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ANTENNA TEST RANGE AUTOMATION

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1.0 Introduction

The NRAO-GB antenna range is used to measure feed patterns over a broad frequency range. It is capable of measuring both the amplitude and the phase response of antenna feeds. Until now, the output of the range equipment was plotted on an X-Y recorder, which produced the only form of output of the range.

This report is a document of a project to interface a personal computer to the range, so that the PC can acquire and store the amplitude and phase vs. azimuth data of a feed. The data may be displayed graphically, printed in tabular or graphical form, and stored on disk. This will greatly simplify the use of the data in other programs, such as the calculation of antenna scatter and spillover temperatures and aperture efficiency.

The first section of this report will be an operational users' manual; next will be a description of the Data Acquisition System's specifications and scaling circuit design; finally, there is a short discussion of the software development.

2.0 Operation

2.1 Equipment Setup

The range software is written in Turbo Pascal and is installed on the hard disk of one of the Electronics Division's IBM-PC's. A QuaTech 12-bit, A to D converter is installed in this PC and is used to acquire the range data. A 3.5-inch rack panel was constructed to house the QuaTech Universal I/O board and pre-scaling amplifiers.

After the computer is turned on, the command 'PATTERNS' will load the graphics driver and run the antenna range program. (See Section 4 for a description of the program and disk organization.) The three BNC connectors on the front of the rack panel should be connected to the proper inputs as labeled. The AZIMUTH port is connected directly to the output of the TURN TABLE CONTROL PANEL. (The access to the output is inside the back of the rack, but a coaxial cable should be already lead out the hole in the top of the rack.) The AMPLITUDE port is connected to the output of the SCIENTIFIC ATLANTA, DIGITAL LIN/LOG DISPLAY SERIES 1830 (the LOG LIN DC OUTPUT PORT). Finally, the PHASE port is connected directly to the PHASE OUTPUT port on the SCIENTIFIC ATLANTA, RECEIVING SYSTEM, SERIES 1750. The receiver must be locked on the transmitting signal just as before.

2.2 Program Menus

The main menu will appear (roughly) as below, and initial values for all the parameters will have been loaded from a file called LASTPARA.

1) FEED
2) LEFT AZIMUTH BOUNDARY
3) RIGHT AZIMUTH BOUNDARY
4) FREQUENCY
5) TELESCOPE
6) PLANE
7) FOCUS
8) COMMENTS

F1- HELP	F2- SYSTEM	F3- LOAD FILE
F4- SAVE FILE	F5- TABULATE	F6- GRAPH
F7- TAKE DATA	F8- LOAD XPOL	F9-
F10- EXIT		

Parameters 1, 4, 6, and 8 only appear on the title block of the graph and the tabulated data when a hard copy printer output is requested. Therefore, they are not essential to the running of the program. The LEFT, and RIGHT AZIMUTH BOUNDARIES (2,3), tell the computer where to begin taking data and stop taking data when option F7 (TAKE DATA) is used, and so they are essential parameters. Any parameter may be changed by simply typing the appropriate number, you will then be asked for the new value of the parameter. After entering it, press return. A brief description of the parameters follows:

1) FEED - A string of up to 80 characters may be entered describing the feed (letters, numbers, and spaces may be used).

2) L.A.B. - This is the left most (counter clockwise) boundary over which you wish data to be taken. It has to be an integer number either positive or negative, but less than 360 degrees.

3) R.A.B. - This is the right most (clockwise) boundary over which you wish data to be taken.

Data is taken at every integer degree and the program allows you to take data through one full rotation of the feed in the azimuth. However, when both polarizations (co and cross) are required, the azimuth boundaries should be set to less than $|125°|$.

4) FREQ. - This is the frequency at which the data is being taken. Any value 1-99, or >1000 will appear as GHz, and any value <1 or >99 and <1000 will appear as MHz.

5) TELE. - This should be either 140, or 300. This along with the type of FOCUS specified will calculate the edge illumination from the feed.

6) PLANE - This will prompt you for either E or H or 45 where 45 refers to the 45 degree plane.

7) FOCUS - This will prompt you for either P or C, corresponding to prime or Cassegrain focus. This, with the TELESCOPE information, will allow the program to calculate the edge illumination of the dish or subreflector assuming the following half-angles:

140-foot CASSEGRAIN	7
140-foot PRIME	60
300-foot	61

8) COMM. - This allows you to enter a string of up to 80 characters of any type.

The items listed as F1 - F10 are functions which may be run by pressing the appropriate function key. A brief description of each follows:

F1 - HELP This will display a help file which gives a condensed version of the information found here.

F2 - SYSTEM The system is initially set to run with a HERCULES graphics card, and an EPSON printer. If this is not the case, then this function allows you to specify the type of graphics card installed, and/or the type of printer being used, so that the plots are produced correctly.

F3-LOAD FILE If previous data has been already saved using the F4 (SAVE FILE) function, then this function will print out a list of the data files saved and ask which one you wish to be loaded. When you use this function, the LASTPARA file is updated from the file you load.

F4-SAVE FILE This function allows you to save the data and parameters in a data file. You will be asked to give a name for the file. The name should have no spaces, and have 8 characters or less.

F5-TABULATE Upon calling this function you will be asked at what interval you wish the data to be displayed. You must give a positive integer number. The data will be tabulated according to the azimuth boundaries you have chosen in the MAIN MENU. The edge illumination will also appear on the screen, and you will be asked if you wish to have a output of the data. With a printer output, a title block is printed containing all of the parameters in the MAIN MENU and the date.

F6 - GRAPH This function will place you in another menu, the GRAPH MENU. This menu appears roughly as:

```
1)  LEFT  GRAPH BOUNDARY
2)  RIGHT GRAPH BOUNDARY
3)  GRAPHED VS. AZIMUTH  (A,P,B,X)
4)  INTERVAL GRID SPACING (AZIMUTH)
5)  MINIMUM AMPLITUDE
6)  INTERVAL GRID SPACING (AMPLITUDE)

F 1 - PLOT      F2 -      F3 -
F 4 -           F5 -      F6 -
F 7 -           F8 -      F9 -
F10 - EXIT
```

To change one of the graph parameters, press the associated number and enter the new value. Initial values for the parameters will be as follows: The boundaries will be whatever they were in the MAIN MENU, amplitude will be graphed vs. azimuth, a grid line will appear every 10 degrees along the azimuth horizontal) axis, the minimum amplitude will be -50 dB (which is as low as it can go), and there will be a grid line every 3 dB along the amplitude (vertical) axis.

The graph parameter 3 allows you to graph amplitude (A), phase (P), both amplitude and phase (B), or copolarization and crosspolarization amplitudes (X) vs. azimuth. When graphing phase, a grid line will appear every 5 degrees along the phase (vertical) axis, parameters 4 and 5 have no meaning in this mode. When graphing both vs. azimuth, the grid is pre-set, so parameters 4, 5 and 6 have no meaning in this mode.

The function key F1 will plot the data according to the parameters set in the GRAPH MENU. When the plot is completed, the bottom of the screen will list three options:

F1 - SMALL COPY
F2 - BIG COPY
F10- EXIT

The function keys F1 and F2 give printer outputs of the graph at either a small or large size. The bottom of the printer output of the graph will list the parameters set in the MAIN MENU, and the the date that the data was taken. The function function key F10 will exit the graphics display and take you back to the GRAPH MENU.

While in the GRAPH MENU, the function key F10 will exit you back to the MAIN MENU.

F7-TAKE DATA

This function will ask you if this is a cross-polarization measurement; the reason being that if it is NOT, then all the amplitude data will be normalized with respect to the largest value, which is usually the value at boresight. However, if you are taking a crosspolarization measurement, then you do not want the amplitude data normalized. Since crosspolarization of a feed is measured relative to the copolarization, and since the copolarization data has been normalized, you will be asked to zero the amplitude meter while at zero degrees azimuth, then rotate the source antenna through 90 degrees and then prompted to start the measurement. Prior to the prompt to move the antenna, you will be asked if you want to plot the copolarization and crosspolarization in the same graph. If you respond with yes, then it will ask if you already made a copolarization measurement. And, if you have not, it will prompt you to make one and return you to the main menu. If you have made a copolarization measurement just proceeding this, it will prompt you to make the crosspolarization measurement. If not, it lets you load the file which has the copolarization data. When the data over the azimuth boundaries specified in the MAIN MENU has been recorded, you will be placed back in the main menu. While making the crosspolarization measurement, the azimuth boundaries are taken to be the same as those in the copolar data.

F8-LOAD XPOL Before taking crosspolarization data, if the option to plot the copolarization and crosspolarization data in the same graph is chosen, the latest data, which is the crosspolarization data, gets appended to the copolarization data in the system memory. At the end of data taking, you will be asked if you want to save this data in a file you name. This name again should have no spaces and have 8 or less characters. Graphing can be done even without saving the data. But if the data is saved and later you want to load the data, F8 function lists the data files saved and allows you to load the required file. **You cannot load a file having both polarization data by F3 (LOAD FILE) function.**

F10 - EXIT This will save the parameters currently listed in the MAIN MENU (and the corresponding data) to the file LASTPARA to be called next time the program is run. The program then terminates and exits to DOS.

