycle waveforms.

Timer2 is not connected to any external pin. It can be used as an internal timer for real-time coding or time-delay applications. It can also prescale timer 0 and timer 1 or be used as a DMA request source.

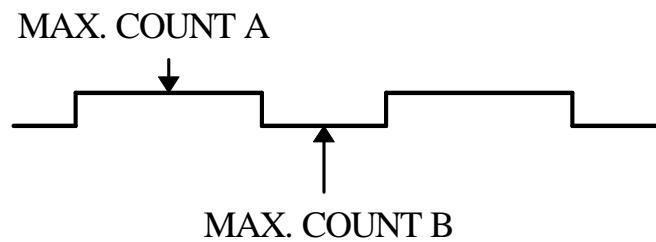
Timer 0 output, P1, is used as the clock input for the AD7852. Timer 0 should therefore not be used by application unless the AD7852 is not used.

The maximum rate at which each timer can operate is 10 MHz for the Am186ER and 20MHz for the R1100, since each timer is serviced once every fourth CPU clock cycle. Timer inputs take up to six clock cycles to respond to clock or gate events. See the sample programs *timer0.c* and *ae_cnt0.c* in the \186\samples\ae directory.

PWM outputs

The Timer0 and Timer1 outputs can also be used to generate non-repetitive or variable-duty-cycle waveforms. The timer output takes up to 6 clock cycles to respond to the clock input. Thus the minimum timer output cycle is $25\text{ ns} \times 6 = 150\text{ ns}$ (at 40 MHz).

Each timer has a maximum count register that defines the maximum value the timer will reach. Both Timer0 and Timer1 have secondary maximum count registers for variable duty cycle output. Using both the primary and secondary maximum count registers lets the timer alternate between two maximum values.



Power-save Mode

The RB is an ideal core module for low power consumption applications. The power-save mode of the Am186ER reduces power consumption and heat dissipation, thereby extending battery life in portable systems. In power-save mode, operation of the CPU and internal peripherals continues at a slower clock frequency. When an interrupt occurs, it automatically returns to its normal operating frequency.

The DS1337 on the RB has a VOFF signal routed to the switching regulator, LM2575. VOFF is controlled by the battery-backed DS1337. The VOFF signal can be programmed by software to be in tri-state or to be active low. The DS1337 can be programmed in interrupt mode to drive the VOFF pin at 1 second, 1 minute, or 1 hour intervals. The user can use the VOFF line to control the switching power supply that turns the power supply on/off. An example program using the VOFF signal can be found in `\tern\186\samples\ra\ra_voff.c`.

3.5 Am186ER PIO lines

The Am186ER has 32 pins available as user-programmable I/O lines. Each of these pins can be used as a user-programmable input or output signal, if the normal shared function is not needed. A PIO line can be configured to operate as an input or output with or without a weak pull-up or pull-down, or as an open-drain output. A pin's behavior, either pull-up or pull-down, is pre-determined and shown in the table below.

After power-on/reset, PIO pins default to various configurations. The initialization routine provided by TERN libraries reconfigures some of these pins as needed for specific on-board usage, as well. These configurations, as well as the processor-internal peripheral usage configurations, are listed below in Table 3.1.

| <i>PIO</i> | <i>Function</i> | <i>Power-On/Reset status</i> | <i>RB Pin No.</i> | <i>RB Initial after ae_init(); function call</i> |
|------------|-----------------|------------------------------|-------------------|--|
| P0 | Timer1 in | Input with pull-up | J1 pin 29 | Input with pull-up |
| P1 | Timer1 out | Input with pull-down | J1 pin 27 | Input with pull-up |
| P2 | /PCS6/A2 | Input with pull-up | J1 pin 34 | /PCS6 |
| P3 | /PCS5/A1 | Input with pull-up | U4 pin 39 | /PCS5: SC26C92 select |
| P4 | DT/R | Normal | H1 pin 1 | Input with pull-up: Step 2 |
| P5 | /DEN/DS | Normal | J1 pin 39 | Input with pull-up |
| P6 | SRDY | Normal | J1 pin 37 | Input with external pull-up |
| P7 | A17 | Normal | N/A | A17 |
| P8 | A18 | Normal | N/A | A18 |
| P9 | A19 | Normal | N/A | Input with pull-up |
| P10 | Timer0 out | Input with pull-down | J1 pin 28 | Input with pull-down |
| P11 | Timer0 in | Input with pull-up | J1 pin 25 | Input with pull-up |
| P12 | DRQ0 | Input with pull-up | J1 pin 38 | Output |
| P13 | DRQ1 | Input with pull-up | U14 pin 16 | Input with pull-up |
| P14 | /MCS0 | Input with pull-up | U14 pin 17 | Input with pull-up |
| P15 | /MCS1 | Input with pull-up | U14 pin 18 | Input with pull-up |
| P16 | /PCS0 | Input with pull-up | J1 pin 31 | /PCS0 |
| P17 | /PCS1 | Input with pull-up | N/A | /PCS1 for U18 HC138 |
| P18 | /PCS2 | Input with pull-up | J1 pin 32 | Input with pull-up |
| P19 | /PCS3 | Input with pull-up | J1 pin 33 | Input with pull-up |
| P20 | SCLK | Input with pull-up | U14.19, U5.8 | Input with pull-up |
| P21 | SDATA | Input with pull-up | U14.15, U5.9 | Input with pull-up |
| P22 | SDEN0 | Input with pull-down | U8.6, U7.6 | Output |
| P23 | SDEN1 | Input with pull-down | J1 pin 23 | Input with pull-down |
| P24 | /MCS2 | Input with pull-up | U5 pin 7 | Input with pull-up |
| P25 | /MCS3 | Input with pull-up | J1 pin 30 | Input with pull-up |
| P26 | UZI | Input with pull-up | J1 pin 36 | Input with pull-up* |
| P27 | TxD | Input with pull-up | N/A | TxD0 |
| P28 | RxD | Input with pull-up | N/A | RxD0 |
| P29 | S6/CLKSEL1 | Input with pull-up | N/A | Output |
| P30 | INT4 | Input with pull-up | U9.4 (buffered) | Input with pull-up |
| P31 | INT2 | Input with pull-up | U8.7 RTC Alarm | Input with pull-up |

* Note: P6, P26 and P29 must NOT be forced low during power-on or reset.

Table 3.1 I/O pin default configuration after power-on or reset

The 32 PIO lines, P0-P31, are configurable via two 16-bit registers, PIOMODE and PIODIRECTION. The

| MODE | PIOMODE reg. | PIODIRECTION reg. | PIN FUNCTION |
|------|--------------|-------------------|---------------------------------|
| 0 | 0 | 0 | Normal operation |
| 1 | 0 | 1 | INPUT with pull-up/pull-down |
| 2 | 1 | 0 | OUTPUT |
| 3 | 1 | 1 | INPUT without pull-up/pull-down |

settings are as follows:

RB initialization on PIO pins in `ae_init()` is listed below:

```

outport(0xff78,0xc7bc); // PDIR1: TxD, RxD, PCS0, PCS1, P29& P22 Output
outport(0xff76,0x2040); // PIOM1
outport(0xff72,0xee73); // PDIR0: A18, A17, PCS6, PCS5, P12 Output
outport(0xff70,0x1040); // PIOM0

```

The C function in the library `re_lib` can be used to initialize PIO pins.

```
void pio_init(char bit, char mode);
```

Where bit = 0-31 and mode = 0-3, see the table above.

Example: `pio_init(12, 2);` will set P12 as output
 `pio_init(1, 0);` will set P1 as Timer1 output

```
void pio_wr(char bit, char dat);
```

`pio_wr(12,1);` set P12 pin high, if P12 is in output mode
`pio_wr(12,0);` set P12 pin low, if P12 is in output mode

```
unsigned int pio_rd(char port);
```

`pio_rd(0);` return 16-bit status of P0-P15, if corresponding pin is in input mode,
`pio_rd(1);` return 16-bit status of P16-P31, if corresponding pin is in input mode,

Some of the I/O lines are used by the RB system for on-board components. We suggest that you not use these lines unless you are sure that you are not interfering with the operation of such components (i.e., if the component is not installed).

| Signal | Pin | Function |
|--------|----------|---|
| P3 | /PCS5 | U4 SCC2692 UART chip select at base I/O address 0x0500 |
| P4 | /DT | Step Two jumper |
| P7 | A17 | Upper address line – Never use by application |
| P8 | A18 | Upper address line – Never use by application |
| P13 | U14.16 | Data In signal for ADS8344 |
| P14 | U14.17 | Bsy signal for ADS8344 |
| P15 | U14.18 | Chip select for ADS8344 |
| P20** | SCLK | Synchronous Clock for U14, U5 |
| P21** | SDAT | Serial Interface for U14, U5 |
| P22 | SDEN0 | Interface with RTC, EEPROM |
| P24 | U5.7 | Chip select for LTC2600 |
| /INT0 | U4.24 | U4 SCC2692 Dual UART interrupt. |
| P27 | N/A | TxD0 |
| P28 | N/A | RxD0 |
| P26* | /CLKSEL2 | Used at power-up/reset to determine system clock multiplier |
| P29* | N/A | Reserved for EEPROM, LED, RTC, and Watchdog timer |
| P31 | INT2 | Tied to DS1337 RTC alarm |

Important Notes:

* The Am186ER CPU uses the P26 and the P29 lines to determine the system clock multiplier at power-up or reset. The CPU has internal pull-ups on these lines to select the default multiplier of four-times (AMD) or eight-times (RDC). It is critical that the user allow these lines to remain high during power-up or reset. Failure to do so will result in undesirable operation. In addition, P6 must also be allowed high during power-on or reset.

** The SCLK and SDAT lines are the synchronous serial port on the Am186ER. Several devices on the RA use these lines, including both DAC7612 (locations U15 and U17), and both ADS8344 (locations U14 and U28). The user is free to use the SCLK and SDAT lines for their application only if the ADCs and DACs are disabled first. This is needed so as not to have more than one device trying to occupy the SDAT line simultaneously.

