

**RTC-AD12E
RTC ADC-DAC Expansion Board
Technical Manual**

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Micromint, Inc.

902 Waterway Place
Longwood, FL 32750
www.micromint.com

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**RTC-AD12E
Analog-to-Digital and Digital-to-Analog
Expansion Board**

1. Specifications

- Drop-in replacement for the RTC-AD12 but also offers enhanced features.
- 12-bit plus sign analog-to-digital converter (ADC)
 - 8 Single-ended or 4 differential channels
 - Gain of each channel is programmable through software for x1, x2, x4, or x8
 - Bipolar (-5 to +5V) input range
 - Conversion time = 15.68 μ S (min.)
 - Conversion start to data valid time = 34.5 μ S (min.)
 - ADC auto-zeros itself before each conversion
 - ADC can self-calibrate at the user's request
- Two 2-channel, 12-bit digital-to-analog converters (DAC)
 - Board can be configured with 0, 2, or 4 channels
 - Outputs are jumper selected for 0-5V, 0-10V, or -5 to +5V
 - Output settling time = 10 μ S (max.)

2. General Description

The RTC-AD12E is an analog-to-digital and digital-to-analog expansion board for the RTC bus. The board features an 8-channel (single-ended) or 4-channel (differential) 12-bit plus sign ADC and up to four channels of 12-bit analog output.

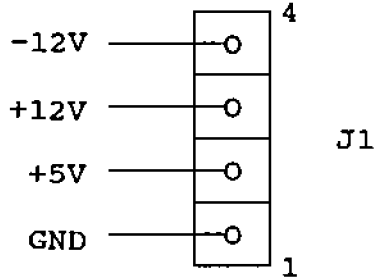
The ADC section can be hard jumpered for a gain of 1 across all the channels or each channel's gain may be set through software. The ADC can accept voltages in the range of -5 to +5 volts. Analog signals are brought onto the board through pin header J3.

The DAC section of the board can be populated for 0, 2, or 4 output channels. The outputs can be set through jumpers to be 0-5V, 0-10V, or -5 to +5V. The analog outputs come off the board through a 2x4 pin header (J5).

3. Power Requirements

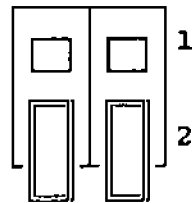
Power is supplied to the board through the RTC bus or connector J1. The board requires the following power:

- +5V @ 175mA
- +12V @ 50mA
- 12V @ 50mA



J1 - Right-angle Power Connector

As stated previously, the power may be supplied to the RTCAD-12E through the RTC bus or from connector J1. Jumper JP1 selects which supply is used.

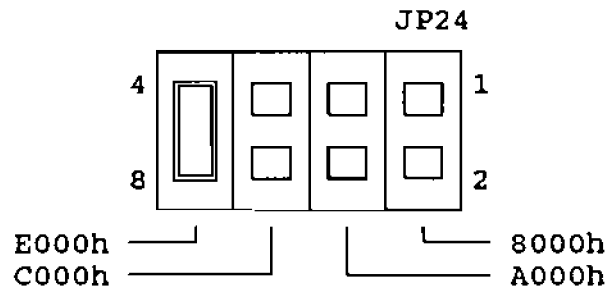


JP1

JP1 shown selecting power from J1

4. Addressing

The RTC-AD12E base address is set using jumper JP24. JP24 allows the base address to be set to 8000h, A000h, C000h, E000h.



JP24 shown selecting a base address of E000H

This address when combined with a function address allows you to control the various sections of the board. The function address' for the board are selected through your software and are as follows:

+00H = ADC *CS (U9 Chip select)
+10H = Input port and ADC EOC status
+20H = ADC *CAL (U9 Calibrate select)

+30H = not used

+40H = Ch. 0 (U13) LS input latch
+41H = Ch. 0 (U13) MS input latch
+42H = Ch. 1 (U13) LS input latch
+43H = Ch. 1 (U13) MS input latch
+50H = Ch. 0 & 1 (U13) Transfer data
+60H = Ch. 2 (U11) LS input latch
+61H = Ch. 2 (U11) MS input latch
+62H = Ch. 3 (U11) LS input latch
+63H = Ch. 3 (U11) MS input latch
+70H = Ch. 2 & 3 (U11) Transfer data

To use a particular function you write to (or read from) the combined address of Base + Function. For example, to start the ADC's self-calibration function you would write to the base address (E000H) + the function (20H) = E020H.