3.0 Data Acquisition System

The following is a list of the system specifications for the data acquisition system. (A diagram of the system layout, and component data sheets appear at the end of the report.)

3.1 QuaTech, PXB-721 Parallel Expansion Board:

This board mounts in a PC expansion slot. Up to three expansion modules may be mounted, allowing flexibility in configuring a system.

3.2 QuaTech, ADM12-10, 12-Bit Analog to Digital Converter Module:

This module was mounted on one of the three ports of the PXB-721. It was configured to accept -5 to +5 volts, with 8 differential input channels, and 12 bit resolution. It has a Max. sampling rate of 24 KHz, a Max. conversion time of 25 microseconds, and it was selected to have sampling triggered by software. The accuracy is 0.024%, the nonlinearity is 0.012% FSR, and the gain error, and offset error were adjusted to zero. A software package was included that allows the main program to make calls for triggering a scan.

3.3 QuaTech, UIO-10 Universal I/O Board:

This board is mounted outside the PC (in the rack panel) and provides connection to the PXB-721. It also contains 24 buffered digital I/O lines.

3.4 Signal Conditioner Board:

The antenna range equipment output that become computer inputs as azimuth, amplitude and phase are characterized as follows:

AZIMUTH:	RANGE -	± 180 degrees, outputs ± 1.8 V
	ACCURACY -	± 1 mV
AMPLITUDE:	RANGE -	Saturates at +8.4 dB, outputs -0.84 V -100 dB, outputs +10.0 V
	ACCURACY -	(± 0.1 dB) ± 10 mV
PHASE:	RANGE -	0 to 360 degrees, outputs to -3.6 V
	ACCURACY -	(± 0.1 degree) ± 1 mV

To improve resolution and take advantage of the full range of the analog to digital converter, amplifiers for the AZIMUTH and PHASE were built having gains of 2.50, and 1.30, respectively. The switching circuit for the AMPLITUDE input uses two comparators and two switches. When the signal is less than +5 V (> -50 dB), one comparator is high, closing the switch for the channel carrying the input signal; the other comparator is low, opening the switch for the channel carrying +5 V. When the signal is greater than +5V (< -50 dB), the channel carrying the signal opens, and the channel carrying +5 V closes, thus giving a protection for the A/D board and placing the minimum amplitude at -50 dB. The output of the switching circuit and ground are reversed entering the UNIVERSAL I/O BOARD because in this way a negative voltage corresponds to a negative amplitude.

4.0 Software Development

The range software is written in Turbo Pascal. A graphics library, Turbo Halo by Media Cybernetics, and Pascal routines provided with the Qua Tech I/O card were utilized. Appendix A shows the relevant disk organization. The batch file PATTERNS.BAT should be executed after booting the PC in order to start the range program. This batch file executes the following commands:

cd \patterns (Changes to the pattern's sub-directory.)

hgc full (Places the Hercules graphics card in the proper mode.)

halortp (Loads drivers needed by Turbo Halo.)

patterns (Runs the PATTERNS.COM program.)

The batch file is provided because the 'hgc full' and 'halortp' commands must be executed after the PC is booted and before PATTERNS.COM is run.

Space dictates that the only section of the source code that will be presented is that which is concerned with the actual acquisition and initial manipulation of data. (This section of the source code appears in Appendix A.)

An integer number corresponding to a voltage is returned when a channel(s) is scanned. The integer 0 is returned for +5 V, and the integer 4095 is returned for -5 V. This and the amplification of the signal is the reason for the unusual scaling factors in the DataRecord PROCEDURE.

The only two variables that enter this section with a value are RazRange and LazRange, which correspond to Right Azimuth Range and Left Azimuth Range, respectively. The value for these two variables are an integer number that is user specified during the running of the program in the MAIN MENU section.

A quick calculation shows that one degree in azimuth corresponds to a real number of 10.2375 in the scaling method described above for the range +5 to -5 V.

The following commands access routines in the software that was sent with the system:

ADC_SETUP(Address) - Tells which address the A/D module is in.

INADC_12(BChannel,Now) - Scans BChannel and places an integer number corresponding to the voltage on the channel in the variable Now.
(Azimuth --- Channel 0,
Amplitude - Channel 1,
Phase ----- Channel 2.)

SCAN12_S(BChannel,EChannel,DataArray) - Scans the channels, BChannel through Channel, and stores integer numbers in the array Data Array.

This section looks at the initial position of the antenna and, if it is within the data taking azimuth, tells the user to move antenna outside azimuth. Once antenna is outside azimuth, then data taking may proceed. Eight scans are averaged and, if the azimuth reading is at an integral degree, then that point is saved. The comparison index, Angle, is then incremented, or decremented by a degree depending upon the direction of rotation of the antenna. This continues until the antenna is outside the azimuth again. The data is then arranged so that it will always appear with the left most point first and the right most point last. If the scan was not for a cross polarization measurement, then the data in the amplitude array is normalized to the largest value.

APPENDIX A

PATTERNS Disk Organization.

```
DIR. OF: B:\
VOL. ID: PATTERNS          (Options: /Cls  /Date  /Ext  /Hidn  /No sort  /Size)

filename.ext  -bytes  --last change--     filename.ext  -bytes  --last change--
*FREE SPACE*   48128                      patterns.     <dir>   08/11/87  13:51
PATTERNS.BAT      45  11/17/87  14:23
       2 File(s)
```

```
DIR. OF: B:\patterns\sor_code
VOL. ID: PATTERNS          (Options: /Cls  /Date  /Ext  /Hidn  /No sort  /Size)

filename.ext  -bytes  --last change--     filename.ext  -bytes  --last change--
*FREE SPACE*   61440                      HALOTURB.P     17896  04/24/86  19:01
.       .      <dir>  08/11/87  13:52     LAB2T   .BIN    4273  12/24/85  09:35
..      .      <dir>  08/11/87  13:52     LAB2T   .P      3712  12/18/85  17:26
GRAPHICS.PAS   18849  11/13/87  17:23     LIB     .PAS    8482  11/06/87  12:27
HALOTURB.BIN    1395  04/22/86  15:55     PAT1    .PAS   50256  11/18/87  09:29
       9 File(s)
```

```
DIR. OF: B:\patterns
VOL. ID: PATTERNS          (Options: /Cls  /Date  /Ext  /Hidn  /No sort  /Size)

filename.ext  -bytes  --last change--     filename.ext  -bytes  --last change--
*FREE SPACE*   61440                      HALOTJET.PRN    4608  10/23/85  13:54
.       .      <dir>  08/11/87  13:51     HELPFIL .PAS    3605  08/04/87  09:48
..      .      <dir>  08/11/87  13:51     LASTPARA.      10942  11/18/87  13:15
FILENAME.        648  11/17/87  14:54     PATTERNS.COM   45394  11/18/87  09:32
HALOEPSN.PRN    5120  04/25/85  15:04     TEST1   .       2542  11/17/87  12:42
HALOHERC.DEV    8881  04/25/86  12:56     TEST2   .       2542  11/17/87  14:25
HALOINDA.DEV    9043  04/25/86  13:12     sor_code.      <dir>  08/11/87  13:52
HALORTP .EXE   82532  06/19/86  09:34     tests   .      <dir>  08/11/87  13:52
      15 File(s)
```

```
DIR. OF: B:\patterns\tests
VOL. ID: PATTERNS          (Options: /Cls  /Date  /Ext  /Hidn  /No sort  /Size)

filename.ext  -bytes  --last change--     filename.ext  -bytes  --last change--
*FREE SPACE*   61440                      ARR     .FIL      32  12/24/85  11:44
.       .      <dir>  08/11/87  13:52     GRAPH   .BIN    3072  03/01/85  03:33
..      .      <dir>  08/11/87  13:52     GRAPH   .P      2048  03/01/85  03:38
ADC12   .EXM     722  12/24/85  11:42
       6 File(s)
```