Table 3.2 I/O lines used for on-board components

3.6 I/O Mapped Devices

I/O Space

External I/O devices can use I/O mapping for access. You can access such I/O devices with *inportb*(port) or *outportb*(port,dat). These functions will transfer one byte or word of data to the specified I/O address. The external I/O space is 64K, ranging from 0x0000 to 0xffff.

The default I/O access time is 15 wait states. You may use the function void *io_wait*(char wait) to define the I/O wait states from 0 to 15. The system clock is 100 ns for both CPUs, while the CPU clock is 25ns for the Am186ER and 12.5ns for the R1100. Details regarding this can be found in the Software chapter, and in the Am186ER User's Manual. Slower components, such as most LCD interfaces, might find the maximum programmable wait state of 15 cycles still insufficient. Due to the high bus speed of the system, some components may need to be attached to I/O pins directly.

For details regarding the chip select unit, please see Chapter 5 of the Am186ER User's Manual.

The table below shows more information about I/O mapping.

| I/O space | Select | Location | Usage |
|---------------|--------|-----------------|----------|
| 0x0000-0x00ff | /PCS0 | J1 pin 31 = P16 | USER* |
| 0x0100-0x01ff | /PCS1 | N/A | USER |
| 0x0200-0x02ff | /PCS2 | J1 pin 32 = P18 | USER |
| 0x0300-0x03ff | /PCS3 | J1 pin 33 = P19 | USER |
| 0x0400-0x04ff | /PCS4 | | Reserved |
| 0x0500-0x05ff | /PCS5 | U4.39 = P3 | SCC26C92 |
| 0x0600-0x06ff | /PCS6 | J1 pin 34 = P2 | USER |

*PCS0 may be used for other TERN peripheral boards, such as FC-0, P50, P100, MM-A.

To illustrate how to interface the RB with external I/O boards, a simple decoding circuit for interfacing to an 82C55 parallel I/O chip is shown in Figure 3.2.

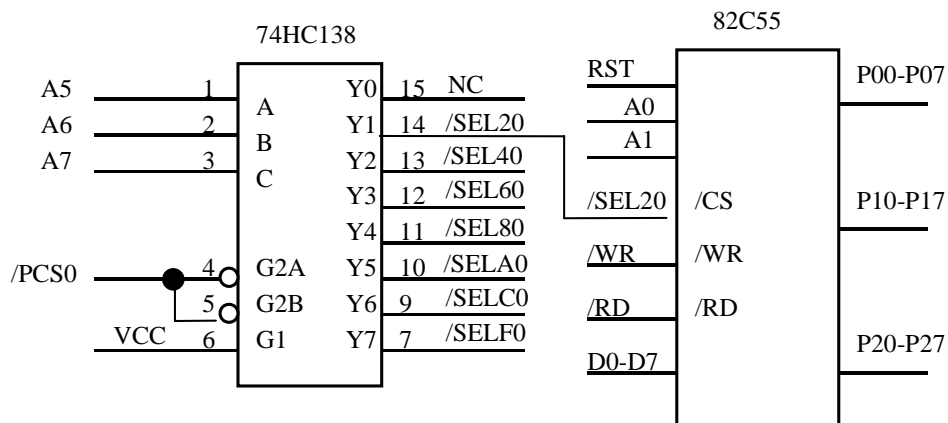


Figure 3.2 Interface the RB to external I/O devices

The function `ae_init()` by default initializes the `/PCS0` line at base I/O address starting at `0x00`. You can read from the 82C55 with `inportb(0x020)` or write to the 82C55 with `outportb(0x020,dat)`. The call to `inportb(0x020)` will activate `/PCS0`, as well as putting the address `0x20` over the address bus. The decoder will select the 82C55 based on address lines A5-7, and the data bus will be used to read the appropriate data from the off-board component.

Real-time Clock DS1337

The DS1337 serial real-time clock is a low-power clock/calendar with two programmable time-of-day alarms and a programmable square-wave output. Address and data are transferred serially via a 2-wire, bidirectional bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The data at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either 24-hour or 12-hour format with AM/PM indicator.

The RTC is accessed via software drivers `rtc_init()` and `rtc_rds()`. Refer to sample code in the `samples\ra` directory for `re_rtc.c`. The sample code is identical to the **RB**'s predecessor, the **RE**. The RTC is located at location U8 and uses a 32KHz crystal. The data sheet can be found in the `tern_docs\parts` directory and is named `ds1337.pdf`.

It is also possible to configure the real-time clock to raise an output line attached to an external interrupt, at 1/64 second, 1 second, 1 minute, or 1 hour intervals. This can be used in a time-driven application, or the **VOFF** signal can be used to turn on/off the controller using the switching power supply, LM2575. See the sample program, `\tern\186\samples\re\ra_voff.c`.

UART SCC2692

The dual UART (SC26C92, Phillips, U4) is a 44-pin PLCC chip. The SC26C92 includes two independent full-duplex asynchronous receiver/transmitters, a quadruple buffered receiver data register, an interrupt control mechanism, programmable data format, selectable baud rate for the receiver and transmitter, a multi-functional and programmable 16-bit counter/timer, an on-chip crystal oscillator, and a multi-purpose input/output including RTS and CTS mechanism.

A 3.6864 MHz external crystal is installed as the default crystal for the dual UART.

For more detailed information, refer to the SC26C92 data sheets (Phillips Semiconductors) or on the CD in the `tern_docs\parts` directory.

Sample programs for the SC26C92 can be found in the `c:\tern\186\samples\re` directory. Other devices on the **RA**, such as both of the U18 high voltage driver and the U17 opto-coupler, use some of the SC26C92's I/O lines. The user must be careful if using the I/O ports on the SC26C92 so as not to inadvertently exercise other devices.

3.7 Other Devices

A number of other devices are also available on the RB. Some of these are optional, and might not be installed on the particular controller you are using. For a discussion regarding the software interface for these components, please see the Software chapter.

On-board Supervisor with Watchdog Timer

The MAX691/LTC691 (U6) is a supervisor chip. With it installed, the RB has several functions: watchdog timer, battery backup, power-on-reset delay, power-supply monitoring, and power-failure warning. These will significantly improve system reliability.

Watchdog Timer

The watchdog timer is activated by setting a jumper on J9 of the RB. The watchdog timer provides a means of verifying proper software execution. In the user's application program, calls to the function `hitwd()` (a routine that toggles the P29 = WDI pin of the MAX691) should be arranged such that the WDI pin is accessed at least once every 1.6 seconds. If the J9 jumper is on and the WDI pin is not accessed within this time-out period, the watchdog timer pulls the WDO pin low, which asserts /RESET. This automatic assertion of /RESET may recover the application program if something is wrong. After the RB is reset, the WDO remains low until a transition occurs at the WDI pin of the MAX691. When controllers are shipped from the factory the J9 jumper is off, which disables the watchdog timer.

The Am186ER has an internal watchdog timer. This is disabled by default with `ae_init()`.

Watchdog jumper, J9.
The J9 header is not populated in this picture.

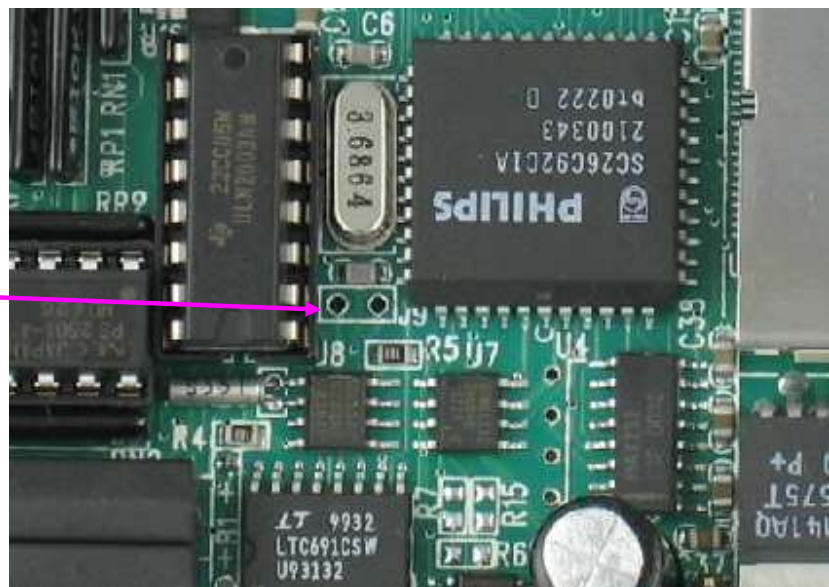


Figure 3.3 Location of watchdog timer enable jumper

Battery Backup Protection

The backup battery protection protects data stored in the SRAM and RTC. The battery-switch-over circuit compares VCC to VBAT (+3 V lithium battery positive pin), and connects whichever is higher to the VRAM (power for SRAM and RTC). Thus, the SRAM and the real-time clock DS1337 are backed up. In normal use, the lithium battery should last about 3-5 years without external power being supplied. When the external power is on, the battery-switch-over circuit will select the VCC to connect to the VRAM.

Power Fail Monitoring

The MAX691 and the NMI interrupt line can be used to monitor power supply. User configurable resistors at locations R6 and R7 can be used to create a voltage divider across PFI, where the source voltage is tied to +V. The input threshold for the PFI is rated a 1.3 volts. If PFI drops below this, the MAX691 supervisor will assert /PFO, which will drive the NMI interrupt line. The user may program the NMI ISR to take critical steps before complete power fail. See `\tern\186\samples\ae\intx.c` for details on interrupts.

EEPROM

A serial EEPROM of 512 bytes (24C04) is installed in U7. The RB uses the P22=SCL (serial clock) and P29=SDA (serial data) to interface with the EEPROM. The EEPROM can be used to store important data such as a node address, calibration coefficients, and configuration codes. It typically has 1,000,000 erase/write cycles. The data retention is more than 40 years. EEPROM can be read and written by simply calling the functions `ee_rd()` and `ee_wr()`.

A range of lower addresses in the EEPROM is reserved for TERN use, 0x00 – 0x1F. The addresses 0x20 to 0x1FF are for user application.

