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IEEE Standard Multichannel Analyzer (MCA) Histogram Data Interchange Format for Nuclear Spectroscopy

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IEEE Standard Multichannel Analyzer (MCA) Histogram Data Interchange Format for Nuclear Spectroscopy

Sponsor

Nuclear Instruments and Detectors Committee of the IEEE Nuclear and Plasma Sciences Society

Approved September 17, 1992

IEEE Standards Board

Abstract: A standard format for data interchange used to transfer multichannel pulse height data on magnetic media between laboratories is provided. The terms used in file records are defined. The contents consist only of ASCII characters and can be transmitted over networks and other direct links. Example programs to read data in FORTRAN, BASIC, and C are provided.
Keywords: data transfer, histogram data interchange, multichannel analyzer, multichannel pulse height data, nuclear spectroscopy

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Introduction

(This introduction is not a part of IEEE Std 1214-1992, IEEE Standard Multichannel Analyzer (MCA) Histogram Data Interchange Format for Nuclear Spectroscopy.)

This document provides a standard format for histogram data for nuclear spectroscopy to facilitate interchange of such data between and within institutions.

At the time it approved this standard, the Nuclear Instruments and Detectors Committee of the IEEE Nuclear and Plasmas Sciences Society had the following membership:

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IEEE Standard Multichannel Analyzer (MCA) Histogram Data Interchange Format for Nuclear Spectroscopy

1. Scope

This standard applies to multichannel pulse height data used in nuclear spectroscopy. It is independent of the source of the data, the device which wrote the data, the device which reads the data, and the medium containing the data.

2. Purpose

The purpose of this standard is to provide a format for data interchange that can be used to transfer multichannel pulse height data between laboratories, and to distribute this data for testing purposes. In order to be compatible with a large number of computer languages, computers, and hardware links, the complete file must be written in ASCII. It is intended that these files be converted to the local format before being used.

3. Definitions

3.1 acquisition start time: The start time of the acquisition of the histogram data, as

DD/MM/YR_HH:NN:SS_

where the '_' (underscore character) is an ASCII space; DD is the day; MM is the month; YR is the year; HH is the hours; NN is the minutes; and SS is the seconds.

3.2 ADC number: A four-character number identifying the ADC (analog to digital converter) used for the data. Leading spaces are interpreted as leading zeros. Normally, the ADC numbers would start at 1 and go up in sequence for a given system. Different systems in a specific laboratory could use non-sequential numbers, e.g., 1 to 4, and 11 to 14, for different types of equipment.

3.3 energy and channel pairs: The energy (keV) of the corresponding channel is stored as energy-channel pairs. Each member of the pair is stored as a 16-character floating point number, with unused pairs being ASCII spaces or zeros. They are stored as ordered pairs, i.e., the first entry is the energy, the second is the channel at that energy, the third is the energy, the fourth is the channel at that energy, and then to the next record. This is intended to provide sufficient numbers of channel pairs to allow for an adequate reconstruction of the energy-channel function by the analysis program.

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3.4 energy and efficiency pairs: The detection efficiency at the corresponding energy is stored as energy-efficiency pairs. Each member of the pair is stored as a 16-character floating point number, with unused pairs being ASCII spaces or zeros. They are stored as ordered pairs, i.e., the first entry is the energy, the second is the efficiency at that energy, the third is the energy, the fourth is the efficiency at that energy, and then to the next record. This is intended to provide sufficient numbers of efficiency pairs to allow for an adequate reconstruction of the efficiency function by the analysis program.

3.5 energy and resolution pairs: The detector resolution at the corresponding energy is stored as energy-resolution pairs. Each member of the pair is stored as a 16-character floating point number, with unused pairs being ASCII spaces or zeros. They are stored as ordered pairs, i.e., the first entry is the energy, the second is the resolution at that energy, the third is the energy, the fourth is the resolution at that energy, and then to the next record. This is intended to provide sufficient numbers of resolution pairs to allow for an adequate reconstruction of the resolution function by the analysis program.

3.6 energy calibration coefficients: The energy *(E)* (in units of keV) versus channel number *(Ch)* coefficients as

$$E = A + B \cdot Ch + C \cdot Ch^2 + D \cdot Ch^3$$

with the coefficients, *A, B, C,* and *D* stored as four successive 14-character numbers including the decimal point. Leading spaces are interpreted as zeros. Any values not used or calculated should be set to all spaces. The *A* term is usually called the offset or zero intercept. The *B* term is usually called the slope of the energy-channel curve. The *C* term is called the quadratic component of the energy-channel curve. The *D* term is called the cubic component of the energy-channel curve.