APPENDIX B

Listing of Important Procedures

```
{***************************************************************************}

PROCEDURE DataRecord(var AzInfo, AmpInfo, PhaseInfo : real;  I : integer);

{ this procedure places the data (azimuth, amplitude, and phase)
  corresponding to every one degree into arrays, and writes them
  to the screen                                                       }

  VAR T : integer;

  BEGIN
    T := round((5 - (AzInfo/409.5)) * 40);
    AzArray[I] := T;
    AmpArray[I] := (5 - (AmpInfo/409.5)) * 10;
    PhaseArray[I] := (5 - (PhaseInfo/409.5)) * 76.923;
    writeln('AZIMUTH = ',AzArray[I]:4:0,'      AMPLITUDE =  ',AmpArray[I]:4:2,
                  PHASE =  ',PhaseArray[I]:4:2);
  END;

{***************************************************************************}
```

```
{*****************************************************************************}
{ inital setup and scaling of variables  }

    GetDT;
    Twonone := false;
    SetWind(DefWind);
    ClrScr;
    DrawBox(x1,y1,x2,Specy2,' TAKE DATA ');
    SetWind(Window2);
    writeln;
    writeln;
    write('IS THIS A CROSS POLARIZATION MEASUREMENT?  ');
    read(ch);
    IF ( upcase(ch) = 'Y' ) THEN          {condition 1}
     BEGIN                                {condition 1}
     writeln;
     writeln;
     write('DO YOU WANT COPOLAR & CROSSPOLAR PLOTS IN THE SAME GRAPH?  ');
     read(ch);
     IF ( upcase(ch) = 'Y' ) THEN          {condition 2}
      BEGIN                                {condition 2}
      writeln;
      writeln;
      write('DID YOU MAKE A COPOLAR MEASUREMENT?  ');
      read(ch);
      IF ( upcase(ch) = 'Y' ) THEN          {condition 3}
       BEGIN                                {condition 3}
       writeln;
       writeln;
       write('DID YOU MAKE A COPOLAR MEASUREMENT JUST PRECEEDING THIS?  ');
       read(ch);
       IF ( upcase(ch) = 'Y' ) THEN          {condition 4}
       goto one ;                            {condition 4}
        writeln;
        writeln('SELECT THE FILE WHICH HAS THE COPOLAR MEASUREMENT');
        writeln('PRESS ANY KEY FOR ACTION....  ');
        REPEAT UNTIL KeyPressed;
        LoadFileSetup;
        SetWind(DefWind);
        ClrScr;
        DrawBox(x1,y1,x2,Specy2,' TAKE DATA ');
        SetWind(Window2);
        One: XPol := true;
        WriteLastParams(Feed,LazRange,RazRange,Freq,Telescope,Plane,
                       Comments,PrinterType,DisplayType,Twonone);
        Twonone := true;
        writeln;
        writeln;
        write('MOVE ANTENNA TO ZERO DEGREES AZIMUTH AND ZERO THE AMPLITUDE ');
        writeln('METER');
        writeln('THEN ROTATE SOURCE ANTENNA THRU 90 DEGREES');
       END                                   {condition 3}
      ELSE                                   {condition 3}
       BEGIN                                 {condition 3}
       writeln;
       writeln('MAKE A COPOLAR MEASUREMENT FIRST');
       writeln('PRESS ANY KEY FOR ACTION....  ');
       REPEAT UNTIL KeyPressed;
       goto Two;
       END;                                  {condition 3}
      END                                   {condition 2}
     ELSE                                   {condition 2}
      BEGIN                                 {condition 2}
        XPol := true;
        writeln;
        writeln;
        write('MOVE ANTENNA TO ZERO DEGREES AZIMUTH AND ZERO THE AMPLITUDE ');
        writeln('METER');
        writeln('THEN ROTATE SOURCE ANTENNA THRU 90 DEGREES');
      END;              { cross polarization condition 2}
```

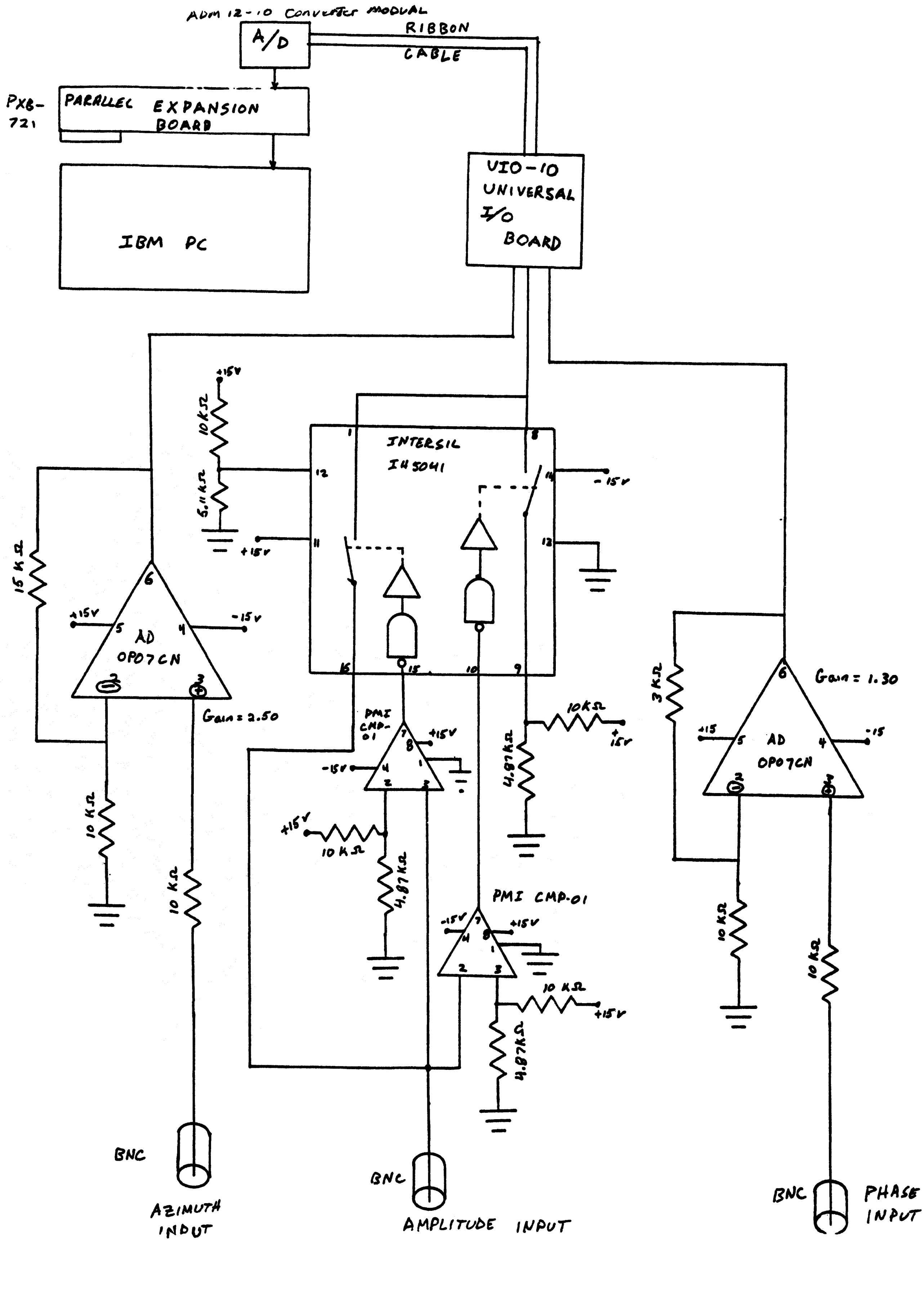
```
 END                                            {condition 1}
ELSE                                            {condition 1}
  BEGIN                                         {condition 1}
    XPol := false;
  END;  { ELSE not cross polarization  condition 1}
writeln;
writeln;
writeln('DO NOT START ANTENNA ROTATION UNTIL PROMPTED TO DO SO.');
writeln;
writeln;
RazVolt := RazRange/40;
LazVolt := LazRange/40;
RazInt := (5 - RazVolt) * 409.50;
LazInt := (5 - LazVolt) * 409.50;
Address := $300;
ADC_SETUP( Address );
BChannel := 0;
EChannel := 2;

{ check to see if antenna is already within the
  data taking azimuth                                         }

REPEAT
  AzAv := 0;
  FOR Count1 := 1 to 8 DO
    BEGIN
      INADC12_S(BChannel,Now);     { look at azimuth 8 times and average }
      AzAv := AzAv + Now;          { data to determine the initial       }
    END;                           { position of the reciever            }
  NowR := AzAv / 8;
  IF ((NowR > RazInt) and (NowR < LazInt)) THEN  { if reciever is inside }
    BEGIN                                        { data azimuth then     }
      Test := false;
      writeln;
      writeln('THE RECEIVING ANTENNA IS ALREADY WITHIN THE DATA TAKING ');
      writeln('AZIMUTH, MOVE THE ANTENNA OUTSIDE EITHER AZIMUTH BOUNDRY');
      writeln('THEN PRESS ANY KEY TO BEGIN THE DATA TAKING PROCESS. ');
      REPEAT UNTIL KeyPressed;
    END
  ELSE              { else reciever is outside data taking azimuth }
    BEGIN
      Test := true;
    END;
UNTIL Test; { anntena is now outside the azimuth boundries so data  }
            { taking may proceed                                    }

writeln;
writeln('START ANTENNA ROTATION NOW');


{ this section takes data (azimuth - channel 0, amplitude - channel 1,
  and phase - channel 2) from either direction.  the data is averaged
  over 8 quick scans and if the point is at a degree, the data is all
  placed into arrays by procedure 'DataRecord'                          }


 IF (NowR < RazInt) THEN    { reciever is outside right azimuth boundary }
  BEGIN
    Place := 1;            { index for storing data in arrays }
    Angle := RazInt;       { index to check to see if at a degree }
    REPEAT
      REPEAT
        AzAv := 0;         { reset temporary values }
        AmpAv := 0;
        PhAv := 0;
        FOR Count5 := 1 to 8 DO     { scan all channels 8 times }
          BEGIN
            SCAN12_S(BChannel,EChannel,DataArray);    { the scan }
            AzAv := AzAv + DataArray[1];
            AmpAv := AmpAv + DataArray[2];       { adding the individual }
            PhAv := PhAv + DataArray[3];         { scan to the total     }
          END;
```

```
          AzAvR := AzAv / 8;
          AmpAvR := AmpAv / 8;            { taking the average }
          PhAvR := PhAv / 8;
        UNTIL (AzAvR >= Angle);                 { kick out if at a degree }
        DataRecord(AzAvR,AmpAvR,PhAvR,Place);   { record data points }
        Place := Place + 1;                     { increment place index }
        Angle := Angle + 10.2375;          { increment angle index by one deg. }
      UNTIL (AzAvR >= LazInt);          { kick out if at left boundary edge }


{ This section arranges all the data in the azimuth, amplitude, and
  phase arrays so that it increases from the most negitive azimuth
  boundry (left) to the most positive (right) boundry                  }

          FOR Count7 := 1 to (Place - 1) DO
            BEGIN
              TempAzArr[Count7] := AzArray[Count7];
              TempAmpArr[Count7] := AmpArray[Count7];
              TempPhaseArr[Count7] := PhaseArray[Count7];
            END;
          FOR Count8 := 1 to (Place - 1) DO
            BEGIN
              Standardize := Place - Count8;
              AzArray[Count8] := TempAzArr[Standardize];
              AmpArray[Count8] := TempAmpArr[Standardize];
              PhaseArray[Count8] := TempPhaseArr[Standardize];
            END;


      END    { reciever moving from right to left and taking data  }


    ELSE     { else reciever is initially outside left boundary   }

{ the procedure for moving from left to right and taking data is identical
  to that documented above with the exception of the initial value of
  'Angle' and the way 'Angle' is incremented                               }

      BEGIN
        Place := 1;
        Angle := LazInt;
        REPEAT
          REPEAT
            AzAv := 0;
            AmpAv := 0;
            PhAv := 0;
            FOR Count6 := 1 to 8 DO
              BEGIN
                SCAN12_S(BChannel,EChannel,DataArray);
                AzAv := AzAv + DataArray[1];
                AmpAv := AmpAv + DataArray[2];
                PhAv := PhAv + DataArray[3];
              END;
            AzAvR := AzAv / 8;
            AmpAvR := AmpAv / 8;
            PhAvR := PhAv / 8;
          UNTIL (AzAvR <= Angle);
          DataRecord(AzAvR,AmpAvR,PhAvR,Place);
          Place := Place + 1;
          Angle := Angle - 10.2375;
        UNTIL (AzAvR <= RazInt);

       END;    { reciever moving from left to right and taking data }


{ This section finds the largest value in the amplitude array and
  stores that value in the variable NORMALIZE to be used later
  to normalize all the data in the amplitude array               }
```

```
  Counting := 0;
  REPEAT                                 { finds the position of 0 degrees azimuth }
    Counting := Counting + 1;
  UNTIL (round(AzArray[Counting]) = 0);
  writeln(AzArray[Counting],'    ',AmpArray[Counting]);
  Normalize := AmpArray[Counting - 11];
  FOR Count := (Counting - 10) to (Counting + 10) DO   { take the twenty  }
    BEGIN                                               { degrees around   }
      IF ( AmpArray[Count] > Normalize) THEN            { 0 azimuth and    }
        BEGIN                                           { find the largest }
          Normalize := AmpArray[Count];                 { value            }
        END;
    END;

{ This section normalizes all the data in the amplitude array to
  the largest value of amplitude                                  }

  IF ( not XPol ) THEN
    BEGIN
      FOR Count9 := 1 to Place DO
        BEGIN
          AmpArray[Count9] := AmpArray[Count9] - Normalize;
        END;
    END;  { if not xpol }

{ This section stores the co and crosspolar array either in LastParams
  file or in LastParams and a file you name                             }

    IF Twonone THEN
      BEGIN
      WriteLastParams(Feed,LazRange,RazRange,Freq,Telescope,Plane,
                      Comments,PrinterType,DisplayType,Twonone);
      CallFile(DumbRule,Twonone);
      writeln;
      write('DO YOU WANT TO SAVE THIS FILE?  ');
      read(ch);
      IF ( upcase(ch) = 'Y' ) THEN
        BEGIN
        SaveFileSetup(Twonone);
        END;
      END;

{****************************************************************************}
```