ADS8344, 16-bit ADC

The ADS8344 is an 8-channel, 16-bit, sampling ADC with synchronous serial interface. In single channel operation a 25KHz sampling rate can be achieved. The ADC can accept input voltages in the range of 0-5 volts, or COM – REF. REF is set to +5V by the precision reference, LT1029, at location U13. Com is located at J2 pin 32 and is user configurable, but is set to GND at the factory. Input channels are routed to the J2 pin header (pins 33-40) for easy access to the device. The ADS8344 used five TTL signals for serial interface. The signals are summarized below. TERN provides two software drivers for this ADC. Please refer to the sample code in the `186\samples\rb` directory (`rb_ad.c`).

| | |
|------|---|
| SCLK | Serial clock from Am186ER |
| P15 | Active low chip select. If low, the ADC will have output on SDAT. |
| P14 | DIN. Serial data in. |
| P13 | BSY. Low while control bytes are being read, and during conversion. |
| SDAT | Serial data out. |
| SHD | Active low power down. Tied to VCC, never in power down. |
| COM | Routed to J2.32. Set by user. Set to GND by default. |
| REF | Set to +5 volts by default by precision reference LT1029. |

The valid analog input range for the ADS8344 is defined as REF to COM, where REF is less than or equal to VCC, and COM is greater than or equal to Ground. Refer to the data sheet in the `tern_docs\parts` directory for additional information (`ads8344.pdf`).

LTC2600, 16-bit DAC

The LTC2600 is an eight channel 16-bit digital-to-analog converter (DAC) in an SO-8 package. It is complete with a rail-to-rail voltage output amplifier capable of driving up to 15mA. It uses 3-wire SPI compatible serial interface and has an output range of 0-REF volts, making 1 LSB equal to REF/65536 V. The reference voltage is tied a 5V precision reference, location U13.

The DAC is installed in location U5 on the RB. It uses P24 for chip select and SCLK and SDAT for serial communication. P24 must be initialized to mode 2 output when driving the DAC. Refer to the sample program `\tern\186\samples\rb\rb_da.c` which has been included in the sample project file `\tern\186\samples\rb\rb.ide`.

Also see the data sheet located from the root of the installation CD, `\tern_dcos\parts\ltc2600.pdf`.

Opto-couplers

Four opto-couplers are installed on the RB, providing high voltage opto-isolation capability. They can be used for digital inputs, relay contact monitoring, or powerline monitoring. Typical ON time is 3 μ s, while typical OFF time is 5 μ s. The corresponding input pins are pulled high via 10k Ω resistor. As a result, an input low signal will turn the opto-couplers on. The package (PS2701-4) is located at U17. The corresponding inputs are /INT1, /INT3, IP5 and IP6. Thus in order to monitor the status of the opto-couplers, the user must initialize the interrupt lines (see `\tern\186\samples\ae\intx.c` for interrupt details) for /INT1 and /INT3 and must monitor the input port of the SC26C92 for IP5 and IP6. An example of monitoring this port can be found in the sample program, `\tern\186\samples\re\re_sc_ip.c`, which can be found as a part of the sample project `rb.ide` in the `\tern\186\samples\rb` directory. The data sheet for the opto-coupler package can be found in `\tern_docs\parts\ps2701.pdf`, from the root of the TERN installation CD-ROM.

Reed Relays

Two Reed relays can be installed on the RB at locations S1 and S2. The relays offer high speed switching compared to electromechanical relays, a specification of 200 V, maximum 1 Amp carry current, 0.5 Amp switching, and 100 million times operation. The relays are connected to OP0 and OP2 of the output port of the SC26C92. See `\tern\186\samples\re\re_sc_op.c` and `\tern_docs\parts\relay9007.pdf` for details.

4-20 mA current drivers

Two channels of 4-20 mA current drivers can be installed. Two analog voltage outputs (V7 and V8) from the 16-bit DAC (LTC2600) can be converted to 4-20 mA current. The current driver power FET (Q1, Q2) can be powered with up to 30V external positive source (J2 pin 22=V++) or on-board positive power via the H4 (V++ = H4.1 = H4.2 = VI+) header. The current driver outputs are routed to the J2 pin header pins 23 and 24.

High-Voltage, High-Current Drivers

The ULN2003A has high voltage, high current Darlington transistor array, consisting of seven silicon NPN Darlington pairs on a common monolithic substrate. All channels feature open-collector outputs for sinking 350 mA at 50V, and integral protection diodes for driving inductive loads. Peak inrush currents of up to 500 mA sinking are allowed.

U18 provides seven high-voltage drivers. These outputs may be paralleled to achieve high-load capability, although each driver has a maximum continuous collector current rating of 350 mA at 50V. The maximum power dissipation allowed is 2.20 W per chip at 25 degrees (°C). V++ connects to the protection diodes in the ULN2003 chips and should be tied to highest voltage in the external load system. V++ can be connected to a user provided voltage at J2 pin 22. **ULN2003 is a sinking driver, not a sourcing driver.** An example of typical application wiring is shown in Fig. 3.4.

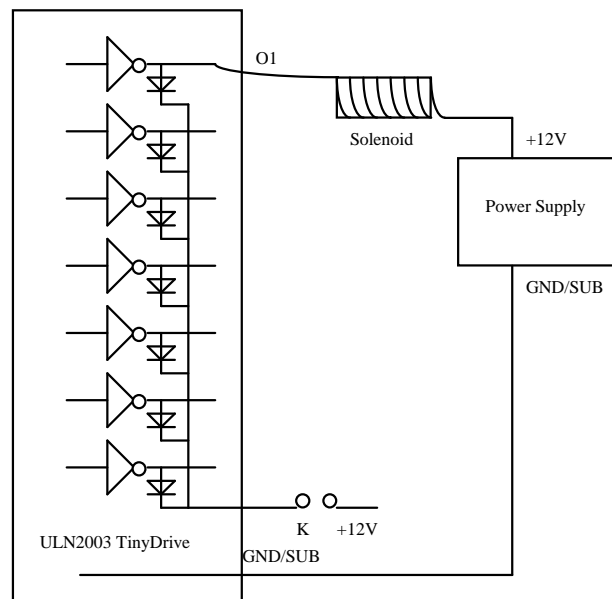


Figure 3.4 Drive inductive load with high voltage/current drivers.

The inputs to the high voltage drivers are connected to the output port of the SC26C92 Dual UART. The user must toggle the state of the SC26C92's output port to drive the high voltage drivers. See the sample program `\tern\186\samples\re\re_sc_op.c` for details. This sample file is also included in the sample project `rb.ide`, found in the `\tern\186\samples\rb` directory.

Compact Flash Interface

By utilizing the compact flash interface on the **RB**, users can easily add widely used 50-pin CF standard mass data storage cards to their embedded application via RS232, TTL I2C, or parallel interface. TERN software supports Linear Block Address mode, 16-bit FAT flash file system, RS-232, TTL I2C or parallel communication. Users can write/read files to/from the CompactFlash card. Users can also transfer files to and from a PC via a Compact Flash card reader. (sandisk.com).

This allows the user to log huge amounts of data from external sources. Files can then be accessed via compact flash reader on a PC.

The `\tern\186\samples\ra` directory includes sample code, `ra_cf.c`, to show reads and writes of raw data by sector. In addition, `\tern\186\samples\fn\fs_cmds1.c` is a simple file system demo with serial port based user interface. Refer to `ra.ide` which has the demo built and ready for download.

3.8 Headers and Connectors

There are two primary connectors on the RB which provide expansion, J1 and J2. The table bellows summarize the signals available on each connector. Most signals on J1 and J2 header are routed directory to the CPU with no buffer protection. This makes the CPU (including SRAM, Flash, and other devices tied to the A/D bus) vulnerable to damage from out of range voltages. The user is therefore responsible for ensuring that out of range voltages are not applied to sensitive lines.

These signals are +3.3V signals, but are +5V tolerant. Any voltages above +5V will certainly damage the board.

Refer to the schematic at the end of this technical manual for complete signal definitions for all headers and connectors.

Expansion Headers J1 and J2

There are two spacing headers for RB expansion. Most signals are directly routed to the Am186ER processor.

| <i>J2 Signal</i> | | | | <i>J1 Signal</i> | | | |
|------------------|----|----|------|------------------|----|----|-------|
| AN0 | 40 | 39 | AN1 | P4 | 40 | 39 | P5 |
| AN2 | 38 | 37 | AN3 | P12 | 38 | 37 | P6 |
| AD4 | 36 | 35 | AD5 | P26 | 36 | 35 | A19 |
| AD6 | 34 | 33 | AD7 | P2 | 34 | 33 | P19 |
| COM | 32 | 31 | GND | P18 | 32 | 31 | P16 |
| DA1 | 30 | 29 | DA3 | P25 | 30 | 29 | P0 |
| DA2 | 28 | 27 | DA4 | P10 | 28 | 27 | P1 |
| DA5 | 26 | 25 | DA6 | IP3 | 26 | 25 | P11 |
| S7 | 24 | 23 | S8 | /INT4 | 24 | 23 | P23 |
| V++ | 22 | 21 | GND | GND | 22 | 21 | GND |
| OT1 | 20 | 19 | OT1- | | 20 | 19 | |
| OT2 | 18 | 17 | OT2- | /RXD0 | 18 | 17 | /RXDA |
| OT3 | 16 | 15 | OT3- | /TXD0 | 16 | 15 | /TXDA |
| OT4 | 14 | 13 | OT4- | | 14 | 13 | |
| GND | 12 | 11 | HV7 | | 12 | 11 | |
| HV6 | 10 | 9 | HV5 | | 10 | 9 | VCC |
| O2+ | 8 | 7 | O2- | GND | 8 | 7 | GND |
| O1+ | 6 | 5 | O1- | | 6 | 5 | |
| ST2 | 4 | 3 | SP2 | /RTC | 4 | 3 | /RXDB |
| ST1 | 2 | 1 | SP1 | /CTS | 2 | 1 | /TXDB |

Table 3.3 Signals for J1 (20X2) and J2 (20X2) expansion ports

Power-off Mode with VOFF signal

A Low Power version RB can use the on-board Real-Time-clock DS1337 to control the VOFF signal.

