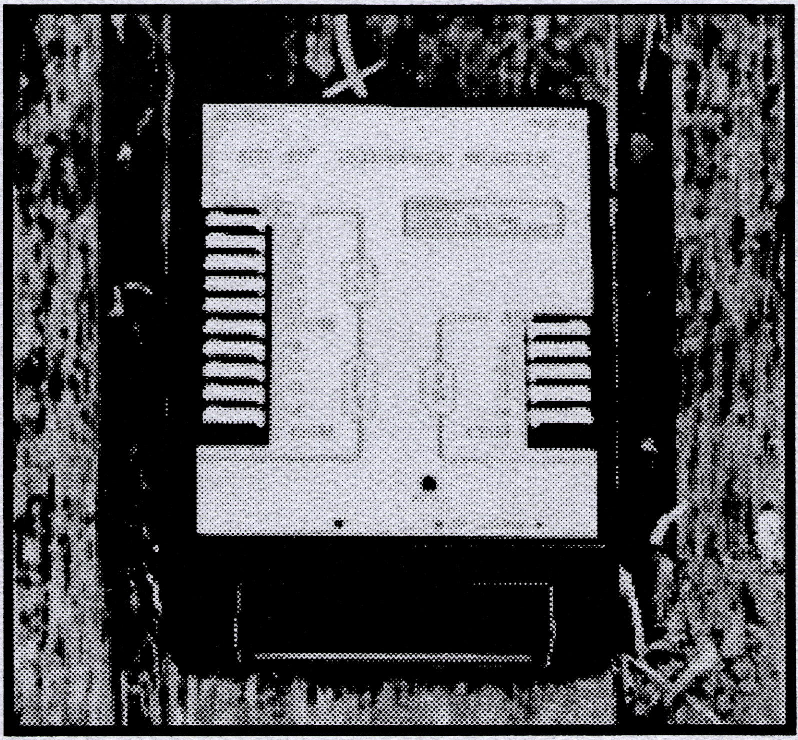
ADCM-48
OWNER'S MANUAL



TRAVTECH
SAN DIEGO, CA

ADCM – 48 OWNER'S MANUAL

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I. Introduction

1. Overview

The purpose of the ADCM-48 is to provide low cost, completely portable basic digital and analog I/O capabilities for the HP 48 calculator. The system provides the most commonly used instrumentation I/O functions in a small, battery powered accessory instrument. The ADCM-48 provides 4 zero to five volt eight-bit analog input channels, 4 TTL/CMOS compatible digital inputs and 4 high current (.5 amp) outputs. The first digital input is also a 60 Khz counter input and the first digital output is also a 1 KHz pulse width modulator output. The power for the unit is provided by an internal 9 volt battery. The power drain is very low and with creative use of the alarm functions on the HP 48 and ADCM-48 sleep mode, a remote data logging and control system capable of several month stand-alone operation can be implemented. The unit makes no physical connection with the HP 48 and communicates with the HP 48 over the infrared calculator to calculator link. This allows for setup convenience, electrical safety and eliminates the risk of damage to the HP 48. Software for common instrumentation setups as well as low level subroutines are included on disk. Extensive application circuits for interfacing to a variety of devices are included in the last chapter of this manual. The user should find it simple to adapt these circuits and programs to his specific needs.

2. Unpacking and Warranty Information

Unpacking:

The ADCM-48 is packaged with the following items:

- ADCM-48 Unit
- ADCM-48 Owner's Manual
- ADCM-48 Owner's Registration Card
- 6 inch lengths of 24 gauge solid wire (quantity 5)
- 5-1/4 inch IBM PC compatible disk containing HP 48 programs*

* Note- this disk may contain addendums or corrections to this manual, these items would be contained in the READ.ME ascii file on the disk (if present).

Any shortages or defective merchandise should be brought to the attention of Travtech at the address shown below as soon as possible.

Warranty Statement:

Travtech will repair or replace, at its option, defective merchandise that in the judgment of Travtech has not been subjected to misuse for a period of 90 days from the date of original purchase. Travtech makes no warranty of any kind for information in this manual or the included software or examples. Travtech assumes no liability for incidental or consequential damages incurred through the use of this product or this manual.

Please fill out and return the enclosed warranty registration card for product registration and possible product updates. Defective merchandise should be returned to the address below with a clear statement of the problem.

Travtech Electronic Instrumentation
10959 Barbados Way
San Diego, CA 92126
Attn: Warranty Repair

3. Specifications

Communication

Type:	HP 48 Infra-Red Calculator to Calculator protocol (and HP printer protocol)
Range:	0.25 inches minimum (6" for printer)

Analog Inputs

Input Configuration:	MOSFET Input Op-Amp Follower
Input Impedance:	1 megohm for Vin from -.6 to 5.7 volts, otherwise 100K ohms.
Input Range:	0 to 5.1 volts (0 to 255), 30V maximum
Resolution/Accuracy:	8 bits, 0.4% accuracy +/- .5 LSB

Digital Inputs

Input Configuration:	74HCT Schmidt Trigger with 100K pullup
Logic High Level:	TTL/CMOS compatible; 2.0 volts minimum
Logic Low Level:	TTL/CMOS compatible; 0.8 volts maximum
Input Current High:	0 μA maximum (floating inputs are high)
Input Current Low:	50 μA (100K pullup)
Maximum Input Level:	30 VDC maximum

Digital Outputs

Output Configuration:	Open drain MOSFET to common
Output Resistance:	1 ohm maximum
Output Current:	.5 amps continuous maximum
Output Voltage:	30 volts maximum in off state .5 volts maximum in on state

Power

Battery Type:	9V, NEDA 1604 (Alkaline)
Battery Life:	60 hours minimum, continuous operation 2000 hours typical in standby
Current Drain:	6 mA maximum, .25 mA standby (PWM active)

Physical/Environmental

Size:	3-1/4" width by 4-3/8" length by 1-1/2" height
Weight:	6 ounces
Connectors:	Augat RDI 2SV Series- Lever action- Wire sizes- #18 to #28 AWG
Temperature Range:	0 to 55 degrees C (32 to 130 degrees F)

II. Basic Operation

This section describes the basic set-up and operation of the ADCM-48. The ADCM-48 is a calculator accessory and as such requires the HP 48 to direct its operations. Usually this involves the use of a program in the HP 48. In this section, you will setup the ADCM-48 and key in a short program that will measure the ADCM-48's internal battery voltage.