APPENDIX C

Schematic and Component Data


ADM 12-10 Converter Modual
A/D
RIBBON
CABLE
PXB-721
PARALLEL EXPANSION BOARD
IBM PC
VIO-10 UNIVERSAL I/O BOARD
INTERSIL IH5041
AD OP07CN
Gain = 2.50
Gain = 1.30
PMI CMP-01
BNC
AZIMUTH INPUT
AMPLITUDE INPUT
PHASE INPUT

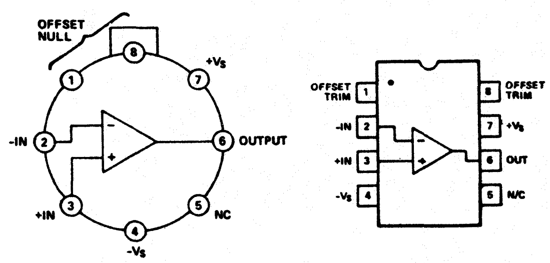
ANALOG DEVICES

Ultra-Low Offset Voltage Op Amp

AD OP-07

FEATURES
Ten Times More Gain Than Other OP-07 Devices (3.0M min)
Ultra-Low Offset Voltage: 10μV
Ultra-Low Offset Voltage Drift: 0.2μV/°C
Ultra-Stable vs. Time: 0.2μV/month
Ultra-Low Noise: 0.35μV p-p
No External Components Required
Monolithic Construction
High Common Mode Input Range: ±14.0V
Wide Power Supply Voltage Range: ±3V to ±18V
Fits 725, 108A/308A Sockets

AD OP-07 FUNCTIONAL BLOCK DIAGRAM



H-PACKAGE **N-PACKAGE**

PRODUCT DESCRIPTION

The AD OP-07 is an improved version of the industry-standard OP-07 precision operational amplifier. A guaranteed minimum open-loop voltage gain of 3,000,000 (AD OP-07A) represents an order of magnitude improvement over older designs; this affords increased accuracy in high closed loop gain applications. Input offset voltages as low as 10μV, bias currents of 0.7nA, internal compensation and device protection eliminate the need for external components and adjustments. An input offset voltage temperature coefficient of 0.2μV/°C and long-term stability of 0.2μV/month eliminate recalibration or loss of initial accuracy.

A true differential operational amplifier, the AD OP-07 has a high common mode input voltage range (±14V) high common mode rejection ratio (up to 126dB) and high differential input impedance (50MΩ); these features combine to assure high accuracy in noninverting configurations. Such applications include instrumentation amplifiers, where the increased open-loop gain maintains high linearity at high closed-loop gains.

The AD OP-07 is available in five performance grades. The AD OP-07E, AD OP-07C and AD OP-07D are specified for operation over the 0 to +70°C temperature range, while the AD OP-07A and AD OP-07 are specified for -55°C to +125°C operation. The devices are packaged in either TO-99 hermetically-sealed metal cans or plastic 8-pin mini DIPS.

PRODUCT HIGHLIGHTS

1. Increased open-loop voltage gain (3.0 million, min) results in better accuracy and linearity in high closed-loop gain applications.
2. Ultra-low offset voltage and offset voltage drift, combined with low input bias currents, allow the AD OP-07 to maintain high accuracy over the entire operating temperature range.
3. Internal frequency compensation, ultra-low input offset voltage and full device protection eliminate the need for additional components. This reduces circuit size and complexity and increases reliability.
4. High input impedances, large common mode input voltage range and high common mode rejection ratio make the AD OP-07 ideal for noninverting and differential instrumentation applications.
5. Monolithic construction along with advanced circuit design and processing techniques result in low cost.
6. The input offset voltage is trimmed at the wafer stage. Unmounted chips are available for hybrid circuit applications.