A sample program (c:\tern\186\samples\ra\ra_voff.c) demonstrates using the real-time clock to control timed "on/off" of the controller. When OFF, the controller consumes less than 100 uA current.

To run the sample, you will need a RB with special requested Low-Power version, optional Real-Time Clock & Battery, and Switching Regulator(LM2575).

SYSTEM DESIGN

Install R15=1M ohm, R4=510K ohm. on the RB. The VOFF signal is connected to the LM2575 VOFF pin and the /EN pin of the TPS76550 low-drop voltage regulator (U25 for ADC/DAC options). The 12V regulator LM78L12 (U20) should not be installed. The U20 pin 1 and pin 8 are shorted by wire. In the low power mode, the max. power voltage allowed is 12V DC. The VOFF signal is also on H0, pin 1. When the VOFF signal is HIGH (2V+), both the LM2575 and TPS76550 regulators are disabled (shut down) and very little current (less than 100 uA) is consumed.

When the signal is TTL LOW, the regulators are enabled. The VOFF pin must be connected to a weak pullup (R15 pullup connection to +12V, the external input voltage; request this configuration for RB when ordering). This means, by default, the board will be "shut-down" even with power connected to the inputs to the regulator.

You can control power on or off via VOFF pin with the following ways:

- 1) mechanical jumper shorting VOFF (H0.1) to GND (H0.2) *forces* the regulator to be enabled. This is the default state for debugging.
- 2) Use on-board real time clock (which is powered by on-board battery).

The real-time clock's alarm (/INTA) can pull a pin LOW. The alarm here acts as a wake-up: at specific times, the RTC will waken your board.

See the sample program (c:\tern\186\samples\ra\ra_voff.c, and c:\tern\186\samples\fb\fb_voff.c) on explaining the second option, of using the real-time clock to control the enabling/disabling of the board at specified real-times.

Chapter 4: Software

Please refer to the Technical Manual of the “C/C++ Development Kit for TERN 16-bit Embedded Microcontrollers” for details on debugging and programming tools.

Guidelines, awareness, and problems in an interrupt driven environment

Although the C/C++ Development Kit provides a simple, low cost solution to application engineers, some guidelines must be followed. If they are not followed, you may experience system crashes, PC hang-ups, and other problems.

The debugging of interrupt handlers with the Remote Debugger can be a challenge. It is possible to debug an interrupt handler, but there is a risk of experiencing problems. Most problems occur in multi-interrupt-driven situations. Because the remote kernel running on the controller is interrupt-driven, it demands interrupt services from the CPU. If an application program enables interrupt and occupies the interrupt controller for longer than the remote debugger can accept, the debugger will time-out. As a result, your PC may hang-up. In extreme cases, a power reset may be required to restart your PC.

For your reference, be aware that our system is remote kernel interrupt-driven for debugging.

The run-time environment on TERN controllers consists of an I/O address space and a memory address space. I/O address space ranges from **0x0000** to **0xffff**, or 64 KB. Memory address space ranges from **0x00000** to **0xfffff** in real-mode, or 1 MB. These are accessed differently, and not all addresses can be translated and handled correctly by hardware. I/O and memory mappings are done in software to define how translations are implemented by the hardware. Implicit accesses to I/O and memory address space occur throughout your program from TERN libraries as well as simple memory accesses to either code or global and stack data. You can, however, explicitly access any address in I/O or memory space, and you will probably need to do so in order to access processor registers and on-board peripheral components (which often reside in I/O space) or non-mapped memory.

This is done with four different sets of similar functions, described below.

poke/pokeb

Arguments: unsigned int segment, unsigned int offset, unsigned int/unsigned char data

Return value: none

These standard C functions are used to place specified data at any memory space location. The **segment** argument is left shifted by four and added to the **offset** argument to indicate the 20-bit address within memory space. **poke** is used for writing 16 bits at a time, and **pokeb** is used for writing 8 bits.

The process of placing data into memory space means that the appropriate address and data are placed on the address and data-bus, and any memory-space mappings in place for this particular range of memory will be used to activate appropriate chip-select lines and the corresponding hardware component responsible for handling this data.

peek/peekb

Arguments: unsigned int segment, unsigned int offset

Return value: unsigned int/unsigned char data

These functions retrieve the data for a specified address in memory space. Once again, the **segment** address is shifted left by four bits and added to the **offset** to find the 20-bit address. This address is then output over the address bus, and the hardware component mapped to that address should return either an 8-bit or 16-bit

value over the data bus. If there is no component mapped to that address, this function will return random garbage values every time you try to peek into that address.

outport/outportb

Arguments: unsigned int address, unsigned int/unsigned char data

Return value: none

This function is used to place the **data** into the appropriate **address** in I/O space. It is used most often when working with processor registers that are mapped into I/O space and must be accessed using either one of these functions. This is also the function used in most cases when dealing with user-configured peripheral components.

When dealing with processor registers, be sure to use the correct function. Use **outport** if you are dealing with a 16-bit register.

inport/inportb

Arguments: unsigned int address

Return value: unsigned int/unsigned char data

This function can be used to retrieve data from components in I/O space. You will find that most hardware options added to TERN controllers are mapped into I/O space, since memory space is valuable and is reserved for uses related to the code and data. Using I/O mappings, the address is output over the address bus, and the returned 16 or 8-bit value is the return value.

For a further discussion of I/O and memory mappings, please refer to the Hardware chapter of this technical manual.

4.1 RE.LIB

RE.LIB is a C library for basic RB operations. It includes the following modules: AE.OBJ, SER0.OBJ, SER1R.OBJ, and AEEE.OBJ. You need to link to RE.LIB in your applications and include the corresponding header files in your source code. The following is a list of the header files:

| Include-file name | Description |
|-------------------|---|
| AE.H | PPI, timer/counter, ADC, DAC, RTC, Watchdog |
| SER0.H | Internal serial port 0, from CPU |
| SER1R.H | External UART SCC26C92 |
| AEEE.H | on-board EEPROM |

Not all functions in the above modules will apply to the RB. For example, “ae.h” was originally created for the A-Engine. Therefore, “ae.h” will include routines for the TLC2543 (for example), not installed on the RB. The user will need to include the header file “re.h” to provide routines for the RB devices. Although “ae.h” was created for a different controller, it will still be needed for a variety of routines used by the RB, such as timers, interrupts, and others. Refer to the actual header file itself to determine which is needed for a certain application.

4.2 Functions in AE.OBJ

4.2.1 R-Engine-A Initialization

ae_init

This function should be called at the beginning of every program running on RB controllers. It provides default initialization and configuration of the various I/O pins, interrupt vectors, sets up expanded DOS I/O, and provides other processor-specific updates needed at the beginning of every program.

There are certain default pin modes and interrupt settings you might wish to change. With that in mind, the basic effects of `ae_init` are described below. For details regarding register use, you will want to refer to the AMD Am186ER Microcontroller User's manual.

- Initialize the upper chip select to support the on-board flash. The CPU registers are configured such that:
 - Address space for the Flash is from 0x80000-0xffff (to map Memcard I/O window)
 - 512K ROM Block size operation.
 - Three wait state operation (allowing it to support up to 120 ns ROMs). With 70 ns ROMs, this can actually be set to zero wait state if you require increased performance (at a risk of stability in noisy environments). For details, see the UMCS (Upper Memory Chip Select Register) reference in the processor User's manual.

```
output(0xffa0, 0x80bf); // UMCS, 512K ROM, 0x80000-0xffff
```

- Initialize LCS (*Lower Chip Select*) for use with the SRAM. It is configured so that:
 - Address space starts 0x00000, with a maximum of 512K RAM.
 - Three wait state operation. Reducing this value can improve performance.
 - Disables PSRAM, and disables need for external ready.

```
output(0xffa2, 0x7fbf); // LMCS, base Mem address 0x0000
```

- Initialize MMCS and MPCS so that **MCS0** and **PCS0-PCS6** (except for PCS4) are configured so:
 - **MCS0** is mapped also to a 256K window at 0x80000. If used with MemCard, this chip select line is used for the I/O window.
 - Sets up **PCS5-6** lines as chip-select lines, with three wait state operation.

```
output(0xffa8, 0xa0bf); // s8, 3 wait states
```

```
output(0xffa6, 0x81ff); // CS0MSKH
```

- Initialize PACS so that **PCS0-PCS3** are configured so that:
 - Sets up **PCS0-3** lines as chip-select lines, with fifteen wait state operation.
 - The chip select lines starts at I/O address 0x0000, with each successive chip select line addressed 0x100 higher in I/O space.

```
output(0xffa4, 0x007f); // CS0MSKL, 512K, enable CS0 for RAM
```

- Configure the two PIO ports for default operation. Most pins are set up as default input, except for P29 (used for driving the LED), pins for SER0, and others.

```
output(0xff78, 0xc7bc); // PDIR1, TxD,RxD,PCS0,PCS1,P29&P22 Output
```

```
output(0xff76, 0x2040); // PIOM1
```

```
output(0xff72, 0xec7b); // PDIR0, A18,A17,PCS6,PCS5, P12 Output
```

```
output(0xff70, 0x1000); // PIOM0
```

- Configure the PPI 82C55 to all inputs. You can reset these by writing to the command register.

```
outputb(0x0103, 0x9a); // all pins are input, I20-23 output
```

```
outputb(0x0100, 0);
```

```
outputb(0x0101, 0);
```

```
outportb(0x0102, 0x01); // I20 high
```

The chip select lines are set to 15 wait states, by default. This makes it possible to interface with many slower external peripheral components. If you require faster I/O access, you can modify this number down as needed. Some TERN components, such as the Real-Time-Clock, might fail if the wait state is decreased too dramatically. A function is provided for this purpose.

void io_wait
Arguments: char wait

Return value: none.