Note: The actual address E020H above includes the following ranges:

E020H-E02FH
E120H-E12FH
E220H-E22FH
.
.
.
FE20H-FE2FH
FF20H-FF2FH

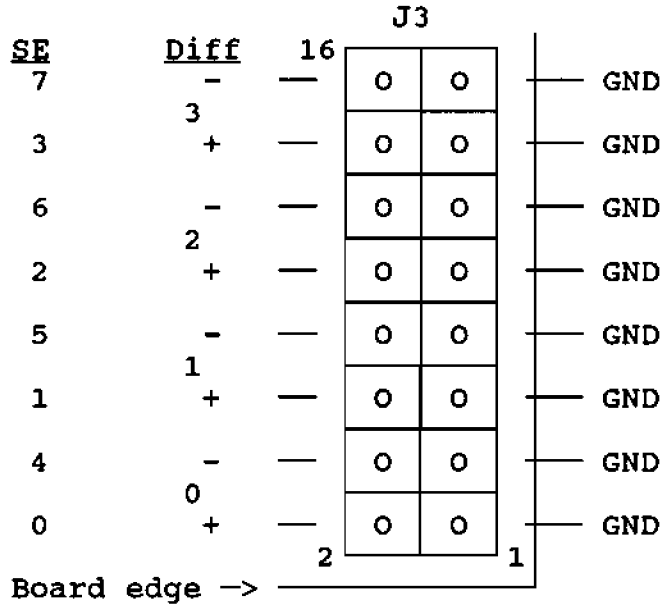
Therefore any address in this range can be used to initiate the self-calibration function. For simplicity we will use only E020H in all the examples. This situation exists for each actual address and is discussed here only for reference and exposing address conflicts.

5. Using the Analog-to-Digital Converter

The ADC section of the RTC-AD12E consists of three parts, a multiplexer (U6), a programmable gain amplifier (U8), and the actual ADC (U9). Accessing the analog-to-digital converter can be as simple as two write and three read statements.

5.1 Analog Input Connector - J3

The analog signals are brought onto the board through connector J3. The drawings below show how the connector is laid out.



5.2 The A/D Conversion Process

Each time a conversion starts, the ADC automatically goes through an auto-zero cycle to minimize zero errors. The ADC can also be put into an auto-calibrate cycle by pulling its *CAL pin low. The auto-calibrate cycle will correct zero, full-scale, and linearity errors. To start the auto-calibrate cycle a dummy value is written to the address equal to Base + 20H. For example:

```

XBY(0E020H) = 0    (in BASIC-52)
OUT $E020,0    (in BASIC-180)
POKE($E020,0)    (in BASIC-11)
    
```

To read an analog input the channel number and gain must be sent to the address equal to Base + 00H. The control word which defines the channel number and gain is configured as follows:

ADC Control Word

Address = Base + 00H

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
 V	 V	Gain			 V	 V	 V	Ch
0	0	1			0	0	0	0
0	1	2			0	0	1	1
1	0	4			0	0	1	0
1	1	8			0	1	0	2
					0	1	1	3
					1	0	0	4
					1	0	1	5
					1	1	0	6
					1	1	1	7

Note that bits 3, 4, & 5 are not used. From the tables above we can see that if we want to read channel 0 with a gain of 1 the control word would be 00H. If we wish to read channel 6 with a gain of 4, the control word would be 86H.

The End of Conversion (EOC) status bit is used to detect when a conversion is complete. The EOC status bit is obtained by reading the address, Base + 10H (E010H in this example). The EOC bit will be low (logical 0) during a conversion or when the analog-to-digital converter is in its calibration cycle. The bit will be high (logical 1) when a conversion is completed.