SPECIFICATIONS (T_A = +25°C, V_S = ±15V, unless otherwise specified)

MODEL / PARAMETER	SYMBOL	AD OP-07E MIN	AD OP-07E TYP	AD OP-07E MAX	AD OP-07C MIN	AD OP-07C TYP	AD OP-07C MAX	AD OP-07D MIN	AD OP-07D TYP	AD OP-07D MAX
OPEN LOOP GAIN	A_{VO}	2,000	5,000		1,200	4,000		1,200	4,000	
		1,800	4,500		1,000	4,000		1,000	4,000	
		300	1,000		300	1,000		300	1,000	
OUTPUT CHARACTERISTICS										
Maximum Output Swing	V_{OM}	±12.5	±13.0		±12.0	±13.0		±12.0	±13.0	
		±12.0	±12.8		±11.5	±12.8		±11.5	±12.8	
		±10.5	±12.0			±12.0				
		±12.0	±12.6		±11.0	±12.6		±11.0	±12.6	
Open-Loop Output Resistance	R_O		60			60			60	
FREQUENCY RESPONSE										
Closed Loop Bandwidth	BW		0.6			0.6			0.6	
Slew Rate	SR		0.17			0.17			0.17	
INPUT OFFSET VOLTAGE										
Initial	V_{OS}		30	75		60	150		60	150
			45	130		85	250		85	250
Adjustment Range			±4			±4			±4	
Average Drift							(Note 2)			(Note 2)
No External Trim	TCV_{OS}		0.3	1.3		0.5	1.8		0.7	2.5
With External Trim	TCV_{OSN}		0.3	1.3		0.4	1.6		0.7	2.5
Long Term Stability	V_{OS}/Time		0.3	1.5		0.4	(Note 2) 2.0		0.5	(Note 2) 3.0
INPUT OFFSET CURRENT										
Initial	I_{OS}		0.5	3.8		0.8	6.0		0.8	6.0
			0.9	5.3		1.6	8.0		1.6	8.0
Average Drift	TCI_{OS}		8 (Note 2)	35		12 (Note 2)	50		12 (Note 2)	50
INPUT BIAS CURRENT										
Initial	I_B		±1.2	±4.0		±1.8	±7.0		±2.0	±12
			±1.5	±5.5		±2.2	±9.0		±3.0	±14
Average Drift	TCI_B		13 (Note 2)	35		18 (Note 2)	50		18 (Note 2)	50
INPUT RESISTANCE										
Differential	R_{IN}	15	50		8	33		7	31	
Common Mode	R_{IN} CM		160			120			120	
INPUT NOISE										
Voltage	e_n p-p		0.35	0.6		0.38	0.65		0.38	0.65
Voltage Density	e_n		10.3	18.0		10.5	20.0		10.5	20.0
			10.0	13.0		10.2	13.5		10.2	13.5
			9.6	11.0		9.8	11.5		9.8	11.5
Current	i_n p-p		14	30		15	35		15	35
Current Density	i_n		0.32	0.80		0.35	0.90		0.35	0.90
			0.14	0.23		0.15	0.27		0.15	0.27
			0.12	0.17		0.13	0.18		0.13	0.18
INPUT VOLTAGE RANGE										
Common Mode	CMVR	±13.0	±14.0		±13.0	±14.0		±13.0	±14.0	
		±13.0	±13.5		±13.0	±13.5		±13.0	±13.5	
Common Mode Rejection Ratio	CMRR	106	123		100	120		94	110	
		103	123		97	120		94	106	
POWER SUPPLY										
Current, Quiescent	I_Q		3.0	4.0		3.5	5.0		3.5	5.0
Power Consumption	P_D		90	120		105	150		105	150
			6.0	8.4		6.0	8.4		6.0	8.4
Rejection Ratio	PSRR	94	107		90	104		90	104	
		90	104		86	100		86	100	
OPERATING TEMPERATURE RANGE	T_{min}, T_{max}	0		+70	0		+70	0		+70
PACKAGE OPTION[4]										
"N" Package										
8-Pin MINI DIP – (N8A)			AD OP-07EN			AD OP-07CN			AD OP-07DN	
"H" Package										
TO-99 – (H08B)			AD OP-07EH			AD OP-07CH			AD OP-07DH	

NOTES

[1] Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power. Additionally, AD OP-07A offset voltage is measured five minutes after power supply application at 25°C, -55°C and +125°C.

[2] Parameter is not 100% tested; 90% of units meet this specification.

[3] Long Term Input Offset Voltage Stability refers to the averaged trend line of V_{OS} vs. Time over extended periods of time and is extrapolated from high temperature test data. Excluding the intitial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5μV – Parameter is not 100% tested: 90% of units meet this specification.

[4] See Section 19 for package outline information.

Specifications subject to change without notice.

INTERSIL

IH5040-IH5051 Family High Level CMOS Analog Gates

FEATURES

- Switches Greater Than 20Vpp Signals With ±15V Supplies
- Quiescent Current Less Than 1μA
- Overvoltage Protection to ±25V
- Break-Before-Make Switching t_{off} 200 nsec, t_{on} 300 nsec Typical
- T^2L, DTL, CMOS, PMOS Compatible
- Non-Latching With Supply Turn-Off
- Low $r_{DS(on)}$ – 35Ω
- New DPDT & 4PST Configurations
- Complete Monolithic Construction IH5040 through IH5047

FUNCTIONAL DIAGRAM

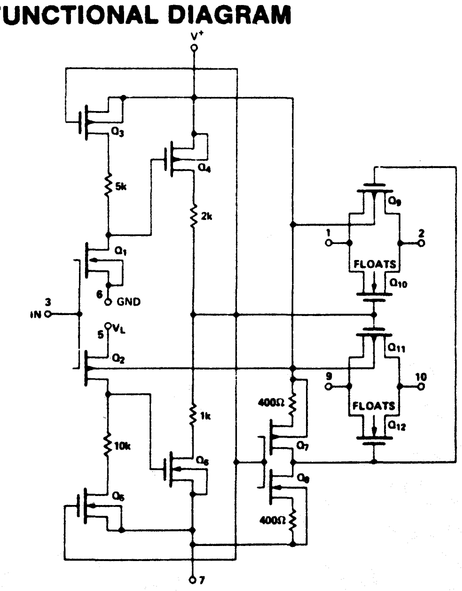


FIGURE 1. TYPICAL DRIVER, GATE – IH5042

ORDERING INFORMATION

IH5040 M JE

- Package
  - DE – 16-Pin Ceramic DIP (Special Order Only)
  - FD-2 – 14-Pin Flatpak
  - JE – 16-Pin CERDIP
  - PE – 16-Pin Plastic DIP
  - TW – TO-100 Metal Can (IH5041/2, IH5044, IH5048, IH5050 Only)
- Temperature Range
  - M – Military -55°C to +125°C
  - C – Commercial 0°C to +70°C
- Basic Part Number

GENERAL DESCRIPTION

The IH5040 family of solid state analog gates are designed using an improved, high voltage CMOS monolithic technology. These devices provide ease-of-use and performance advantages not previously available from solid state switches. This improved CMOS technology provides input overvoltage capability to ±25 volts without damage to the device, and destructive latch-up of solid state analog gates has been eliminated. Early CMOS gates were destroyed when power supplies were removed with an input signal present. The IH5040 CMOS technology has eliminated this serious systems problem.

Key performance advantages of the 5040 series are TTL compatibility and ultra low-power operation. The quiescent current requirement is less than 1μA. Also designed into the 5040 is guaranteed Break-Before-Make switching, which is accomplished by extending the t_{on} time (300 nsec TYP.) so that it exceeds t_{off} time (200 nsec TYP.). This insures that an ON channel will be turned OFF before an OFF channel can turn ON. This eliminates the need for external logic required to avoid channel to channel shorting during switching.

Many of the 5040 series improve upon and are pin-for-pin and electrical replacements for other solid state switches.

FUNCTIONAL DESCRIPTION

INTERSIL PART NO.	TYPE	$r_{DS(on)}$	PIN/FUNCTIONAL EQUIVALENT (Note 1)
IH5040	SPST	75Ω	
IH5041	Dual SPST	75Ω	
IH5042	SPDT	75Ω	DG 188AA/BA
IH5043	Dual SPDT	75Ω	DG 191AP/BP
IH5044	DPST	75Ω	
IH5045	Dual DPST	75Ω	DG 185AP/BP
IH5046	DPDT	75Ω	
IH5047	4PST	75Ω	
IH5048 Dual	SPST	35Ω	
IH5049 Dual	DPST	35Ω	DG 184AP/BP
IH5050	SPDT	35Ω	DG 187AA/BA
IH5051 Dual	SPDT	35Ω	DG 190AP/BP

NOTE 1. See Switching State diagrams for applicable package equivalency.

Pin and functional equivalent monolithic versions of the DG181, DG182, DG187 and DG188 are available. See data sheet for this and also IH181 to IH191.