This function sets the current wait state depending on the argument *wait*.

```
wait=0, wait states = 0, I/O enable for 100 ns
wait=1, wait states = 1, I/O enable for 100+25 ns
wait=2, wait states = 2, I/O enable for 100+50 ns
wait=3, wait states = 3, I/O enable for 100+75 ns
wait=4, wait states = 5, I/O enable for 100+125 ns
wait=5, wait states = 7, I/O enable for 100+175 ns
wait=6, wait states = 9, I/O enable for 100+225 ns
wait=7, wait states = 15, I/O enable for 100+375 ns
```

4.2.2 External Interrupt Initialization

There are up to six external interrupt sources on the RB, consisting of five maskable interrupt pins (**INT4-INT0**) and one non-maskable interrupt (**NMI**). There are also an additional eight internal interrupt sources not connected to the external pins, consisting of three timers, two DMA channels, both asynchronous serial ports, and the **NMI** from the watchdog timer. For a detailed discussion involving the ICUs, the user should refer to Chapter 9 of the AMD Am186ER Microcontroller User's Manual - or the R1100 user's manual, both available on the CD under the **amd_docs** directory. (**Remember, DMA channels to and from the serial port not available on the R1100.**)

TERN provides functions to enable/disable all of the 5 maskable external interrupts. The user can call any of the interrupt init functions listed below for this purpose. The first argument indicates whether the particular interrupt should be enabled, and the second is a function pointer to an appropriate interrupt service routine that should be used to handle the interrupt. The TERN libraries will set up the interrupt vectors correctly for the specified external interrupt line.

At the end of interrupt handlers, the appropriate in-service bit for the IR signal currently being handled must be cleared. This can be done using the **Nonspecific EOI command**. At initialization time, interrupt priority was placed in **Fully Nested** mode. This means the current highest priority interrupt will be handled first, and a higher priority interrupt will interrupt any current interrupt handlers. So, if the user chooses to clear the in-service bit for the interrupt currently being handled, the interrupt service routine just needs to issue the nonspecific EOI command to clear the current highest priority IR.

To send the nonspecific EOI command, you need to write the **EOI** register word with 0x8000.

```
outport(0xff22, 0x8000);
```

See Chapter 9 of Am186ER technical manual (tern_docs) for additional details. Sample code is also available in the **tern\186\samples\ae** directory, 'intx.c'.

void intx_init
Arguments: unsigned char i, void interrupt far(* intx_isr) ()

Return value: none

These functions can be used to initialize any one of the external interrupt channels (for pin locations and other physical hardware details, see the Hardware chapter). The first argument **i** indicates whether this

particular interrupt should be enabled or disabled. The second argument is a function pointer, which will act as the interrupt service routine. The overhead on the interrupt service routine, when executed, is about 20 μ s.

By default, the interrupts are all disabled after initialization. To disable them again, you can repeat the call but pass in 0 as the first argument.

The NMI (Non-Maskable Interrupt) is special in that it can not be masked (disabled). The default ISR will return on interrupt.

```
void int0_init( unsigned char i, void interrupt far(* int0_isr)() );
void int1_init( unsigned char i, void interrupt far(* int1_isr)() );
void int2_init( unsigned char i, void interrupt far(* int2_isr)() );
void int3_init( unsigned char i, void interrupt far(* int3_isr)() );
void int4_init( unsigned char i, void interrupt far(* int4_isr)() );
void nmi_init(void interrupt far (* nmi_isr)());
```

4.2.3 I/O Initialization

Two ports of 16 I/O pins each are available on the RB. Hardware details regarding these PIO lines can be found in the Hardware chapter.

Several functions are provided for access to the PIO lines. At the beginning of any application where you choose to use the PIO pins as input/output, initialize the appropriate pins in one of the four available modes. Before selecting pins for this purpose, make sure that the peripheral mode operation of the pin is not needed for a different use within the same application. (Example, if using the ADS8344, P15 is needed as the chip select, so it will be unavailable for any other purpose while the ADC is being used).

You should also confirm the PIO usage that is described above within **ae_init()**. During initialization, several lines are reserved for TERN usage and you should understand that these are not available for your application. There are several PIO lines that are used for other on-board purposes. These are all described in some detail in the Hardware chapter of this technical manual. For a detailed discussion toward the I/O ports, please refer to Chapter 14 of the AMD Am186ER User's Manual. Also see Table 3.2 in this manual.

Please see the sample program **ae_pio.c** in **tern\186\samples\ae**. You will also find that these functions are used throughout TERN sample files, as most applications do find it necessary to re-configure the PIO lines.

The function **pio_wr** and **pio_rd** can be quite slow when accessing the PIO pins. Depending on the pin being used, it might require from 5-10 μ s. The maximum efficiency you can get from the PIO pins occur if you instead modify the PIO registers directly with an **outport** instruction. Performance in this case will be around 1-2 μ s to toggle any pin. Refer to '**re_speed.c**' for the fastest possible access.

The data register is **0xff74** for PIO port 0, and **0xff7a** for PIO port 1.

void pio_init

Arguments: char bit, char mode

Return value: none

bit refers to any one of the 32 PIO lines, 0-31.

mode refers to one of four modes of operation.

- 0, normal operation
- 1, input with pullup/down
- 2, output
- 3, input without pull

unsigned int pio_rd:**Arguments:** char port**Return value:** byte indicating PIO status

Each bit of the returned 16-bit value indicates the current I/O value for the PIO pins in the selected port.

void pio_wr:**Arguments:** char bit, char dat**Return value:** none

Writes the passed in dat value (either 1/0) to the selected PIO.

4.2.4 Timer Units

The three timers present on the RB can be used for a variety of applications. All three timers run at $\frac{1}{4}$ of the processor clock rate, which determines the maximum resolution that can be obtained. Be aware that if you enter power save mode, the timers will operate at a reduced speed as well.

These timers are controlled and configured through a mode register that is specified using the software interfaces. The mode register is described in detail in chapter 10 of the AMD AM186ER User's Manual.

The timers can be used to time execution of your user-defined code by reading the timer values before and after execution of any piece of code. For a sample file demonstrating this application, see the sample file *timer.c* in the directory *tern\186\samples\ae*.

Two of the timers, **Timer0** and **Timer1** can be used for pulse-width modulation with a variable duty cycle. These timers contain two max counters, where the output is high until the counter counts reaches maxcount A before switching and counting to maxcount B.

It is also possible to use the output of **Timer2** to pre-scale one of the other timers, since 16-bit resolution at the maximum clock rate specified gives you only 150 Hz. Only by using **Timer2** can you slow this down even further. The sample files *timer02.c* and *timer12.c*, located in *tern\186\samples\ae*, demonstrate this.

The specific behavior that you might want to implement is described in detail in chapter 10 of the AMD AM186ER User's Manual.

void t0_init**void t1_init****Arguments:** int tm, int ta, int tb, void interrupt far(*t_isr)()**Return values:** none

Both of these timers have two maximum counters (MAXCOUNTA/B) available. These can all be specified using **ta** and **tb**. The argument **tm** is the value that you wish placed into the **T0CON/T1CON** mode registers for configuring the two timers.

The interrupt service routine **t_isr** specified here is called whenever the full count is reached if the interrupt bit in the **T0CON/T1CON** is set, with other behavior possible depending on the value specified for the control register. If the interrupt bit is not set, the user can poll the status if the **MC** bit in the timer control registers. Polling the **MC** bit offers a way to monitor timer status without using interrupts.

void t2_init**Arguments:** int tm, int ta, void interrupt far(*t_isr)()**Return values:** none.

Timer2 behaves like the other timers, except it only has one max counter available, and no I/O pins.

4.2.5 Analog-to-Digital Conversion

Serial ADC ADS8344

The ADS8344 ADC unit, at location U14, provide 8 channels of 0-5V analog inputs. For details regarding the hardware configuration, see the Hardware chapter.

The following functions will drive the 16-bit ADC. Maximum speed recorded is about 25 KHz, over two times faster than its earlier 12-bit predecessor. The order of functions given here should be followed in actual implementation.

```
unsigned char rb_ad16 ( char ch);
unsigned int format_data( unsigned int ad);
```

The control byte, *ch*, drives the ADS8344 in 8 channel single-ended mode, by default. The ADS8344 also supports 4 channel differential mode. This can be achieved by changing the control byte passed to the 'rb_ad16' routine. See the ADS8344 data sheet for details on how to define the control byte, '[ads8344.pdf](#)' in the `tern_docs\parts` directory.

For a sample file demonstrating the use of the ADC, please see `rb_ad.c` in `tern\186\samples\rb`.

This sample is also included in the `rb.ide` test project in the `tern\186` directory.

4.2.6 Digital-to-Analog Conversion

Serial LTC2600

The serial DAC LTC2600 uses a serial interface with the CPU for operation. Three control lines are used, /CS = P24, SCK = SCLK, and SDI = SDAT. Each PIO lines must be initialized as output (mode 2) for operation. The user defined function `da_16` is provided to give a one statement interface with the device. The function can be found in the sample file, `rb_da.c`, in the directory `\tern\186\samples\rb`.

```
void da_16
```

```
Arguments: unsigned char mode, unsigned int dac
```

```
Return value: none
```

This function drives the DAC at position U5, outputs are DA1-6, V7, V8. The argument *mode* determines which channels are to be written to. The values for *mode* are:

```
0x30   DAC A
0x31   DAC B
0x32   DAC C
0x33   DAC D
0x34   DAC E
0x35   DAC F
0x36   DAC G
0x37   DAC H
0x3F   All DACs
```

See the data sheet. From the root of the installation CD, `\tern_docs\parts\ltc2600.pdf`.

4.2.7 Other library functions

On-board supervisor MAX691 or LTC691

The watchdog timer offered by the MAX691 or LTC691 offers an excellent way to monitor improper program execution. If the watchdog timer (**J9**) jumper is set, the function `hitwd()` must be called every 1.6

seconds of program execution. If this is not executed because of a run-time error, such as an infinite loop or stalled interrupt service routine, a hardware reset will occur.

void hitwd**Arguments:** none**Return value:** none

Resets the supervisor timer for another 1.6 seconds.

void led**Arguments:** int ledd**Return value:** none

Turns the on-board LED on or off according to the value of **ledd**.