2. Initial Set-up of the ADCM-48

Turn the ADCM-48 off by moving the slide switch at the front of the unit (end with red bezel) to the "off" position. Install a fresh 9 volt alkaline battery in the lower rear of the unit by pressing down and back on the battery access cover. Snap the battery onto the battery clip and replace the battery door. Put the unit upright with the red bezel towards the HP 48. Put the unit into the standby power position. The unit is now on but "sleeping" awaiting a command from the HP 48 (the power drain in this mode is very low).

Put the HP 48 into "IR" communication mode (as opposed to wired communication mode) by first entering the I/O menu, then the "SETUP" submenu and pressing the "IR/W" softkey at the left of the menu. The first line of the display should read:

```
IR/wire:    IR
```

If it does not, press "IR/W" again to toggle back to this mode. **The ADCM-48 always requires the IR mode** (in programs, this mode can be selected by setting flag -33).

Place the HP 48 directly in front of, centered and in contact with the ADCM-48. The small triangles on the top of the HP 48 and at the front top of the ADCM-48 should line up.

Enter the HP 48 I/O menu and advance to the serial command submenu by pressing "NXT" twice. The softkeys on the bottom line of the display should read:

```
XMIT SRECV STIME SBRK BUFLE
```

Send a break character to the ADCM-48 by pressing the "SBRK" softkey on the HP 48. The small green "ACTIVE" lamp on the ADCM-48 should light each time this key is pressed. This indicates that the ADCM-48 has received a message over the IR link. If this lamp does not light, check the alignment of the calculator and verify that the previous steps were performed correctly. If the lamp still does not light, the unit may require service.

The ADCM-48 has been processing and responding to the break characters sent to it. The ADCM-48 interprets BREAK as a command and returns a string. Though BREAK is used as an expedient for this initial check-out, it is not used in normal operation. To view the characters sent back by the ADCM- 48, press "BUFLE" to obtain the number of characters in the HP 48's receive buffer, then press "DROP" to put this number in level 1. Press SRECV to receive the string. What is displayed varies but will be a quoted string that represents the characters represented by the binary values sent back by the ADCM-48.

The ADCM-48 is now fully operational and is ready to receive commands from the HP 48. You may notice that there is some lag in the processing of break characters. This is because the break sequence itself is long. The speed in interpreting break characters is not indicative of the speed of the ADCM-48.

---

2. A Quick ADCM-48 Test

The following short program will read out the battery voltage of the battery installed in the ADCM-48. The program is called "BATV" on the disk if you wish to load it. (See HP 48 Owner's Manual for details).

```
< <-33 SF
20 CHR
XMIT DROP
BUFLEN DROP
SRECV DROP
NUM .04 * > >
```

press "ENTER" to end program entry

press 'BATV' "STO" to store the program

The BATV program should now appear in the current directory's VAR menu at the far left. Each time the BATV softkey is pressed, the ADCM-48's ACTIVE lamp will light very briefly and the battery voltage will be returned to level 1. This value should be greater than 6.3 and less than 9.4 for a good battery. This program is useful as a battery and general operation test. **The battery should be replaced when its voltage is less than 6.3 volts or when ADCM-48 operation becomes erratic.**

An enhanced version of the BATV program is discussed in detail in the next chapter. This simple program contains all of the concepts used in all ADCM-48 programs. The program begins by making sure that the calculator is in IR mode. It then sends a 20 to the ADCM-48 over the IR link. This code instructs the ADCM-48 to get the battery voltage and send it to the HP 48 over the IR link. The battery voltage is returned over the link as a single character. It is then decoded by the program by the NUM command. Finally this value is multiplied by .04 because the sensitivity of the ADCM-48 battery measurement is .04 volts per bit.

3. Input and Output Connectors

The lever action input and output connectors on the ADCM-48 allow easy field terminations with no tools. They are opened by putting a fingernail under the end of the white lever and lifting. The lever will rise straight up to a position just past vertical. Some short lengths of stripped wire are included in the ADCM-48 package. Insert a wire into the center of the side (outside edge) of the connector to about a quarter inch depth. Make sure that the wire is centered in the jaws of the connector and push the white lever down to its home position. This should require only **moderate** force. The wire should withstand a slight tug if properly installed. Only one wire at a time can be installed into a connector site. Wire sizes from 28 to 18 gauge may be used. Although wire larger than 18 gauge will damage the connectors, solid wire sizes smaller than 28 gauge usually will hold adequately (the wire included is 24 gauge solid).

III.Programming with the ADCM-48

This section describes the command set and programming of the HP 48 with the ADCM-48. The basic command set contains only 4 simple commands with several variations. There are also several advanced commands that enhance this basic set and allow access to the counter, pwm and A/D converter burst modes. This section should allow the user to write his own low level routines such as the battery voltage program from the last chapter.

1. Basic Command Set

The basic ADCM-48 command set consists of 4 single character, or more precisely, single byte commands. These commands are sent from the HP 48 to the ADCM-48 over the IR link. The ADCM-48 interprets the command sent, performs the appropriate function and returns any data requested to the HP 48 over the IR link. All of the basic commands return a single character value, though some of the advanced commands return multiple bytes or strings. It is important to remember that the ADCM-48 is always a "slave" to the HP 48 and only speaks when spoken to. The HP 48 initiates all messages and the ADCM-48 responds only once to a command. (there is one exception to this rule: the HP Printer Data Logger Mode discussed later)

ADCM-48 commands are "built" by assembling the appropriate command number as detailed below and executing the "CHR" command to convert the number to a character. All commands are sent to and from the ADCM-48 as single characters (or series of single characters for advanced commands). Returned characters are converted into numbers by using the "NUM" command.

The four basic ADCM-48 commands are GET_ANALOG, GET_DIGITAL, PUT_DIGITAL and SLEEP. The format of these commands is a single character split into two halves (nybbles in programmer's jargon). The 'top' half is a command type portion which tells the ADCM-48 which command is being sent. The 'bottom' half is the data portion which passes data to the ADCM-48 appropriate for the command. The two halves are simply added to produce a complete ADCM-48 command. The commands are converted to a single character by using the CHR command. The basic commands are detailed in the pages that follow.