IH5040-IH5051 Family

INTERSIL

ABSOLUTE MAXIMUM RATINGS

Current (Any Terminal) . . . . < 30mA
Storage Temperature . . . . -65°C to +150°C
Operating Temperature . . . . -55°C to +125°C
Power Dissipation 450mW
(All Leads Soldered to a P.C. Board)
Derate 6mW/°C Above 70°C
Lead Temperature (Soldering, 10 sec) . . . . 300°C

$V^+ - V^-$	< 33V
$V^+ - V_D$	< 30V
$V_D - V^-$	< 30V
$V_D - V_S$	< ±22V
$V_L - V^-$	< 33V
$V_L - V_{IN}$	< 30V
V_L-GND	< 20V
V_{IN}-GND	< 20V

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS (@ 25°C, V^+ = +15 V, V^- = −15 V, V_L = +5 V)

PER CHANNEL		MIN./MAX. LIMITS							
		MILITARY			COMMERCIAL				
SYMBOL	CHARACTERISTIC	-55°C	+25°C	+125°C	0	+25°C	+70°C	UNITS	TEST CONDITIONS
$I_{IN(ON)}$	Input Logic Current	1	1	1	1	1	1	µA	V_{IN} = 2.4 V Note 1
$I_{IN(OFF)}$	Input Logic Current	1	1	1	1	1	1	µA	V_{IN} = 0.8 V Note 1
$r_{DS(on)}$	Drain–Source On Resistance	75(35)	75(35)	150(60)	80 (45)	80 (45)	130 (45)	Ω	(IH5048 Thru IH5051) I_S = 10 mA V_{ANALOG} = -10 V to +10 V
$\Delta r_{DS(ON)}$	Channel to Channel $r_{DS(ON)}$ Match		25 (15) (typ)			30(15) (typ)		Ω	(IH5048 thru IH5051)
V_{ANALOG}	Min. Analog Signal Handling Capability		±11(±10)			±10(±10)		V	
$I_{D(OFF)}$	Switch OFF Leakage Current	1(1)	1(1)	100(100)	5(5)	5(5)	100(100)	nA	V_{ANALOG} = -10 V to +10 V (IH5048 thru IH5051
$I_{D(ON)}$ $+I_{S(ON)}$	Switch On Leakage Current	2(2)	2(2)	200(200)	10 (10)	10 (10)	100(200)	nA	V_D = V_S = -10 V to + 10 V (IH5048 thru IH5051)
t_{on}	Switch "ON" Time		500(250)			500(300)		ns	R_L = 1 kΩ, V_{ANALOG} = -10 V to +10 V See Fig A
t_{off}	Switch "OFF" Time		250(150)			250(150)		ns	R_L = 1 kΩ, V_{ANALOG} = -10 V to +10 V See Fig A (IH5048 thru IH5051)
$Q_{(INJ.)}$	Charge Injection		15 (10)			20 (10)		mV	See Fig B (IH5048 thru IH5051)
OIRR	Min. Off Isolation Rejection Ratio		54			50		dB	f = 1 MHz, R_L = 100Ω, C_L ≤ 5 pF See Fig. C, (Note 1)
I^+_Q	+ Power Supply Quiescent Current	1	1	10	10	10	100	µA	
I^-_Q	− Power Supply Quiescent Current	1	1	10	10	10	100	µA	V^+ = +15 V, V^- = -15 V, V_L = +5 V V_L = +5 V
I^-_{LQ}	+5 V Supply Quiescent Current	1	1	10	10	10	100	µA	
I_{GND}	Gnd Supply Quiescent Current	1	1	10	10	10	100	µA	
CCRR	Min. Channel to Channel Cross Coupling Rejection Ratio		54			50		dB	One Channel Off Any Other Channel Switches as per Fig E (Note 1)

Note 1: Not tested in production.

TEST CIRCUITS

FIG. A

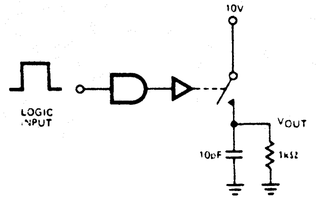


FIG. B

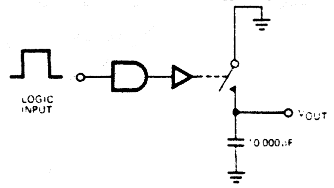
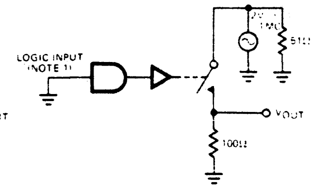


FIG. C



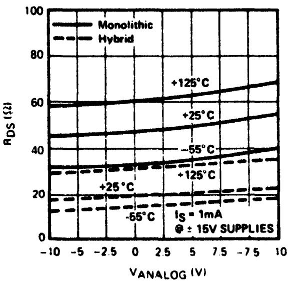
NOTE 1: Some channels are turned on by high "1" logic inputs and other channels are turned on by low "0" inputs; however 0.8V to 2.4V describes the min. range for switching properly. Refer to logic diagrams to see absolute value of logic input required to produce "ON" or "OFF" state.

IH5040-IH5051 Family

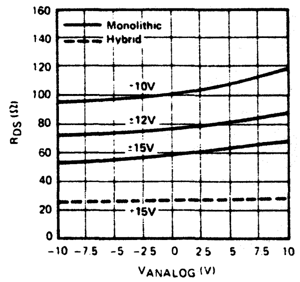
INTERSIL

TYPICAL ELECTRICAL CHARACTERISTICS (Per Channel)

$r_{DS(on)}$ vs V_{ANALOG} SIGNAL



$r_{DS(on)}$ vs POWER SUPPLY VOLTAGE



CHARGE INJECTION vs V_{ANALOG} (SEE FIG. B) C_L = 10,000pF

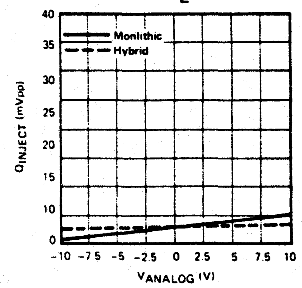
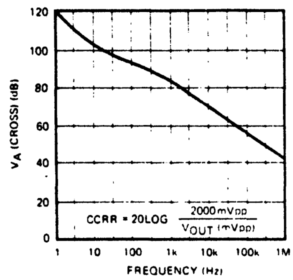


FIGURE D

CROSS COUPLING REJECTION vs FREQUENCY



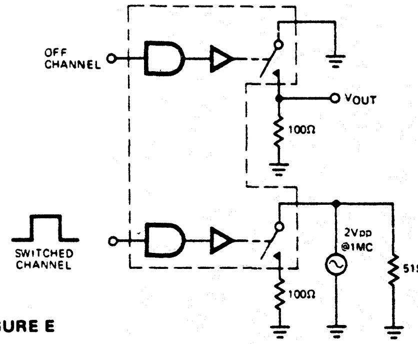
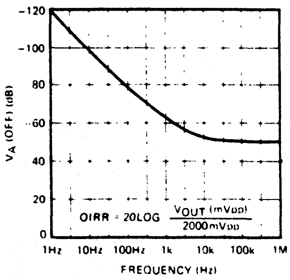


FIGURE E

OFF ISOLATION vs FREQUENCY



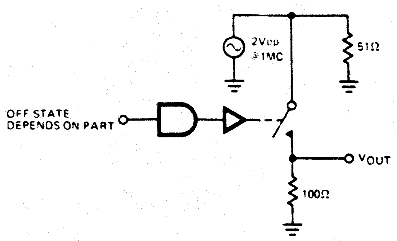
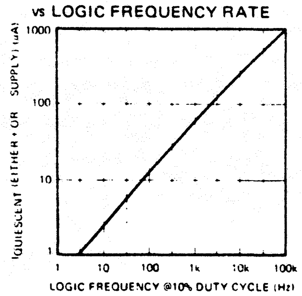


FIGURE F

POWER SUPPLY QUIESCENT CURRENT vs LOGIC FREQUENCY RATE



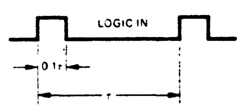
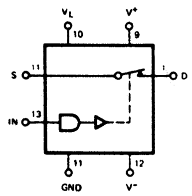
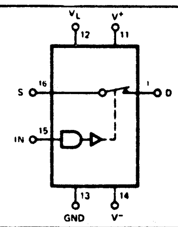


FIGURE G

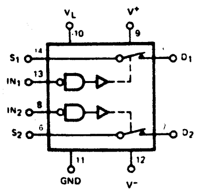
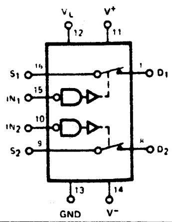
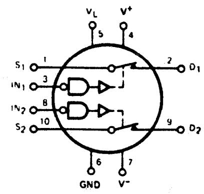
?WITCHING STATE DIAGRAMS

?WITCH STATES ?RE FOR LOGIC "1" INPUT	(OUTLINE DWG FD-2)	(OUTLINE DWGS DE, JE, PE)	(OUTLINE DWG TO-100)

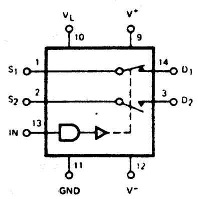
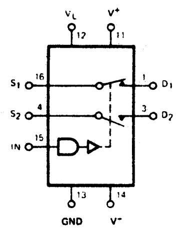
?PST
?H5040 ($r_{DS(on)} < 75\Omega$)