Real-Time Clock

The real-time clock can be used to keep track of real time. Backed up by a lithium-coin battery, the real time clock can be accessed and programmed using two interface functions. See `\tern\186\samples\re\re_rtc.c` for a sample program. There is a common data structure used to access and use both interfaces.

```
typedef struct{
    unsigned char sec1; One second digit.
    unsigned char sec10; Ten second digit.
    unsigned char min1; One minute digit.
    unsigned char min10; Ten minute digit.
    unsigned char hour1; One hour digit.
    unsigned char hour10; Ten hour digit.
    unsigned char day1; One day digit.
    unsigned char day10; Ten day digit.
    unsigned char mon1; One month digit.
    unsigned char mon10; Ten month digit.
    unsigned char year1; One year digit.
    unsigned char year10; Ten year digit.
    unsigned char wk; Day of the week.
} TIM;
```

int rtc_rd**Arguments:** TIM *r**Return value:** int error_code

This function places the current value of the real time clock within the argument **r** structure. The structure should be allocated by the user. This function returns 0 on success and returns 1 in case of error, such as the clock failing to respond.

int rtc_rds**Arguments:** char* realTime**Return value:** int error_code

This function is slightly different from the `rtc_rd` function. It places the current value of the real time clock into a character string instead of the `TIM` structure, making it a more convenient function than `rtc_rd`.

This function places the current value of the real time clock in the char* realTime. The string has a format of “week year10 year1 month10 month1 day10 day1 hour10 hour1 min10 min1 second10 second1”. The **rtc_rds** function also places a null terminating character at the end of the time string. It is important to note that you must be sure to make the destination character string long enough to hold the real time clock value plus the null character. A destination character string that is too short will result in the data immediately following the character string in memory to be overwritten, causing unknown results.

For example “3040503142500\0” represents Wednesday May 3, 2004 at 02:25.00 pm. There are only two positions for the year, so the user must decide how to determine the hundreds and thousands digit of the year. Here we just assume “04” correlates to the year 2004.

The length of char * realTime must be at least 14 characters, 13 plus one null terminating character.

This function returns 0 on success and returns 1 in case of error, such as the clock failing to respond.

Void rtc_init

Arguments: char* t

Return value: none

This function is used to initialize and set a value into the real-time clock. The argument **t** should be a null-terminated byte array that contains the new time value to be used.

The byte array should correspond to { *weekday, year10, year1, month10, month1, day10, day1, hour10, hour1, minute10, minute1, second10, second1, 0* }.

If, for example, the time to be initialized into the real time clock is Friday June 6, 2003, 10:55:30 am, the byte array would be initialized to: unsigned char t[14] = { 5, 0, 3, 0, 6, 0, 6, 1, 0, 5, 5, 3, 0};

Delay

In many applications it becomes useful to pause before executing any further code. There are functions provided to make this process easy. For applications that require precision timing, you should use hardware timers provided on-board for this purpose.

void delay0

Arguments: unsigned int t

Return value: none

This function is just a simple software loop. The actual time that it waits depends on processor speed as well as interrupt latency. The code is functionally identical to:

```
while(t) { t--;}
```

Passing in a **t** value of 600 causes a delay of approximately 1 ms.

void delay_ms

Arguments: unsigned int

Return value: none

This function is similar to delay0, but the passed in argument is in units of milliseconds instead of loop iterations. Again, this function is highly dependent upon the processor speed.

unsigned int crc16**Arguments:** unsigned char *wptr, unsigned int count**Return value:** unsigned int value

This function returns a simple 16-bit CRC on a byte-array of **count** size pointed to by **wptr**.

void ae_reset**Arguments:** none**Return value:** none

This function is similar to a hardware reset, and can be used if your program needs to re-start the board for any reason. Depending on the current hardware configuration, this might either start executing code from the ACTF Boot Utility or from some other address.

4.3 Functions in SER0.OBJ

The functions described in this section are prototyped in the header file **ser0.h** in the directory **tern\186\include**.

The Am186ER only provides one asynchronous serial port. The RB comes standard with the SC26C92, providing two additional asynchronous ports. The serial port on the Am186ER will be called SER0, and the two UARTs from the SC26C92 will be referred to as SER1 and SER2.

This section will discuss functions in **ser0.h** only, as SER0 pertains to the Am186ER.

By default, SER0 is used by the DEBUG kernel (re80_115.hex) for application download/debugging in STEP 1 and STEP 2. **The following examples that will be used, show functions for SER0, but since it is used by the debugger, you cannot directly debug SER0.** This section will describe its operation and software drivers. The following section will discuss, SER1 and SER2, which pertain to the external SC26C92 UART. SER1 and SER2 will be easier to implement in applications, as they can be directly debugged in the Paradigm C/C++ environment.

TERN interface functions make it possible to use one of a number of predetermined baud rates. These baud rates are achieved by specifying a divisor for 1/16 of the processor frequency.

The following table shows the function arguments that express each baud rate, to be used in TERN functions for **SER0 ONLY**. SER1 and SER2 have baud rates based upon different arguments. These are based on a 40 MHz CPU clock (80MHz boards will have all baud rates doubled).

| Function Argument | Baud Rate |
|-------------------|-----------|
| 1 | 110 |
| 2 | 150 |
| 3 | 300 |
| 4 | 600 |
| 5 | 1200 |
| 6 | 2400 |

| Function Argument | Baud Rate |
|-------------------|------------------|
| 7 | 4800 |
| 8 | 9600 |
| 9 | 19,200 (default) |
| 10 | 38,400 |
| 11 | 57,600 |
| 12 | 115,200 |
| 13 | 250,000 |
| 14 | 500,000 |
| 15 | 1,250,000 |
| 16 | 28,800 |

Table 4.1 Baud rate values for ser0 only

As of January 25, 2004, the function argument “16” was added for initializing SER0. This new rate provides a baud rate of 28,000 for 40MHz boards, and 57,600 for 80MHz boards.

After initialization by calling `so_init()`, SER0 is configured as a full-duplex serial port and is ready to transmit/receive serial data at one of the specified 15 baud rates.

An input buffer, `ser0_in_buf` (whose size is specified by the user), will automatically store the receiving serial data stream into the memory by DMA0 operation. In terms of receiving, there is no software overhead or interrupt latency for user application programs even at the highest baud rate. DMA transfer allows efficient handling of incoming data. The user only has to check the buffer status with `serhit0()` and take out the data from the buffer with `getser0()`, if any. The input buffer is used as a circular ring buffer, as shown in Figure 4.1. However, the transmit operation is interrupt-driven.

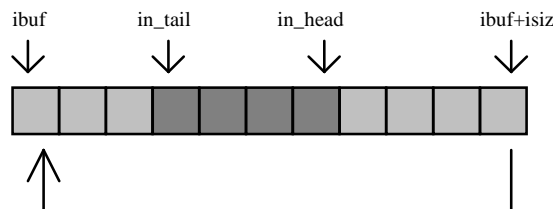


Figure 4.1 Circular ring input buffer

The input buffer (`ibuf`), buffer size (`isiz`), and baud rate (`baud`) are specified by the user with `so_init()` with a default mode of 8-bit, 1 stop bit, no parity. After `so_init()` you can set up a new mode with different numbers for data-bit, stop bit, or parity by directly accessing the Serial Port 0 Control Register (SPOCT) if necessary, as described in chapter 12 of the Am186ER manual for asynchronous serial ports.

Due to the nature of high-speed baud rates and possible effects from the external environment, serial input data will automatically fill in the buffer circularly without stopping, regardless of overwrite. If the user does not take out the data from the ring buffer with `getser0()` before the ring buffer is full, new data will overwrite the old data without warning or control. Thus it is important to provide a sufficiently large buffer if large amounts of data are transferred. For example, if you are receiving data at 9600 baud, a 4-KB buffer will be able to store data for approximately four seconds.

However, it is always important to take out data early from the input buffer, before the ring buffer rolls over. You may designate a higher baud rate for transmitting data out and a slower baud rate for receiving data. This will give you more time to do other things, without overrunning the input buffer. You can use

`serhit0()` to check the status of the input buffer and return the offset of the `in_head` pointer from the `in_tail` pointer. A return value of 0 indicates no data is available in the buffer.

You can use `getser0()` to get the serial input data byte by byte using FIFO from the buffer. The `in_tail` pointer will automatically increment after every `getser0()` call. It is not necessary to suspend external devices from sending in serial data with /RTS. Only a hardware reset or `s0_close()` can stop this receiving operation.

For transmission, you can use `putser0()` to send out a byte, or use `putasers0()` to transmit a character string. You can put data into the transmit ring buffer, `s0_out_buf`, at any time using this method. The transmit ring buffer address (`obuf`) and buffer length (`osiz`) are also specified at the time of initialization. The transmit interrupt service will check the availability of data in the transmit buffer. If there is no more data (the head and tail pointers are equal), it will disable the transmit interrupt. Otherwise, it will continue to take out the data from the out buffer, and transmit. After you call `putser0()` and transmit functions, you are free to do other tasks with no additional software overhead on the transmitting operation. It will automatically send out all the data you specify. After all data has been sent, it will clear the busy flag and be ready for the next transmission.

The sample program `ser1_0.c` demonstrates how a protocol translator works. It would receive an input HEX file from SER1 and translate every ':' character to '?'. The translated HEX file is then transmitted out of SER0. This sample program can be found in `tern\186\samples\ae`.

Software Interface

Before using the serial ports, they must be initialized.