Basic Command Set:

GET ANALOG

Top Half	16 (high nybble = 1)
Bottom Half	Code: 0 Analog Input 1 1 Analog Input 2 2 Analog Input 3 3 Analog Input 4 4 Battery Voltage 5- All 5 values (5 characters returned)
Action	Requested analog channel(s) returned
Value Returned	Character- code represents 0 to 255 bit value of analog input with 20 millivolts per bit (5 character string for code 5)
Remarks	Input channels have a sensitivity of 20 millivolts (.02V) per bit and battery is 40 millivolts (.04V) per bit. Code 5 is the equivalent of sending each of the 5 single channel commands in succession.

Examples:

Get Channel 1	16	(16 + 0)
Get Channel 2	17	(16 + 1)
Get Channel 3	18	(16 + 2)
Get Channel 4	19	(16 + 3)
Get Battery Volts	20	(16 + 4)
Get All Channels	21	(16 + 5)

GET_DIGITAL

Top Half	32 (high nybble = 2)
Bottom Half	None (0)
Action	State of digital inputs returned
Value Returned	Character- code represents 0 to 15 binary sum of 4 inputs. Input 1 is 1,Input 2 is 2,Input 3 is 4,Input 4 is 8.
Remarks	Unused (floating) inputs are high. If no inputs are connected, this command will return 15 (1 + 2 + 4 +8). Inputs can be thus be used by tying switches from inputs to common. Open switches will read high, closed switches will read low.
Examples	Value Returned 12 — Inputs 3 and 4 high Inputs 1 and 2 low (8+4)
	Value Returned 14 — Inputs 2, 3 and 4 high Input 1 low (8+4+2)

PUT_DIGITAL

Top Half	48 (high nybble = 3)
Bottom Half	Binary value of 4 outputs, as above
Action	Digital outputs set to value sent
Value Returned	None
Remarks	Outputs which are "1" conduct from their output to common (ie sink current). The power up default value of all outputs is off, no current flow. When unit exits standby mode- all outputs briefly turn on. (~ .5 seconds).

Examples

1, 2 on, 3, 4 off	51	(48+2+1)
1, 2, 3 on, 4 off	55	(48+3+2+1)
1 on, 2, 3, 4 off	49	(48+1)

SLEEP

Top Half	240 (high nybble = 15)
Bottom Half	Code: 0 Enter Sleep Mode Immediately 1 Disable Automatic Sleep Feature
Action	ADCM-48 enters very low power state or will disable automatic sleep mode
Value Returned	None
Remarks	Sending any IR to ADCM-48 will wake unit once asleep. Sleep mode will occur automatically if no command is sent to ADCM-48 in ten minutes unless automatic sleep is disabled by this command. Automatic sleep can be re-enabled by putting unit to sleep and waking it or by a reset command (see advanced commands). Command sent to wake up the ADCM-48 will not be responded to. Disabling sleep can be especially useful in cases where the digital outputs are used since their values are not maintained during sleep.
Examples	Sleep Now 240 (240) Disable Sleep 241 (240 + 1)

2. Command Set Example 1- Battery Voltage Program

The battery voltage program presented in the last chapter makes use of the GET_ANALOG command. This program is annotated below:

```
1   -33     ;flag -33 = IR transmit/receive flag
2   SF      ;set flag to enable IR communication
3   20      ;GET_ANALOG for channel 5 (battery) 16 + 4
4   CHR     ;convert to character for transmission
5   XMIT    ;transmit character without kermit
6   DROP    ;drop transmit ok "1" from level 1
```

```
7   BUFLEN      ;get receive buffer status and length
8   DROP        ;drop buffer error status "1"- leave length
9   SRECV       ;get "n" bytes from receive buffer- usually 1
10  DROP        ;drop receive status- leave char in level 1
11  NUM         ;convert char returned to a number 0 to 255
12  .04 *       ;multiply value by 40 millivolts per bit
```

Line number 3 is the actual GET_ANALOG value, in this case 20, for converting the battery voltage. It is converted to a character in line 4 for transmission. The value .04 used in line 12 for converting the A/D bits to volts is unique to channel 5 for the battery. All external input channels have a sensitivity of .02 volt/bit for an input range of 0 to 5.1 volts.

---

3. Command Set Example 2- Get Input

The following program, DIN, will repeatedly read and display the state of the digital inputs. By taking a length of wire and tying digital inputs to common, the digital input value can be changed. Remember that floating digital inputs, return a value of 1. The inputs are "binary weighted" with input 1 having a value of 1, input 2 having a value of 2, input 3 having a value of 4 and input 4 having a value of 8. With all inputs floating, the display will read 15; with input 4 tied low, the display will read 7 (1 + 2 + 4); with inputs 1 and 3 tied low, the display will read 10, etc.

```
-33         ;flag -33 is the IR transmit/receive flag
SF          ;set flag to enable IR
CLLCD       ;clear lcd- (make pretty)
"Digital Input Demo";text string- (make pretty)
WHILE       ;set up infinite loop
1 1 ==      ;always true condition
REPEAT      ;beginning of infinite loop
32          ;GET_DIGITAL command
CHR         ;convert to character
XMIT        ;send to ADCM-48
DROP        ;drop transmit ok "1" from level 1
```

```
12 BUFLEN        ;get receive buffer status and length
13 DROP          ;drop buffer error status "1"- leave length
14 SRECV         ;get "n" bytes from receive buffer- usually 1
15 DROP          ;drop receive status- leave char in level 1
16 NUM           ;convert char returned to a number 0 to 15
17 5 DISP        ;display on line 5 left side
18 END           ;end of loop- return to repeat statement
```

Note: since this program contains an infinite loop, it must be aborted with the attention "ON" key.

You will notice the ACTIVE lamp on the ADCM-48 blinking at a brisk rate, this is the effect of the looping of the program. The center portion of this program, lines 9 through 16, are identical to the center portion (lines 4 through 11) of the last program. This program segment appears in most ADCM-48 input type programs and is included as a subroutine called ADSR (ADCM-48 send and receive). Other "low-level" subroutines included on the disk are described in the next chapter.