EOC Status

Address = Base + 10H

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
x	x	x	x	x	x	x	EOC

To determine the status of the conversion, a dummy value is first written to the EOC bit. The conversion is then started and the EOC bit is read. Once the EOC bit goes high the conversion is completed.

After it has been determined that the conversion is complete, the data may be read. This is accomplished by doing two reads of the analog-to-digital converter at address Base + 00H. The first read produces the four most significant bits and the sign bit. The second read produces the eight least significant bits.

First Read - MSBs & sign

Address = Base + 00H

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sign	Sign	Sign	Sign	Bit 11	Bit 10	Bit 9	Bit 8

Second Read - LSBs

Address = Base + 00H

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Reading the ADC can be broken down into four steps.

- 1 - Reset the EOC status by writing a dummy value to it.
- 2 - Send a control word containing the gain and channel number to start the conversion.
- 3 - Wait for EOC.
- 4 - Read the data from the ADC.

5.3 Sample A/D Programs

BASIC-52 ADC sample

```

10 REM BASIC-52 - RTC-AD12E ADC sample program
20 REM ***** Address Initialization *****
30 ADCB = 0E000h
40 ADCC = 0E020h
50 ADCE = 0E010h
60 REM ***** Calibrate the ADC *****
70 XBY(ADCE)=0
80 XBY(ADCC) = 0 : REM start by pulsing *CAL low
90 IF ((XBY(ADCE).AND.1)=0) THEN 90
100 REM ***** Choose a channel, set the gain, and read the channel *****
110 INPUT "Select a channel (0-7)",CHNL
120 INPUT "Select a gain (1,2,4,8)",GN
130 IF GN=1 THEN GN=0H
140 IF GN=2 THEN GN=40H
150 IF GN=4 THEN GN=80H
160 IF GN=8 THEN GN=0C0H
170 XBY(ADCE)=0
    
```

```

180 XBY(ADCB) = (GN + CHNL) : REM start the conversion
190 IF ((XBY(ADCE).AND.1)=0) THEN 190
200 ADCH = XBY(ADCB)
205 ADCH=ADCH.AND.1Fh
210 ADCL = XBY(ADCB)
220 IF (ADCH<16) THEN ADC=((256*(ADCH.AND.15)+ADCL)/4096)*5
230 IF (ADCH>15) THEN ADC=-(((1FFFH.XOR.(256*ADCH+ADCL))+1)/4096)*5
240 PRINT "Channel ",CHNL, " reads ",ADC, " volts"
250 GOTO 110

```

BASIC-180 ADC sample

```

10 'BASIC-180 - RTC-AD12E ADC sample program
20 INTEGER ADCB, ADCE, ADCC, ADCH, ADCL, GN, CHNL, EOC
30 REAL ADC
40 PRINT
50 ' ***** Address Initialization *****
60 ADCB = $E000
70 ADCE = $E010
80 ADCC = $E020
90 ' ***** Calibrate the ADC *****
95 OUT ADCE,0
100 OUT ADCC,0      'start the auto-calibrate cycle
110 IF BAND(INP(ADCE),1)=0 THEN 110
120 ' ***** Choose a channel, set the gain, and read it *****
130 PRINT "Select a channel (0-7)"
140 INPUT CHNL
150 PRINT "Select a gain (1,2,4,8)"
160 INPUT GN
170 IF GN=1 THEN GN=$0
180 IF GN=2 THEN GN=$40
190 IF GN=4 THEN GN=$80
200 IF GN=8 THEN GN=$C0
205 OUT ADCE,0
210 OUT ADCB,(GN+CHNL)      'start the conversion
220 IF BAND((INP(ADCE)),1)=0 THEN 220      'wait for EOC to go low
230 ADCH=INP(ADCB)      'read MSBs and sign
240 ADCL=INP(ADCB)      'read LSBs
250 'determine if value is pos. or neg. and convert
260 IF ADCH<16 THEN ADC=((256*(BAND(ADCH,15))+ADCL)/4096)*5
270 IF ADCH>15 THEN ADC=-(((BXOR($FFFF,(256*ADCH+ADCL))+1)/4096)*5)
280 PRINT "Channel ";CHNL;" reads ";ADC;" volts"
290 GOTO 130

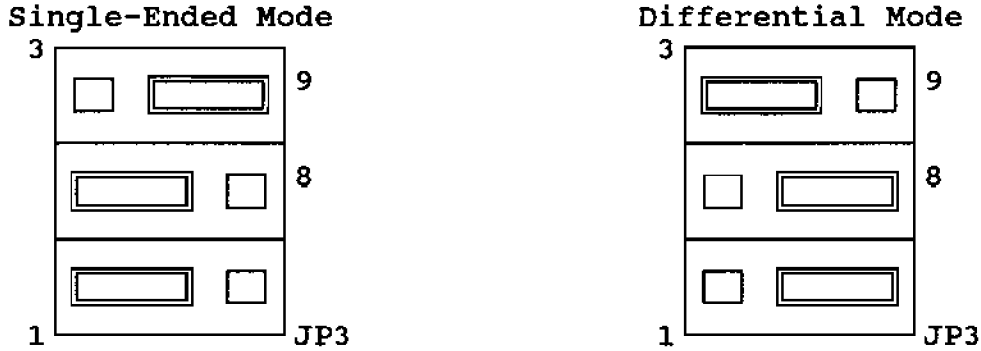
```