There is a data structure containing important serial port state information that is passed as argument to the TERN library interface functions. The **COM** structure should normally be manipulated only by TERN libraries. It is provided to make debugging of the serial communication ports more practical. Since it allows you to monitor the current value of the buffer and associated pointer values, you can watch the transmission process.

```
typedef struct {
    unsigned char ready;           /* TRUE when ready */
    unsigned char baud;
    unsigned char mode;
    unsigned char iflag;           /* interrupt status */
    unsigned char *in_buf;        /* Input buffer */
    int in_tail;                   /* Input buffer TAIL ptr */
    int in_head;                   /* Input buffer HEAD ptr */
    int in_size;                   /* Input buffer size */
    int in_crcnt;                  /* Input <CR> count */
    unsigned char in_mt;           /* Input buffer FLAG */
    unsigned char in_full;        /* input buffer full */
    unsigned char *out_buf;       /* Output buffer */
    int out_tail;                  /* Output buffer TAIL ptr */
    int out_head;                  /* Output buffer HEAD ptr */
    int out_size;                  /* Output buffer size */
    unsigned char out_full;       /* Output buffer FLAG */
    unsigned char out_mt;         /* Output buffer MT */
    unsigned char tms0;           /* transmit macro service operation */
    unsigned char rts;
    unsigned char dtr;
    unsigned char en485;
    unsigned char err;
    unsigned char node;
    unsigned char cr;             /* scc CR register */
}
```

```

unsigned char slave;
unsigned int in_seg; /* input buffer segment */
unsigned int in_offs; /* input buffer offset */
unsigned int out_seg; /* output buffer segment */
unsigned int out_offs; /* output buffer offset */
unsigned char byte_delay; /* V25 macro service byte delay */
} COM;

```

sn_init

Arguments: unsigned char *b*, unsigned char* *ibuf*, int *isiz*, unsigned char* *obuf*, int *osiz*, COM* *c*
Return value: none

This function initializes either SER0 with the specified parameters. *b* is the baud rate value shown in Table 4.1. Arguments *ibuf* and *isiz* specify the input-data buffer, and *obuf* and *osiz* specify the location and size of the transmit ring buffer.

The serial ports are initialized for 8-bit, 1 stop bit, no parity communication.

There are a couple different functions used for transmission of data. You can place data within the output buffer manually, incrementing the head and tail buffer pointers appropriately. If you do not call one of the following functions, however, the driver interrupt for the appropriate serial-port will be disabled, which means that no values will be transmitted. This allows you to control when you wish the transmission of data within the outbound buffer to begin. Once the interrupts are enabled, it is dangerous to manipulate the values of the outbound buffer, as well as the values of the buffer pointer. The following functions are shown as 'putser*n*', where *n* is the serial port in use. This section applies only to SER0, thus 'putser0'.

putser*n*

Arguments: unsigned char *outch*, COM **c*
Return value: int *return_value*

This function places one byte *outch* into the transmit buffer for the appropriate serial port. The return value returns one in case of success, and zero in any other case.

putsers*n*

Arguments: char* *str*, COM **c*
Return value: int *return_value*

This function places a null-terminated character string into the transmit buffer. The return value returns one in case of success, and zero in any other case.

DMA transfer automatically places incoming data into the inbound buffer. *serhit*n**() should be called before trying to retrieve data.

serhit*n*

Arguments: COM **c*
Return value: int *value*

This function returns 1 as *value* if there is anything present in the in-bound buffer for this serial port.

getser*n*

Arguments: COM **c*
Return value: unsigned char *value*

This function returns the current byte from **sn_in_buf**, and increments the **in_tail** pointer. Once again, this function assumes that **serhitn** has been called, and that there is a character present in the buffer.

getsersn

Arguments: COM c, int len, char* str

Return value: int value

This function fills the character buffer **str** with at most **len** bytes from the input buffer. It also stops retrieving data from the buffer if a carriage return (ASCII: **0x0d**) is retrieved.

This function makes repeated calls to **getser**, and will block until **len** bytes are retrieved. The return **value** indicates the number of bytes that were placed into the buffer.

Be careful when you are using this function. The returned character string is actually a byte array terminated by a null character. This means that there might actually be multiple null characters in the byte array, and the returned **value** is the only definite indicator of the number of bytes read. Normally, we suggest that the **getsers** and **putsers** functions only be used with ASCII character strings. If you are working with byte arrays, the single-byte versions of these functions are probably more appropriate.

Miscellaneous Serial Communication Functions

One thing to be aware of in both transmission and receiving of data through the serial port is that TERN drivers only use the basic serial-port communication lines for transmitting and receiving data. Hardware flow control in the form of **CTS** (Clear-To-Send) and **RTS** (Ready-To-Send) is not implemented. There are, however, functions available that allow you to check and set the value of these I/O pins appropriate for whatever form of flow control you wish to implement. Before using these functions, you should once again be aware that the peripheral pin function you are using might not be selected as needed. For details, please refer to the Am186ES User's Manual.

char sn_cts(void)

Retrieves value of **CTS** pin.

void sn_rts(char b)

Sets the value of **RTS** to **b**.

Completing Serial Communications

After completing your serial communications, you can re-initialize the serial port with **s0_init()**; to reset default system resources.

sn_close

Arguments: COM *c

Return value: none

This closes down the serial port, by shutting down the hardware as well as disabling the interrupt.

The asynchronous serial I/O port available on the Am186ER processor has many other features that might be useful for your application. If you are interested in having more control, please read Chapter 12 of the manual for a detailed discussion of other features available to you.

4.4 Functions in SER1R.OBJ

The functions found in this object file are prototyped in `ser1r.h` in the `tern\186\include` directory.

The SC26C92 is a component that is used to provide a two additional asynchronous ports. It uses a 3.6864 MHz crystal, different from the system clock speed, for driving serial communications. This means the divisors and function arguments for setting up the baud rate for SER1 and SER 2 are different than for SER0.

The SC26C92 component has its own 3.6864 MHz crystal providing the clock signal. This allows for the generation of industry standard baud rates.

| Function Argument | Baud Rate |
|-------------------|-----------|
| 6 | 28,800 |
| 7 | 4,800 |
| 8 | 9,600 |
| 9 | 19,200 |
| 10 | 38,400 |
| 11 | 57,600 |
| 12 | 115,200 |

Table 4.2 Baud rate values for SER1 and SER 2

Unlike the other serial ports, DMA transfer is not used to fill the input buffer for SCC. Instead, an interrupt-service-routine is used to place characters into the input buffer. If the processor does not respond to the interrupt—because it is masked, for example—the interrupt service routine might never be able to complete this process. Over time, this means data might be lost in the SCC as bytes overflow.

Initialization occurs in a manner otherwise similar to SER0. A **COM** structure is once again used to hold state information for the serial port. The in-bound and out-bound buffers operate as before, and must be provided upon initialization.

s1_init

Arguments: unsigned char **b**, unsigned char* **ibuf**, int **isiz**, unsigned char* **obuf**, int **osiz**, COM* **c**

Return value: none

This function initializes SER1 with the specified parameters. **b** is the baud rate value shown in Table 4.2. Arguments **ibuf** and **isiz** specify the input-data buffer, and **obuf** and **osiz** specify the location and size of the transmit ring buffer.

s2_init

Arguments: unsigned char **b**, unsigned char* **ibuf**, int **isiz**, unsigned char* **obuf**, int **osiz**, COM* **ca**, COM * **cb**

Return value: none

This function initializes SER2 with the specified parameters. **b** is the baud rate value shown in Table 4.1. Arguments **ibuf** and **isiz** specify the input-data buffer, and **obuf** and **osiz** specify the location and size of the transmit ring buffer.

NOTE: The only difference between functions for SER1 and SER2 is that SER2 functions requires both COM arguments.

As a part of initializing the serial port, the function call also sets up the interrupt service routine that handles the data transfer between the SC26C92 and the AM186ER. The SC26C92 UART takes up external interrupt **/INT0** on the CPU. As a part of the “**ser1r.h**”, **s1_isr()**; has been created to automatically handle the need for an interrupt service routine. Since both channels on the SC26C92 use the same interrupt, there is no need for an ISR for SER2.

By default, the SC26C92 is enabled for both *transmit* and *receive*. This will allow for the use of an RS-232 in full-duplex mode. Once this is done, you can transmit and receive data as needed. If flow control is needed, the user may implement one of the many SC26C92 I/O lines, OP0-OP7 and IP0-IP6. Not all I/Os are available at external pins, and some are used by other devices. See the RA schematic for pin availability. For a sample file showing RS232 full duplex communications, please see **re_scc.c** in the directory **tern\186\samples\re**, as well as **re_sc_op.c** for a sample of the I/O port on the SC26C92.

RS485 operation is half-duplex only, which means transmission does not occur concurrently with reception. The RS485 driver will echo back bytes sent to the SCC. As a result, if using the optional RS-485/422 driver on SER2, you will need to disable *receive* while *transmitting*. While transmitting, you will also need to place the RS485 driver in transmission mode as well. While you are receiving data, the RS485 driver will need to be placed in receive mode only.

sn_send_e/sn_rec_e

Arguments: none

Return value: none

This function enables transmission or reception on the SC26C92 UART for channel *n*, where *n* can be ‘1’ or ‘2’. After initialization, both of these functions are disabled by default. If you are using RS485, only one of these two functions should be enabled at any one time.

Transmission and reception of data using the SCC is in most ways identical to SER0. The functions used to transmit and receive data are similar. For details regarding these functions, please refer to the previous section.

`putsern`

`putsersn`

`getsern`

`getsersn`

The above functions work for both SER1 and SER2, yet it is still important to remember that any function call to **s2_init** or **putsers2** must pass both COM arguments. Refer to the full definition of **s2_init()** for the format that must be followed for all calls to SER2.

Flow control is also handled in a mostly similar fashion. The follow table summarizes the flow control signals.

| Channel | Flow control line | SCC name | Location on RA |
|---------|-------------------|----------|----------------|
| SER1 | RTS | OP0 | J2 pin 1 |
| SER1 | CTS | IP0 | J2 pin 36 |
| SER2 | RTS | OP1 | J1 pin 3 |
| SER2 | CTS | IP1 | J2 pin 24 |

```
unsigned char s1_cts ( void ); // reads IP0 = J2.36
```

```
void s1_rts ( char b ); // drives OP0 = J2.1
```

```
unsigned char s2_cts ( void ); // reads IP1 = J2.24
```

```
void s2_rts ( char b ); // drives OP1 = J1.3
```

Other SCC functions are similar to those for SER0 and SER1.

```
sn_close
```

```
serhitn
```

```
clean_sern
```

4.5 Functions in AEEE.OBJ

The 512-byte serial EEPROM (*24C04*) provided on-board allows easy storage of non-volatile program parameters. This is usually an ideal location to store important configuration values that do not need to be changed often. Access to the EEPROM is quite slow, compared to memory access on the rest of the controller.