4. Advanced Command Set

The following commands are also recognized by the ADCM-48 and perform special functions. These commands allow access to the counter ,pwm, fast A/D functions and HP printer data logger mode of the ADCM-48 as well as special diagnostics. They are generally more complex in their syntax and involve some hardware subtleties. They are presented separately to allow a new user to get accustomed to the basic command set.

The Counter Input:

The counter input is an alternate function of digital input 1. Digital input 1 can be used as a counter input and as a digital input simultaneously. Each low to high transition on this input will increment a 24 bit (0 to over 16 million) counter in the ADCM-48. This counter will respond to input count rates with a frequency up to 100 Khz or events with a duration longer than 10 microseconds. There are two counter commands. The COUNT command allows starting, stopping, reading and resetting the counter under HP 48 control. The FREQ command enables the counter for precisely one second and returns the value to the HP 48. The value returned represents the number of counts in one second or the frequency of the input.

The PWM Output:

The pulse width modulator (PWM) output is an alternate function of digital output 1. When output 1 is being used as a PWM output, it can not be used as a normal output and output commands will affect only the other 3 outputs. A PWM is an output which switches on and off rapidly and repeatedly, in this case about 900 times per second. The relative amount of time which the output spends in the on state can be varied from 0 (never on) to 128 (on about half the time) to 255 (always on) in steps of 1 bit. By varying the PWM value between over these extremes, analog type control of many devices can be achieved. For example a lamp's brightness or a motor's speed can be varied using the PWM output. If the PWM output is used to switch a known voltage and is then filtered, a DAC (digital to analog converter) can be implemented. The PWM command is unique in that it is the only command which requires two bytes to be sent to the ADCM-48. The first is the PWM command and the second is the PWM value. Once the PWM is enabled, it must be disabled explicitly by sending a PWM disable or RESET command. The PWM is also disabled upon waking.

Advanced Command Set:

RESET

Top Half	0 (high nybble = 0)
Bottom Half	None
Action	Initialize ADCM-48
Value Returned	None
Remarks	Useful as an error exit in programs or for waking up ADCM-48. State of all outputs are off, PWM is disabled, counter is stopped and reset, message and communication error counts are reset, automatic sleep timer is reset.

COUNT

Top Half	64 (high nybble = 4)
Bottom Half	Code 0 read counter 1 stop counter 2 start counter 4 reset counter 5 read highest 8 bits of count
Action	Counter function per codes above
Value Returned	Code 0 hi byte/low byte counts Code 1-4 none Code 5 highest byte of count
Remarks	When reading counter (code 0) first byte returned is high byte of 16 bit counts (multiply by 256), second byte is low byte (add). For a full 24 bit count, use value from code 5 and multiply by 65536, then add to result of code 0. Code 5 value is also useful as an overflow check and is often not used directly. Resetting counter does not stop counter. Stopped counter can be read repeatedly and will not change.

Examples

Read Counter	64	(64+0)
Reset Counter	68	(64+4)
Read Highest Byte	69	(64+5)
Start Counter	66	(64+2)
Stop Counter	65	(64+1)

PWM

Top Half	80 (high nybble = 5)
Bottom Half	Code 0 enable 1 disable
Second Byte	PWM value- (none for disable)
Action	PWM value set to second byte or disabled
Value Returned	None
Remarks	PWM must be explicitly disabled once enabled. Digital output commands will only affect the high three outputs when PWM is enabled. PWM is the only two byte command. When PWM is disabled, value previously on digital output 1 is not restored. When the PWM is active, the ADCM-48 is unable to use internal power saving modes, if very long battery life is a concern, disable when not in use. Power up and reset value is disabled.
Examples	PWM to 64 (25%) 80 64 (2 bytes) PWM to 230 (90%) 80 230 (2 bytes) Disable PWM 81 (80 + 1)

FREQ

Top Half	96 (high nybble = 6)
Bottom Half	None
Action	Frequency of digital input 1 returned after one second
Value Returned	Hi byte/low byte of counts in 1 second
Remarks	ADCM-48 will be busy for 1 second. Value returned is same format as read counter above. State of counter after FREQ will be stopped but not reset (counts can be re-read). Highest count can be read with counter command code 5 above if desired

BURST1

Top Half	112 (high nybble = 7)
Bottom Half	Input Channel number Code (0 to 4)
Action	131 analog samples at .01 seconds per sample
Values Returned	131 Characters- code represents 0 to 255 bit value of analog input with 20 millivolts per bit
Remarks	131 values returned for graphing purposes. ADCM-48 will be busy for 1.31 seconds following this command and will not respond to commands.

BURST2

Top Half	128 (high nybble = 8)
Bottom Half	Input Channel number Code (0 to 4)
Action	131 analog samples at .01 seconds per sample immediately after digital input 1 goes to logic 0 state
Values Returned	131 Characters- code represents 0 to 255 bit value of analog input with 20 millivolts per bit
Remarks	ADCM-48 will be "hung" waiting for either input 1 to fall or any command to be sent. Any command will abort this command while waiting for input 1 to fall. After input 1 falls, ADCM-48 will be busy for 1.31 seconds and will not respond to commands.

DIAGS

Top Half	224 (high nybble = 14)
Bottom Half	Code 0 send copyright and version 1 send msg/comm error cts
Action	Diagnostics sent per code above
Value Returned	Code 0- string copyright and ver. Code 1- hi byte/low byte of msg count, number of communication errors
Remarks	diagnostic purposes only

HP PRINTER DATA LOGGER

Top Half	208 (high nybble = 13))
Bottom Half	Code = Interval Between Samples 0 5 seconds 1 15 seconds 2 30 seconds 3 60 seconds 4 1 minute 5 5 minutes 6 30 minutes 7 1 hour
Action	ADCM-48 enters data logger mode and sends all analog values to HP printer at an interval selected by the code.
Remarks	With 5 seconds per sample selected, printer batteries must be fresh (especially with 82240A printer), AC adapter is recommended. ADCM must be turned off to exit this mode. Active LED will light on each sample.

Note: This command is very unique. It instructs the ADCM-48 to send all analog values to an HP printer (82240 A/B) at a selected time interval. It does not return values to the calculator. The purpose of this command is to free the calculator when doing simple data logging tasks.