BASIC-11 ADC sample

```
10 REM BASIC-11 - RTC-AD12E sample program
20 REM ***** Address Initialization *****
30 B=$C000
40 C=$C020
50 E=$C010
60 REM ***** Calibrate the ADC *****
70 POKE(E,$0)
80 POKE(C,$0) : REM start by pulsing *CAL low
90 IF ((PEEK(E).AND.1)=0) THEN 90
100 REM ***** Choose a channel, set the gain, and read the channel *****
110 INPUT "Select a channel (0-7)",CH
120 INPUT "Select a gain (1,2,4,8)",GN
130 IF GN=1 THEN 140 ELSE 150
140 GN=$0
150 IF GN=2 THEN 160 ELSE 170
160 GN=$40
170 IF GN=4 THEN 180 ELSE 190
180 GN=$80
190 IF GN=8 THEN 200 ELSE 210
200 GN=$C0
210 POKE(E,$0)
220 POKE(B,(GN+CH)) : REM start the conversion
230 IF ((PEEK(E).AND.1)=0) THEN 230
240 H=PEEK(B)
250 H=H.AND.$1F
260 L=PEEK(B)
280 IF (H<16) THEN 290 ELSE 320
290 AD=(256*(H.AND.15)+L)
300 N=1
310 GOTO 360
320 IF (H>15) THEN 330 ELSE 430
330 H=H.AND.$0F
340 AD=($FFF.EOR.(256*H+L))+1
350 N=-1
360 A1=AD/819 : REM 819 = 1V
370 AX=(AD-(819*A1))*10
380 A2=AX/819
390 AX=(AX-(819*A2))*10
400 A3=AX/819
410 AX=(AX-(819*A3))*10
420 A4=AX/819
430 A1=A1*N
440 PRINT "Channel ";CH;" reads ";A1;".";A2;A3;A4
450 PRINT
460 GOTO 110
```

5.4 Differential versus Single-ended Inputs

The previous discussion and sample code have dealt with using the RTC-AD12E in single-ended mode. Using the board in differential mode is very similar. In single-ended mode the signal being measured is referenced to the ground of the RTC-AD12E. In differential mode the signal is not referenced to ground.



JP3 is used to select single-ended or differential mode as shown above. No changes in software are needed except to note that in differential mode there are only four channels instead of eight. The four differential channels are read as channels 0-3.

5.5 Emulating the RTCAD-12

The RTC-AD12E can also be used as a drop-in replacement for the original RTC-AD12 board. To do this, JP5 is set on pins 3-5 and 4-6 so that the gain applied to the inputs will always be x1.