Part of the EEPROM is reserved for TERN use specifically for this purpose.

Addresses **0x00** to **0x1f** on the EEPROM is reserved for system use, including configuration information about the controller itself, jump address for Step Two, and other data that is of a more permanent nature.

The rest of the EEPROM memory space, **0x20** to **0x1ff**, is available for application use.

```
ee_wr
```

```
Arguments: int addr, unsigned char dat
```

```
Return value: int status
```

This function is used to write the passed in **dat** to the specified **addr**. The return value is 0 in success.

ee_rd**Arguments:** int addr**Return value:** int data

This function returns one byte of data from the specified address.

4.6 Other Sample code

The following is a list of other sample code available for the RB. Each will show an example implementation of the specific hardware and are located in the tern\186\samples\ra directory. Most can also be found in the **rb.ide** test project.

```
tern\186\samples\re\re_sc_op.c    // output port of SC26C92, controls ULN2003, relays
\tern\186\samples\re\re_sc_ip.c  // input port of SC26C92, reads 2 of the opto-coupler inputs
tern\186\samples\re\re_rtc.c     // Real Time clock
tern\186\samples\fn\fs_cmds1.c   // file system demo, see ra.ide
```

4.6.1 File system support

TERN libraries support FAT file system for the Compact Flash interface. Refer to Chapter 4 of the FlashCore technical manual (tern_docs\manuals\flashcore.pdf) for a summary of the available routines. The libraries and header files are as follows:

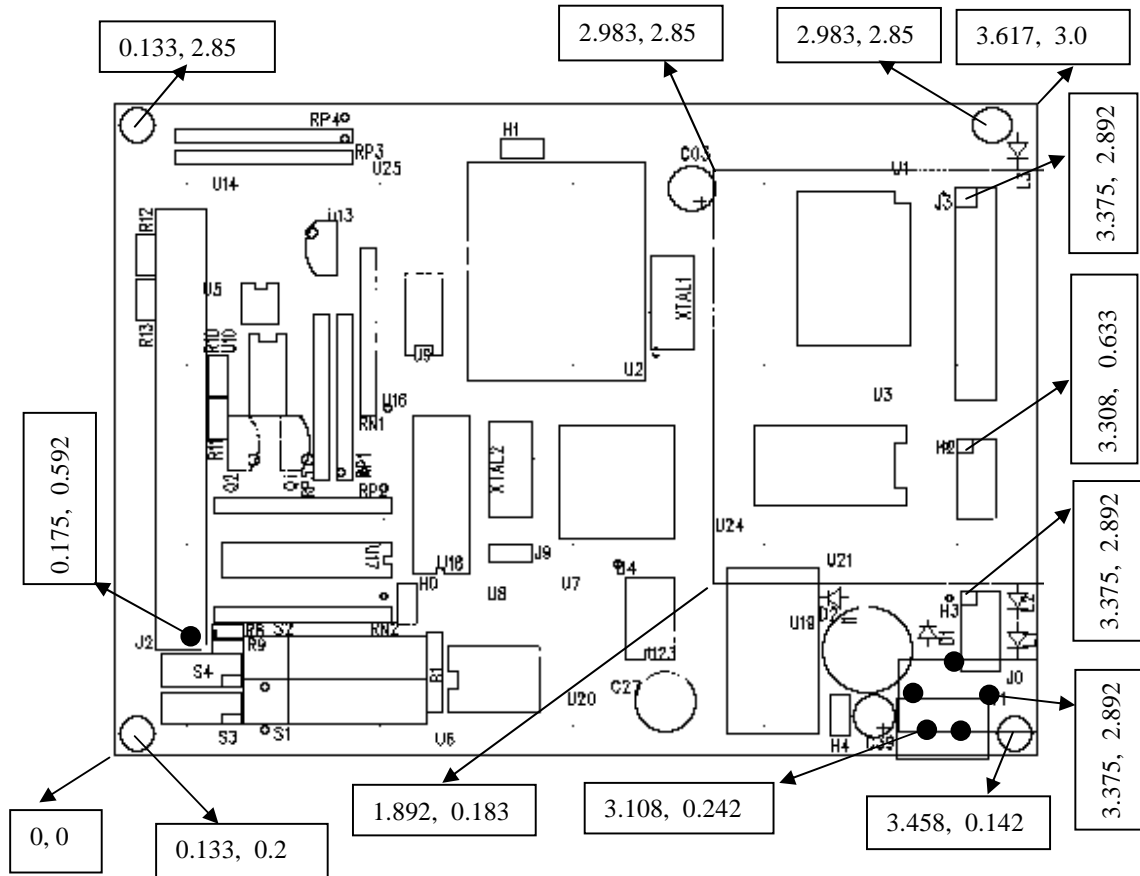
```
fileio.h
filegio.h
filesy16.lib
mm16.lib
```

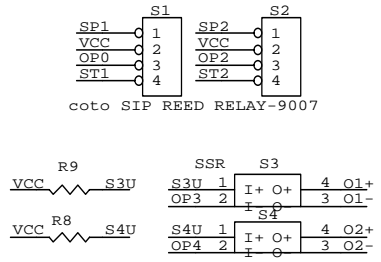
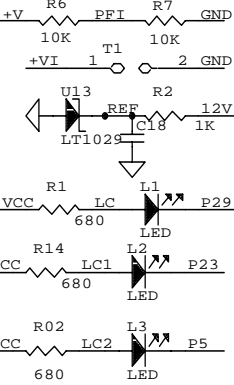
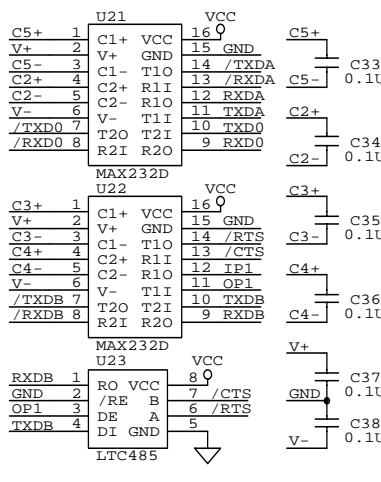
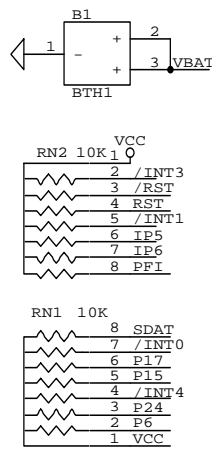
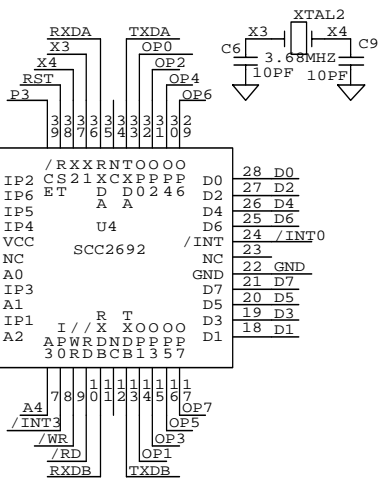
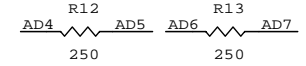
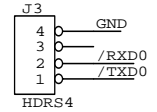
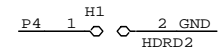
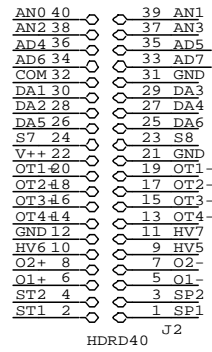
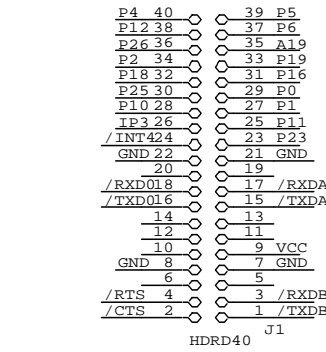
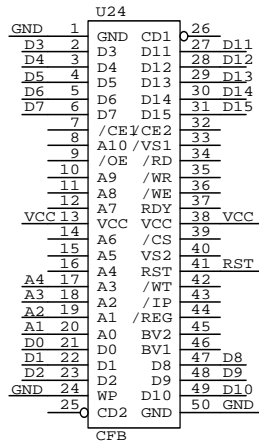
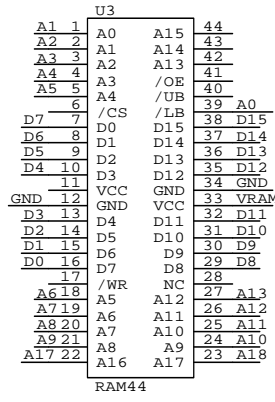
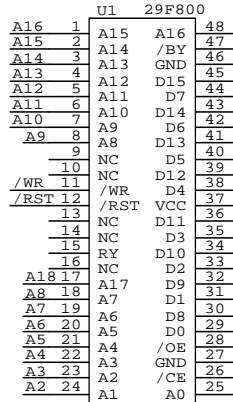
The RB uses a 16-bit external A/D bus. The user must then link to the libraries for 16-bit external busses, filesy16.lib and mm16.lib. In addition, if using the fs_cmds1 sample, you must define 'TERN_186' and 'TERN_16_BIT' in the ROM node's local options.

Libraries are found in the tern\186\lib directory and header files in the tern\186\include directory. Refer to **ra.ide** for two samples, ra_cf.c and fs_cmds1.c.

Appendix A: Layout

RB mechanical dimensions. All dimensions are in inches.





| | | |
|--------------|-----------------|--------------|
| STE/TERN | | |
| Title | | |
| R-ENGINE-BOX | | |
| Size | Document Number | REV |
| B | RB-MAN.SCH | 04 |
| Date: | March 14, 2005 | Sheet 1 of 1 |