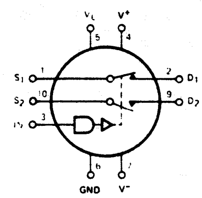
?UAL SPST
?H5041 ($r_{DS(on)} < 75\Omega$)

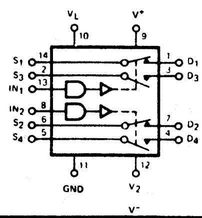
?PDT
?H5042 ($r_{DS(on)} < 75\Omega$)

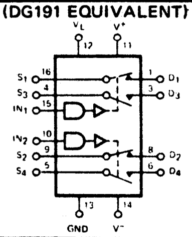
(DG188 EQUIVALENT)



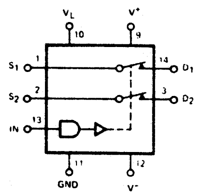
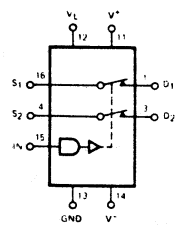
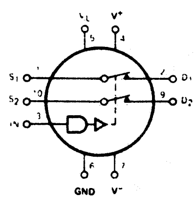
DUAL SPDT
IH5043 ($r_{DS(on)} < 75\Omega$)



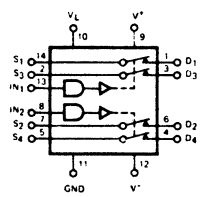
(DG191 EQUIVALENT)



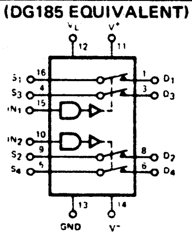
DPST
IH5044 ($r_{DS(on)} < 75\Omega$)

DUAL DPST
IH5045 ($r_{DS(on)} < 75\Omega$)



(DG185 EQUIVALENT)



PMI

CMP-01
FAST PRECISION COMPARATOR

Precision Monolithics Inc.

FEATURES

- **Fast Response Time .... 180ns Max**
- **High Input Slew Rate 92V/μs**
- **Low Offset Voltage .... 0.3mV Typical, 0.8mV Max**
- **Low Offset Current .... 4nA Typical, 25nA Max**
- **Low Offset Drift .... 1μV/°C, 30pA/°C**
- **Standard Power Supplies .... +5V or ±5V to ±18V**
- **Guaranteed Operation from Single +5V Supply**
- **No Pull-Up Resistor Required for TTL Drive**
- **Wired OR Capability**
- **Fits 111, 106, 710 Sockets**
- **Easy Offset Nulling .... Single 2kΩ Potentiometer**
- **Easy to Use .... Free from Oscillations**

ORDERING INFORMATION†

+25°C V_{OS} (mV)	PACKAGE HERMETIC TO-99 8-PIN	DIP 8-PIN	PLASTIC DIP 8-PIN	OPERATING TEMPERATURE RANGE
0.8	CMP01J*	CMP01Z*	—	MIL
0.8	CMP01EJ	CMP01EZ	CMP01EP	COM
2.8	CMP01CJ	CMP01CZ	CMP01CP	COM

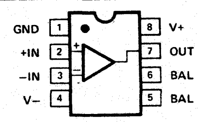
*For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

†All commercial and industrial temperature range parts are available with burn-in. For ordering information see 1986 Data Book, Section 2.

GENERAL DESCRIPTION

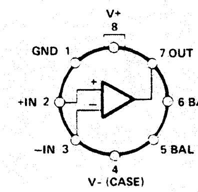
The CMP-01 is a monolithic fast precision voltage comparator using an advanced NPN-Schottky Barrier Diode process. It features fast response time to both large and small input signals, while maintaining excellent input characteristics. The CMP-01 is capable of operating over a wide range of supply voltages including single ended 5 volt supply. The large output current sinking and high output voltage capability assure good application flexibility, while the combination of fast response, high accuracy, and freedom from oscillation assure performance in precision level detectors and 12 and 13-bit A/D converters. The CMP-01 is pin-compatible to earlier 111, 106, and 710 types. For applications requiring lower input offset and bias currents, refer to the CMP-02 data sheet.

PIN CONNECTIONS



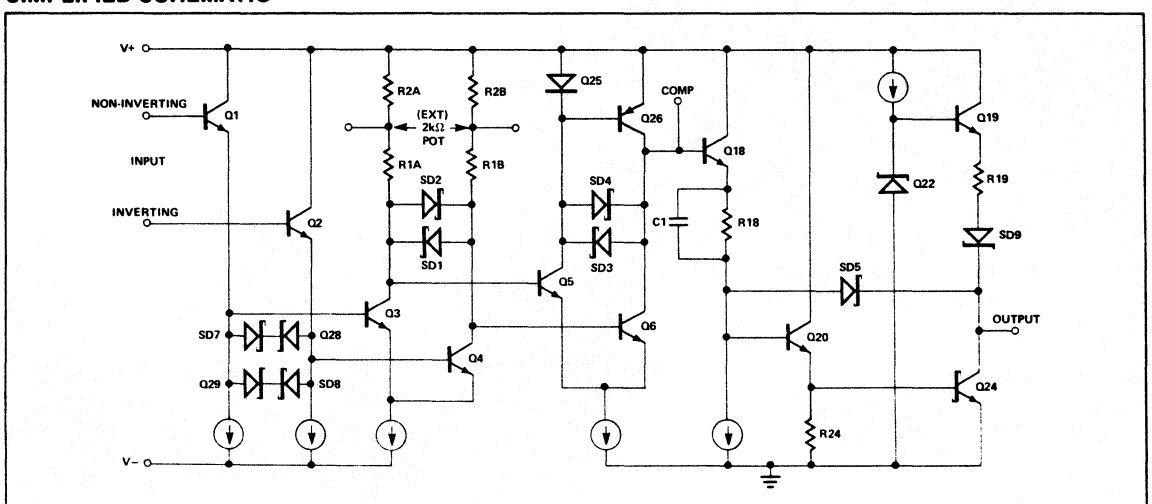
8-PIN HERMETIC MINI-DIP (Z-Suffix)

EPOXY MINI-DIP (P-Suffix)



TO-99 (J-Suffix)

SIMPLIFIED SCHEMATIC



1/86, Rev. A

ABSOLUTE MAXIMUM RATINGS (Note 2)

Total Supply Voltage, V+ to V− 36V
Output to Ground .... −5V to +32V
Output to Negative Supply Voltage 50V
Ground to Negative Supply Voltage 30V
Positive Supply Voltage to Ground .... +30V
Positive Supply Voltage to Offset Null .... 0 to 2V
Power Dissipation (See Note 1) 500mW
Differential Input Voltage .... ±11V
Input Voltage (V_S = ±15V) .... ±15V
Output Sink Current (Continuous Operation) 75mA
Operating Temperature Range
CMP-01 .... −55°C to +125°C
CMP-01E, CMP-01C .... 0°C to +70°C
DICE Junction Temperature (T_j) .... −65°C to +150°C
Storage Temperature Range .... −65°C to +150°C
P-Suffix .... −65°C to +125°C

Lead Temperature (Soldering, 60 sec) .... 300°C
Output Short-Circuit Duration — to ground ..... Indefinite
to V+ .... 1 Minute

NOTES:

1. Maximum package power dissipation vs. ambient temperature.

PACKAGE TYPE	MAXIMUM AMBIENT TEMPERATURE FOR RATING	DERATE ABOVE MAXIMUM AMBIENT TEMPERATURE
TO-99 (J)	80°C	7.1mW/°C
Epoxy Mini-DIP (P)	36°C	5.6mW/°C
Hermetic Mini-DIP (Z)	75°C	6.7mW/°C