5. Command Set Example 3- PWM

The following program, DIM, makes use of the advanced command PWM to allow dimming of a lamp or speed control of a motor connected to the PWM output. The output is variable from 0 to 100% by prompting the user for input. The load's positive connection should be connected to a power source and its negative connection should be connected to the ADCM-48 PWM output. The common connection of the power supply should be connected to the ADCM-48 output common connection.

```
CLLCD            ;clear lcd- make pretty
"PWM DEMO"       ;display title for demo
3 DISP           ;display this on line 3
.25 WAIT         ;advertise for 1/4 sec
"0 to 100% Output?";prompt user for input
" " INPUT OBJ    ;generate prompt and get input
2.55 *           ;multiply by 2.55 for percent to pwm
CHR              ;convert value to chr code for xmit
80 CHR           ;get pwm command and convert
SWAP +           ;put in xmit order and concatenate
XMIT             ;send to ADCM-48
DIM              ;endless loop
```

6. Command Set Example 4- FREQ

The following program, FREAK, makes use of the advanced command FREQ to read the frequency of digital input 1. It demonstrates the formatting of multiple byte counter values sent from the ADCM-48 for display. A convenient frequency source is the ADCM-48's PWM output if none is available. To use the PWM as a source, run the last example program, input a value of 50% and abort it. The PWM output will continue to produce a 903.53Hz signal with a 50% duty cycle on output 1. Tie output 1 to input 1 with a short length of wire. The following program will read this as a frequency of between 903 and 904 Hz.

```
BUFLEN          ;get buffer length for clear buffer
DROP SRECV      ;get chars- clear buffer
CLLCD           ;clear lcd- make pretty
"FREQUENCY COUNTER DEMO";;title
2 DISP          ;display on line 2
WHILE 1 1 = =   ;set up infinite loop
REPEAT          ;top of loop
96 CHR XMIT     ;send freq command
DROP            ;clear xmit ok 1
1.1 WAIT        ;wait for 1 second +
1 SRECV         ;receive high byte from ADCM-48
DROP NUM        ;clear rcv ok 1, convert to number
256 *           ;* 256 for high byte
1 SRECV         ;receive low byte from ADCM-48
DROP NUM        ;clear rcv ok 1, convert to number
+               ;add low and high byte to produce number
STR             ;convert to string for pretty display
"  FREQ  ="     ;generate title for label
SWAP +          ;swap number and string, concatenate
" Hz" +         ;concatenate units, hertz
5 DISP          ;display string created on line 5
END             ;end of while loop- infinite loop
```

7. Programming and Operation Tips

Programming the ADCM-48 is straight forward. The tips below should be helpful in developing your own programs.

Before writing a program, walk through it by sending the commands manually to the ADCM-48. It will be helpful to create a custom menu that contains XMIT, SRCV, BUFLEN, NUM and CHAR to simplify building, sending, receiving and converting commands and responses from the ADCM-48.

The alarm functions on the HP 48 allow for some exciting programming and control possibilities with the ADCM-48. The programmable function "OFF" allows the HP 48 to be turned off from within a program. Likewise, the ADCM-48 SLEEP command will do essentially the same thing for the ADCM-48. The combination of the HP 48 program type alarms and the ADCM-48 sleep mode allows for a stand-alone data logger with very long life.

There is nothing magic about the 20 millivolts per bit sensitivity of the analog input channels. If you have a sensor that for example produces a voltage proportional to wind speed, this sensitivity can replace the 20 millivolts for a readout directly in wind speed units.

The ADCM-48 is constantly trying to internally conserve power much like the HP 48 itself. Because of the nature of the PWM command, most of these internal power saving modes must be disabled and the battery life is reduced. If long battery life is a major concern, enable the PWM only when required and disable it after using it.

The programming examples given here are very light on error checking and trapping. In real world applications, these things are much more important. Software checks can and should be used in critical applications. These software checks would included checking the success values returned in level 1 by XMIT and SRECV. XMIT will return a 0 value in low battery situatations. It will sometimes return 0 values sporadically when batteries are marginal or are getting weak.

Hardware loopback can also be implemented. For example, tying digital outputs to digital inputs and reading the input back in the program, will make certain that outputs are in the state that the program intends them to be in. A periodic readout of communication errors and battery voltage are also good system integrity self checks.

The output only type commands, PWM and PUT DIGITAL, can be handled very quickly by the ADCM-48 since no values are returned. These commands can be directly concatenated and sent as a continuous string. This is especially useful for the digital output command, and makes it possible to sequence outputs very rapidly; essentially limited only by the 2400 baud transmission rate of the calculator. For example, sending the string "12481248124812480" will sequence the digital outputs very rapidly three times and turn them off. It is just coincidence that the CHR values for these outputs correspond with their values.

The automatic power down feature can be a nuisance at times when developing a program. It is often useful to disable sleep while writing and debugging a long program. Sleep can be restored by sending a reset command or turning the unit off and then back on again.

IV. Using the Provided Software

This section describes the HP 48 software included on the disk. This software includes 3 complete demonstration applications and several useful subroutines (loading from disk is covered in the HP 48 Owner's Manual). The disk may also contain other bonus programs that were developed after the printing of this manual (see the readme.doc file on the disk if present).

1. Demonstration Applications

This section describes the operation of the three demonstration applications. While potentially useful, these programs are primarily intended for demonstration purposes and are provided "as-is".

DVM4 A 4 Channel Digital Voltmeter

This application reads in and displays all four analog inputs simultaneously. Each channel is read once per second and displayed. Higher speeds can be achieved by modifying this program to read fewer channels, use the get all analog command (code 5) or by using "burst" modes discussed in the advanced command section. The basis of this program is similar to the battery voltage example given previously. Some refined output has been added as well as multiple GET_ANALOG commands. This program contains an infinite loop and must be aborted manually.

GET4 Digital Input Display

This application reads in and displays in "ON-OFF" format the state of the digital inputs. The structure of the basic program is similar to the second example given in the programming chapter. Its output has been dressed up to produce more user friendly output.

CHASE 4 Channel Output Chaser

This program rapidly sequences 4 lamps or LED's connected to the 4 digital outputs as a "chaser". The interfacing section in the next chapter describes how to connect lamps or LED's to the ADCM-48 to complete the hardware portion of this example. Appropriate current limiting must be used with LED's.