3.7 digital offset: The offset is the position of the intersection point of the zero voltage input value on the channel number axis. The digital offset value is subtracted from the ADC output value before storage. This corresponds to the first channel in the stored spectrum. It is expressed as six characters with leading spaces interpreted as leading zeros. The digital offset is used where the low channel part of the data does not contain useful information and is digitally discarded before storage in the memory. This number is added to the stored data channel number to obtain the ADC output value. This allows various spectra to be compared even if they are incomplete.

3.8 live time: The live time, in seconds and fraction thereof, of acquisition of the spectrum. It is expressed as 14 characters including decimal point with leading zeros interpreted as zeros.

3.9 number of channels: A six-character number (no decimal point) giving the number of channels included in this file. The last record contains blank data for the data in excess of the actual number of channels. Leading spaces are interpreted as zeros.

3.10 peak full-width-half-maximum (FWHM) calibration coefficients: The full-width-half-maximum (also called shape) *(F)* versus channel number *(Ch)* coefficients as

$$F = P + Q \cdot Ch^I + R \cdot Ch^{2I} + W \cdot Ch^{3I}$$

with the coefficients, *P, Q, R,* and *W* stored as four successive 14-character numbers including the decimal point, and *I* as a four-character number including the decimal point. Leading spaces are interpreted as zeros. Any values not used or calculated should be set to all spaces. The *P* term is usually called the offset or zero intercept. The *I* is the lowest exponent of the channel number. In most cases *I* will be 0.5 for a quadratic dependance of the FWHM with channel and *I* will be 1.0 for linear dependance of the FWHM with channel. The *Q* term is the multiplier for the lowest power dependance of the FWHM-channel curve. The *R* term is the multiplier of the second exponent term of the FWHM-channel curve. The *W* term is the multiplier of the third exponent term of the FWHM-channel curve.

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3.11 real time: The real time, in seconds and fraction thereof, of acquisition of the spectrum. It is expressed as 14 characters including decimal point with leading zeros interpreted as zeros.

3.12 sample description –1, –2, –3, –4: Four 64-character records containing a sample description. These records will provide information on the source of the sample being analyzed. If not used they should be set to spaces.

3.13 sample time: The time of the physical collection of the sample material, as

DD/MM/YR_HH:NN:SS_

where the '_' (underscore character) is an ASCII space; DD is the day; MM is the month; YR is the year; HH is the hours; NN is the minutes; and SS is the seconds.

3.14 segment number: A four-character number identifying the subsection of the ADC used for the data. Leading spaces are interpreted as leading zeros. This will be used in a system where the ADC is shared by several data inputs and is multiplexed among the inputs. Each input could be a separate detector, and there is not necessarily any correlation between any two detector inputs.

The subsystem identification, ADC number, and segment number should provide sufficient data to be able to trace this data to the apparatus that collected it. This will enable other data, such as calibration spectra or background spectra, which are stored separately, to be identified with this spectrum. In large distributed systems, the ADC and segment numbers are not enough to uniquely identify the data.

3.15 spare: This record is unused at this time. It is reserved for expansion of the standard.

3.16 spectral data: The channel data are stored with the channel number at the beginning of each record. The channel number is six characters. The first channel is channel 0. The channel data is 10 characters per number, separated by a space. There are 5 channels per line giving a total line length of 61 characters, including the end-of-record character. Leading spaces are interpreted as zeros.

3.17 subsystem identification: An eight-character label further describing the system. Leading spaces are not interpreted as leading zeros. This is used with the system identification to uniquely describe the data.

3.18 system identification: An eight-character label describing the system. Leading spaces are not interpreted as leading zeros. This is intended to be used to identify the laboratory or experimental apparatus where the data were collected. This, along with the subsystem identification, can be used to uniquely describe the source of the data.

3.19 user defined: These 12 records can be used to contain any text data that needs to go with the spectrum.

4. General

The data file shall consist of a variable number of 70-byte records. Each record shall start with a four-byte prefix with the value of A004, indicating that the records are in ASCII with four bytes in the prefix. The prefix shall be followed by 64 bytes of data. All records shall end with two bytes containing a carriage return and line feed characters. All unused bytes in a record shall be filled with ASCII spaces. File records shall be as shown in Table 1. The terms used in Table 1 are defined in clause 3.