2. Absolute ratings apply to both DICE and packaged parts, unless otherwise noted.

ELECTRICAL CHARACTERISTICS at V_S = ±15V, T_A = 25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	CMP-01 CMP-01E MIN	TYP	MAX	CMP-01C MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{OS}	$R_S \le 5k\Omega$, (Note 1)	—	0.3	0.8	—	0.4	2.8	mV
Input Offset Current	I_{OS}	(Note 1)	—	4	25	—	5	80	nA
Input Bias Current	I_B		—	350	600	—	400	900	nA
Differential Input Resistance	R_{IN}	(Note 2)	150	300	—	100	200	—	kΩ
Voltage Gain	A_V	V_O = 0.4V to 2.4V, (Notes 1, 2)	200	500	—	100	500	—	V/mV
Response Time (Note 3)	t_r	100mV step, 5mV Overdrive							ns
		No Load (No Pull-Up)	—	110	180	—	110	180	
		5kΩ to 5v (Pull-Up)	—	110	—	—	110	—	
		TTL Fan-Out = 4, No Pull-Up	—	110	—	—	110	—	
		5V Step 5mV Overdrive							
		No Load (No Pull-Up)	—	160	—	—	160	—	
		5kΩ to 5v (Pull-Up)	—	160	—	—	160	—	
		TTL Fan-Out = 4, No Pull-Up	—	160	—	—	160	—	
Input Slew Rate			—	92	—	—	92	—	V/μs
Input Voltage Range	CMVR		±12.5	±13	—	±12.5	±13	—	V
Common-Mode Rejection Ratio	CMRR		94	110	—	90	110	—	dB
Power Supply Rejection Ratio	PSRR	$5V \le V_{S+} \le 18V$, $-18V \le V_{S-} \le 0V$	80	100	—	74	98	—	dB
Positive Output Voltage	V_{OH}	$V_{IN} \ge 3mV$, $I_O = 320\mu A$	2.4	3.2	—	—	—	—	V
		$V_{IN} \ge 3mV$, $I_O = 240\mu A$	—	—	—	2.4	3.4	—	
		$V_{IN} \ge 3mV$, I_O = 0mA	2.4	4.8	—	2.4	4.8	—	
Saturation Voltage	V_{OL}	$V_{IN} \le -10mV$, I_{sink} = 0mA	—	0.16	0.4	—	0.16	0.4	V
		$V_{IN} \le -10mV$, $I_{sink} \le 6.4mA$	—	0.3	0.45	—	0.31	0.45	
		$V_{IN} \le -10mV$, $I_{sink} \le 12mA$ (CMP-01 only)	—	0.36	0.5	—	—	—	
Output Leakage Current	I_{LEAK}	$V_{IN} \ge 10mV$, V_O = +30V	—	0.03	2	—	0.05	8	μA
Positive Supply Current	I+	$V_{IN} \le -10mV$	—	5.6	8	—	5.6	8.5	mA
Negative Supply Current	I−	$V_{IN} \le -10mV$	—	1.3	2.2	—	1.3	2.2	mA
Power Dissipation	P_d	$V_{IN} \le -10mV$	—	103	153	—	103	161	mW
Offset Voltage Adjustment Range		Nulling Pot ≥ 2kΩ	—	±5	—	—	±5	—	mV

NOTES:

1. These parameters are specified as the maximum values required to drive the output between the logic levels of 0.4V and 2.4V with a 1kΩ load tied to +5V; thus, these parameters define an error band which takes into account the worst case effects of voltage gain and input impedance.
2. Guaranteed by design.
3. Sample tested.

VOLTAGE COMPARATORS

ELECTRICAL CHARACTERISTICS at V_{S+} = 5V, V_{S-} = 0V, T_A = 25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	CMP-01 / CMP-01E MIN	CMP-01 / CMP-01E TYP	CMP-01 / CMP-01E MAX	CMP-01C MIN	CMP-01C TYP	CMP-01C MAX	UNITS
Input Offset Voltage	V_{OS}	$R_S \leq 5k\Omega$, (Note 1)	—	0.4	1.5	—	0.5	3.5	mV
Input Offset Current	I_{OS}	(Note 1)	—	3	21	—	4	65	nA
Input Bias Current	I_B		—	250	500	—	300	720	nA
Voltage Gain	A_V	V_O = 0.4V to 2.4V, (Notes 1, 2)	—	50	—	—	50	—	V/mV
Response Time	t_r	100mV Step, 5mV Overdrive 5kΩ to 5V (Pull-Up) TTL Fan-Out = 4, 5kΩ to 5V (Pull-Up)	— —	150 150	— —	— —	150 150	— —	ns
Input Voltage Range	CMVR		1.8	1.7-3.8	3.5	1.8	1.7-3.8	3.5	V
Saturation Voltage	V_{OL}	$V_{IN} \leq$ -10mV, $I_{sink} \leq$ 6.4mA	—	0.3	0.45	—	0.3	0.45	V
Positive Supply Current	I+	$V_{IN} \leq$ -10mV	—	2.3	3.2	—	2.4	3.8	mA
Power Dissipation	P_d	$V_{IN} \leq$ -10mV	—	11 5	16	—	12	19	mW

ELECTRICAL CHARACTERISTICS at V_S = ±15V, -55°C ≤ T_A ≤ 125°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	CMP-01 MIN	CMP-01 TYP	CMP-01 MAX	UNITS
Input Offset Voltage	V_{OS}	$R_S \leq 5k\Omega$, (Note 1) V_{S+} = 5V, V_{S-} = 0V, (Note 1)	— —	0.5 0.6	1.6 2.8	mV
Average Input Offset Voltage Drift Without External Trim With External Trim	TCV_{OS} TCV_{OSn}	$R_S = 50\Omega$	— —	1.5 1	— —	μV/°C
Input Offset Current	I_{OS}	T_A = +125°C, (Note 1) T_A = -55°C, (Note 1)	— —	4 5	25 45	nA
Average Input Offset Current Drift	TCI_{OS}	+25°C ≤ T_A ≤ +125°C -55°C ≤ T_A ≤ +25°C	— —	12 35	— —	pA/°C
Input Bias Current	I_B	T_A = +125°C T_A = -55°C	— —	330 550	600 1400	nA
Voltage Gain	A_V	V_O = 0.4V to 2.4V, (Notes 1, 2)	100	500	—	V/mV
Response Time	t_r	100mV Step, 5mV Overdrive, (Note 2) T_A = +125°C, No Load T_A = -55°C, No Load	— —	220 100	— —	ns
Input Voltage Range	CMVR		±12	±13	—	V
Common-Mode Rejection Ratio	CMRR		88	106	—	dB
Power Supply Rejection Ratio	PSRR	5V ≤ V_{S+} ≤ 15V, -15V ≤ V_{S-} ≤ 0V	75	96	—	dB
Positive Output Voltage	V_{OH}	$V_{IN} \geq$ 4mV, I_O = 200μA	2.4	3	—	V
Saturation Voltage	V_{OL}	$V_{IN} \leq$ -10mV, I_{sink} = 0mA $V_{IN} \leq$ -10mV, I_{sink} = 6.4mA	— —	0.20 0.32	0.4 0.5	V

NOTES:
1. These parameters are specified as the maximum values required to drive the output between the logic levels of 0.4V and 2.4V with a 1kΩ load tied to +5V; thus, these parameters define an error band which takes into account the worst case effects of voltage gain and input impedance.
2. Guaranteed by design.

ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $0°C \leq T_A \leq 70°C$, unless otherwise noted.

			CMP-01E			CMP-01C			
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{OS}	$R_S \leq 5k\Omega$, (Note 1)	—	0.4	1.4	—	0.5	3.5	mV
		$V_{S+} = 5V$, $V_{S-} = 0V$, (Note 1)	—	0.5	2.4	—	0.6	4.3	
Average Input Offset Voltage Drift									
Without External Trim	TCV_{OS}	$R_S = 50\Omega$	—	1.5	—	—	1.8	—	$\mu V/°C$
With External Trim	TCV_{OSn}		—	1.0	—	—	1.2	—	
Input Offset Current	I_{OS}	$T_A = +70°C$, (Note 1)	—	4	25	—	5	80	nA
		$T_A = 0°C$, (Note 1)	—	5	45	—	6	120	
Average Input Offset Current Drift	TCI_{OS}	$+25°C \leq T_A \leq +70°C$	—	12	—	—	12	—	pA/°C
		$0°C \leq T_A \leq +25°C$	—	35	—	—	40	—	
Input Bias Current	I_B	$T_A = +70°C$	—	330	600	—	340	900	nA
		$T_A = 0°C$	—	400	950	—	450	1200	
Voltage Gain	A_V	$V_O = 0.4V$ to $2.4V$, (Notes 1, 2)	100	500	—	70	500	—	V/mV
Response Time	t_r	100mV Step, 5mV Overdrive							ns
		$T_A = +70°C$, No Load	—	150	—	—	150	—	
		$T_A = 0°C$, No Load	—	100	—	—	100	—	
Input Voltage Range	CMVR		±12.0	±13.3	—	±12.0	±13.3	—	V
Common-Mode Rejection Ratio	CMRR		90	108	—	86	108	—	dB
Power Supply Rejection Ratio	PSRR	$5V \leq V_{S+} \leq 15V$, $-15V \leq V_{S-} \leq 0V$	77	98	—	70	88	—	dB
Positive Output Voltage	V_{OH}	$V_{IN} \geq 4mV$, $I_O = 200\mu A$	2.4	3.2	—	2.4	3.2	—	V
Saturation Voltage	V_{OL}	$V_{IN} \leq -10mV$, $I_{sink} = 0$	—	0.17	0.4	—	0.17	0.4	V
		$V_{IN} \leq -10mV$, $I_{sink} = 6.4mA$	—	0.3	0.5	—	0.31	0.5	

NOTES:

1. These parameters are specified as the maximum values required to drive the output between the logic levels of 0.4V and 2.4V with a 1kΩ load tied to +5V; thus, these parameters define an error band which takes into account the worst case effects of voltage gain and input impedance.
2. Guaranteed by design.