2. Subroutines/Toolbox:

These routines should simplify ADCM-48 programming tasks.

ADSR ADCM Send and Receive Response

Takes a command from level 1 as a number, converts to a character, sends to ADCM-48, receives response from ADCM-48 and converts to a number. A core sequence of many ADCM-48 programs.

BATT Battery voltage and Status

Returns battery voltage to level 2 in volts and battery status (1 being ok or 0 no good) to level 1. Essentially the same as the BATV program used previously except compares battery voltage to 6.3 volts to return 1/0 value for quick test.

V. Interfacing Circuit Examples

The circuits described in this section are designed to be a library of basic circuits from which the user can draw. An introductory section which suggests general guidelines and references is followed by specific application circuit examples. The application circuits are divided into 3 sections, analog input related, digital input related and digital output related.

NOTE

Interfacing to the ADCM-48 is straight forward. The digital and analog inputs are forgiving of faults and can take +/- 30 volts without damage. The digital outputs can sink a maximum of 0.5 amp from a 30 volt source. Some care must be taken to avoid exceeding these maximum values. Direct shorts of the digital outputs to a high current source will permanently damage the ADCM-48.

CAUTION

None of the examples shown involve the use of 115 VAC line power. Great caution should be used in interfacing the ADCM-48 to line powered equipment or loads. Special attention should be paid to grounding and isolation. Potentially lethal voltages exist in all line powered equipment. USE CAUTION.

1. References

The application examples presented in the next section will hopefully cover the majority of user applications. The references below should be invaluable sources of information for interfacing and customizing the application circuits provided. Travtech can also provide help in interfacing different systems to the ADCM-48, please call or write

"The Art of Electronics" by Horowitz and Hill
Published by Cambridge University Press

An excellent resource for instrumentation related topics. Lots of circuit examples and practical data on modern parts and methods. The new edition (1990) includes a chapter on low power design techniques.

"CMOS Cookbook " by Don Lancaster
Published by SAMS

A classic source of analog and digital design information and circuits. Well written, practical and results oriented.

"Op-Amp Cookbook" by Walter Jung
Published by SAMS

Practical op-amp circuits for nearly any application. Well presented theory and limitations for most circuits.

Circuit Scrapbook Vol. 1 and Vol. 2 by Forrest Mims III
Published by SAMS

Hobbyist/Hacker circuits of high quality. Optoelectronic/LED and clever sensor circuits are a favorite topic among others.

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2. Analog Input Circuits

Analog Input Specifications/Model

Input Impedance

The analog inputs are all identical and appear like a 1 megohm resistor to ground for inputs from -.6 to 5.6 volts. For inputs below -.6 or over 5.6 volts, they will appear like a 100K resistor to ground or to 5 volts respectively.

The nominal 1 megohm input impedance means that circuits interfaced to the ADCM-48 should have an output resistance of less than 4K ohms to preserve full 8 bit accuracy. When a higher impedance source is connected to the analog inputs, a voltage divider is formed with the internal 1 megohm resistance and the source resistance. A resistance of 4K ohms is the point where this voltage divider ratio would decrease below 99.6% or 8 bits of accuracy. If higher impedance sources must be used, corrections can be made in the user software for this voltage divider effect.

Analog to Digital Converter Resolution/Full Scale Voltage

The basic resolution of the analog to converter in the ADCM-48 is 8 bits. This means that analog voltages are converted to a number from 0 to (2^8)-1 or 0 to 255. The resolution is the the inverse of this quantity or 0.4%. The accuracy of the converter is also 0.4%. The full scale input voltage of the analog to digital converter is 5.1 volts. This is the voltage at which the ADCM-48 will output a value of 255. This makes the step size of a single bit .020 volts or 20 millivolts.

When setting up an experiment or measurement, highest accuracy and resolution will be obtained when the maximum range of the A/D can be used. This is similar to choosing the proper range on a standard digital voltmeter. If you are working with small signals, add an amplifier to bring them into line with the input range of the ADCM-48. If you are working with large signals, you will need to add a divider to bring them into range.

Measuring Small Voltages

Measuring small voltages requires an amplifier. A circuit for a basic amplifier with a gain of 10 or 100 is shown. The gain of this amplifier can be made switchable by bringing the bottom of the input resistors to an ADCM-48 digital output rather than ground. Generally, the 1 ohm resistance of the ADCM-48 outputs will be inconsequential.

Measuring Large Voltages

Measuring larger voltages requires a voltage divider. The output impedance of the voltage divider should be less than 4k for best accuracy. A circuit for a 10:1 and 100:1 divider is shown.

Measuring Temperature

Temperature can be measured in a variety of ways. The simple circuit shown uses a temperature dependent current source. "The Art of Electronics" presents several other temperature measuring circuits using thermocouples, thermistors and RTD's.

Measuring Resistance

Resistance is measured by passing a known current through an unknown resistance. The voltage developed is proportional to the resistance per ohm's law (V = IR). The circuit shown is a current source which outputs a constant current of 10 uA to 10 mA depending on a user selected resistor. The voltage directly across the unknown resistance is measured and scaled to give an output proportional to resistance.

3. Digital Input Circuits

Digital Input Specification/Model

The digital inputs electrically appear to be a 100K ohm resistor to +5 volts. The threshold for a logic high (1) is any voltage greater than 2v. The threshold for a logic low is any voltage less than .8v. These levels are compatible with TTL or 5V CMOS logic.

Interfacing Switches

Switches are interfaced by simply connecting them between an input and common. Open switches will read high, and closed switches will read low.

Interfacing an Optocoupler

An optocoupler can be interfaced as shown. Optocouplers are very useful for eliminating grounding and level shifting problems. The drive for the led is provided by the circuit to be interfaced and should be appropriately current limited using a resistor.

Interfacing Higher Voltage Logic

Higher threshold logic can be interfaced using a voltage divider as shown. The value of R1 can be calculated using the formula given for any threshold voltage.

4. Digital Output Circuits

Output Specification/Model

The digital outputs electrically look like a switch to ground. This switch has less than 1 ohm of resistance and can pass .5 amps safely. The maximum voltage on the outputs is 30 volts. A load to be controlled is connected between a positive voltage and an ADCM-48 output. The negative or common output of the supply voltage is connected to the ADCM-48 output common pin. The PWM output is a normal output and all the following discussion applies to it as well. The frequency of the PWM output is 903.53 Hz, this value is quite precise and can be used for timing if desired.

Driving an LED

An LED is driven using the circuit shown. Current limiting is provided by the resistor. Resistor values can be calculated using the formula provided.

Driving a Relay

An electromechanical relay is driven using the circuit shown. The diode shown protects the ADCM-48 from surge voltages produced by the relay's coil inductance when current is interrupted.

Driving Logic

Logic can be driven using the circuit shown. Vcc is the supply voltage of the logic that is being interfacing to.

Driving an Incandescent Lamp

An incandescent lamp is interfaced as shown. Remember the .5 amp output limit. Many incandescent lamps draw more than .5 amps of current.

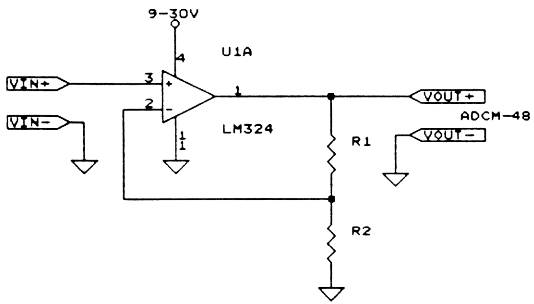
Driving a Stepper Motor

A small stepper motor such as the part number provided can be directly interfaced as shown. Large stepper motors may draw more than the .5 amp maximum current. Stepper motors are usually specified by a winding resistance rather than a current. Stepper motors which have resistances lower than 10 ohms at 5 volts or 24 ohms at 12 volts will draw more than .5 amps. Demonstration software for driving a stepper motor is provided.

VI. Appendices

MEASURING SMALLER AND LARGER VOLTAGES

SMALL SIGNAL AMPLIFIER

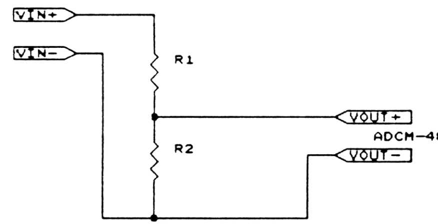


TYPICAL VALUES USING 5% RESISTOR VALUES
(ERRORS APPROX. 1% + RESISTOR TOL.)

V(FS)	GAIN	R1	R2
.50	10	82K	9.1K
.05	100	1M	10K

FORMULA: GAIN= 1 + (R1/R2)

LARGE SIGNAL DIVIDER



TYPICAL VALUES USING 5% RESISTOR VALUES
(ERRORS APPROX. 1% + RESISTOR TOL.)

V(FS)	RATIO	R1	R2
50V	10:1	82K	9.1K
500V	100:1	1M	10K

(1/4 WATT)

FORMULA: RATIO= 1+R1/R2

ANALOG INPUT RANGES		
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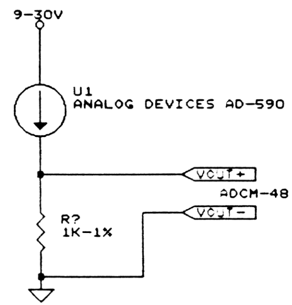
TEMPERATURE MEASURING CIRCUIT



FORMULA:

VOUT= 10 millivolts/degree kelvin

BITS= (TEMP +273) / 2

2.23V at -50 degrees C	(111 bits)
2.98V at 25 degrees C	(148 bits)
4.23V at +150 degrees C	(211 bits)

(BASIC RESOLUTION = 2 DEGREES)

TEMPERATURE MEASUREMENT		
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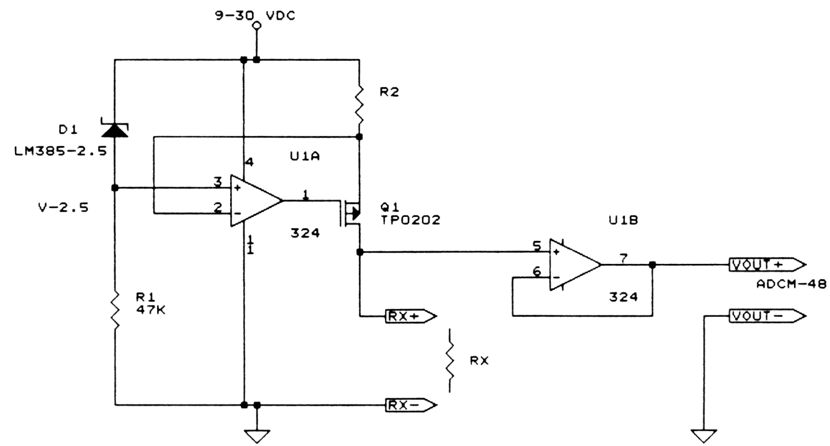
RESISTANCE TO VOLTAGE CONVERTER



R2 VALUE FOR VARIOUS FULL SCALE RANGES	
OHMS(FS)	R2
500	120
5K	1.2K
50K	12K
500K	120K

OHMS CONVERTER CIRCUIT		
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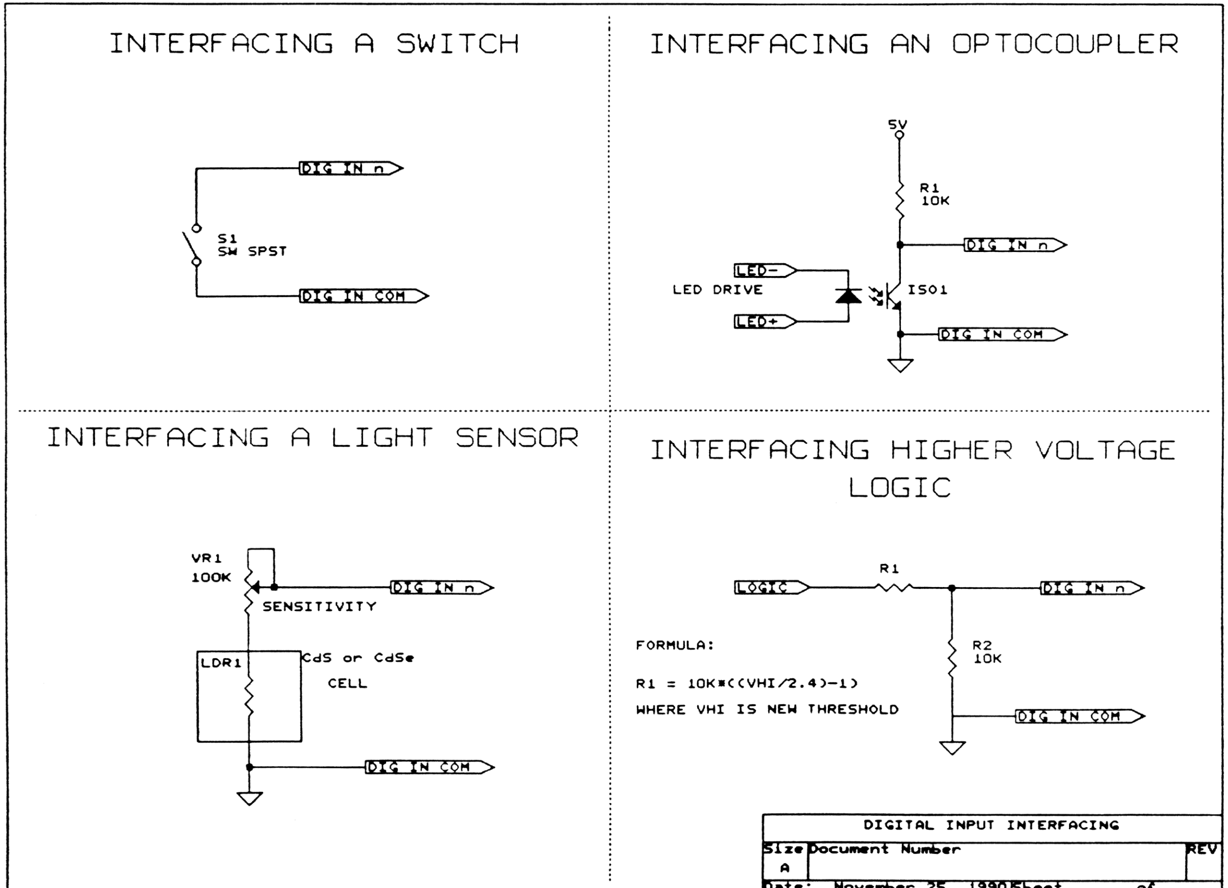
INTERFACING A SWITCH
DIG IN n
S1
SW SPST
DIG IN COM
INTERFACING AN OPTOCOUPLER
5V
R1
10K
DIG IN n
LED-
LED DRIVE
IS01
LED+
DIG IN COM
INTERFACING A LIGHT SENSOR
VR1
100K
DIG IN n
SENSITIVITY
LDR1
CdS or CdSe
CELL
DIG IN COM
INTERFACING HIGHER VOLTAGE
LOGIC
R1
LOGIC
DIG IN n
FORMULA:
R2
10K
R1 = 10K*((VHI/2.4)-1)
WHERE VHI IS NEW THRESHOLD
DIG IN COM
DIGITAL INPUT INTERFACING
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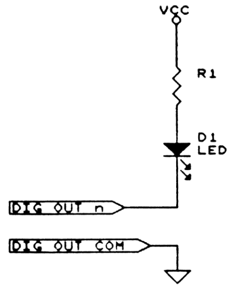
DRIVING AN LED

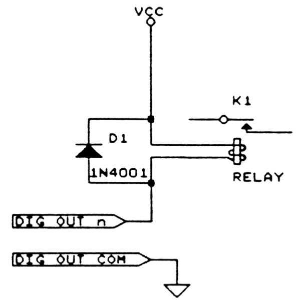


R1 = (VCC-2)/I LED

FOR VCC=5V AND I LED = 15 mA; R = 200

FOR VCC=9V AND I LED = 15 mA; R= 350

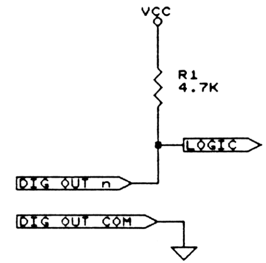
DRIVING A RELAY



VCC MAX= 30 V

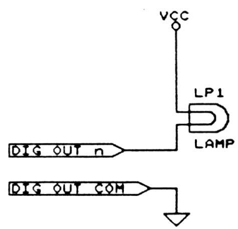
I MAX = .5 A

DRIVING LOGIC



FOR CMOS- R1 MAY BE 47K

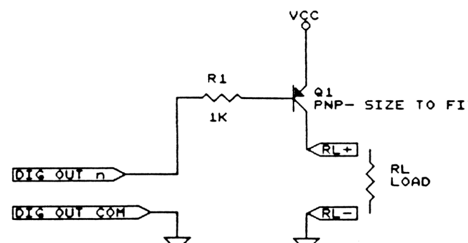
DRIVING A LAMP



VCC MAX= 30 V

I MAX = .5 A

DRIVING A GROUND REFERENCED LOAD



Q1&R1 DEPEND ON LOAD
POWER FET MAY BE USED

OUTPUT CIRCUITS		
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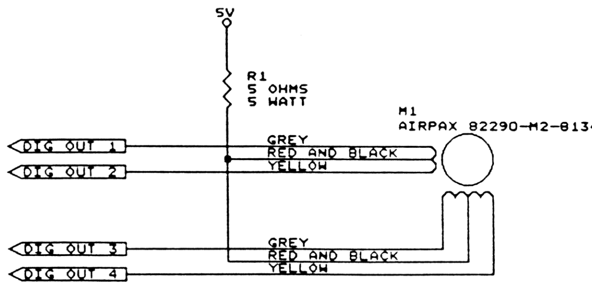
INTERFACING A STEPPER MOTOR



R1 LIMITS MAXIMUM CURRENT TO .5 A FOR THIS MOTOR

VOLTAGES UP TO 30 VOLTS MAY BE USED WITH APPROPRIATE MOTOR AND CURRENT LIMITIING

FOR ADDITIONAL DETAILS AND APPLICATIONS, SEE AIRPAX'S STEPPER MOTOR APPLICATION DATA

STEPPER MOTOR INTERFACE		
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