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Table 1—File Records

Record no.	Record contents*
1	System identification, subsystem identification, analog to digital converter number, segment number, digital offset
2	Live time, real time, number of channels
3	Acquisition start time, sample collection time
4	Energy calibration coefficients
5	Peak full-width-half-maximum (FWHM) calibration coefficients
6	Sample description –1
7	Sample description –2
8	Sample description –3
9	Sample description –4
10	Spare
11–22	Energy and channel pairs
23–34	Energy and resolution pairs
35–46	Energy and efficiency pairs
47–58	User defined
59–End Spectral Data	

*See clause 3, Definitions

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```
01 A004SYS 011  R&D LAB   1   1     0
02 A004 .30000000E+04 .31110000E+04  8192
03 A00401/10/87 12:55:00 00/ 0/00 00:00:00
04 A004-.91891420E+01 .25253880E+00 .21011320E-07 .00000000E+00
05 A004 .51970650E+01 .64495420E-03 .51749480E-08 .00000000E+001.00
06 A004Calibration spectrum for IEC standard -1
07 A004                                      -2
08 A004                                      -3
09 A004                                      -4
10 A004SPARE
11 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
12 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
   records omitted
21 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
22 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
23 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
24 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
   records omitted
32 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
33 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
34 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
35 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
   records omitted
45 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
46 A004   .00000000E+00   .00000000E+00   .00000000E+00   .00000000E+00
47 A004USER RECORDS
48 A004USER RECORDS
   records omitted
57 A004USER RECORDS
58 A004USER RECORDS
59 A004     0         0         0         0         0         0
60 A004     5         0         0         0         0         0
61 A004    10         0         0         0         0         0
62 A004    15         0         0         0         0         0
63 A004    20        12       104       201       296       417
64 A004    25       474       432       391       437       371
65 A004    30       368       355       329       312       300
66 A004    35       301       314       252       291       270
67 A004    40       271       269       246       226       225
68 A004    45       227       266       243       229       244
69 A004    50       238       207       244       251       248
70 A004    55       272       300       292       297       283
   remaining records omitted
```

Figure 1—Example file

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Annexes

(These annexes are not a part of IEEE Std 1214-1992, IEEE Standard Multichannel Analyzer (MCA) Histogram Data Interchange Format for Nuclear Spectroscopy, but are included for information only.)

Annex A
Example FORTRAN program segment to read data

(informative)

This is not a complete program and the exact syntax may be different depending on the compiler used.

```
      CHARACTER*8 ID1,ID2,ACQDAT,ACQTIM,SAMDAT,SAMTIM
      CHARACTER*64 SAMDES(4),SPARE,USER(12)
      INTEGER*2 MCANUM,SEGNUM,DIGOFF,NUMCHN
      REAL*4 LIVETM,REALTM,ENGCAL(4),FWHCAL(4),FWHEXP,EFFENG(24)
      REAL*4 EFFVAL(24),SPCTMP(5),SPECTR(8192),ENGCHN(24)
      REAL*4 ENGVAL(24),FWHENG(24),FWHVAL(24)
C open the spectrum file
      OPEN(UNIT=4,NAME=' ',ACCESS='SEQUENTIAL',FORM='FORMATTED')
C read the identification labels and the mca and segment numbers
      READ(4,100) ID1,ID2,MCANUM,SEGNUM,DIGOFF
100   FORMAT(4X,2A8,2I4,I6)
C read the livetime, realtime and the length of the spectrum
      READ(4,110) LIVETM,REALTM,NUMCHN
110   FORMAT(4X,2E14.8,I6)
C read the spectrum acquisition date and time and the sample
date/time
      READ(4,120) ACQDAT,ACQTIM,SAMDAT,SAMTIM
120   FORMAT(4X,4(A8,1X))
C read the energy calibration factors
      READ(4,130) ENGCAL
130   FORMAT(4X,4E14.8)
C read the FWHM calibration factors
      READ(4,140) FWHCAL,FWHEXP
140   FORMAT(4X,4E14.8,F4.2)
C read the sample description -1
      READ(4,150) SAMDES(1)
150   FORMAT(4X,A64)
C read the sample description -2
      READ(4,150) SAMDES(2)
C read the sample description -3
      READ(4,150) SAMDES(3)
C read the sample description -4
      READ(4,150) SAMDES(4)
C skip the spare record
      READ(4,150) SPARE
      DO 200 I=1,24,2
C read the energy/channel pairs
C   two pairs per record
        READ(4,160) ENGCHN(I),ENGVAL(I),ENGCHN(I+1),ENGVAL(I+1)
160     FORMAT(4X,4E16.8)
```

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```
200   CONTINUE
      DO 201 I=1,24,2
C read the energy/FWHM pairs
C 23-34.Energy and resolution pairs; two pairs per record
        READ(4,160) FWHENG(I),FWHVAL(I),FWHENG(I+1),FWHVAL(I+1)
201   CONTINUE
      DO 202 I=1,24,2
C read the efficiency calibration energy/efficiency pairs
C 35-46.Energy and efficiency; two pairs per record
        READ(4,160) EFFENG(I),EFFVAL(I),EFFENG(I+1),EFFVAL(I+1)
202   CONTINUE
      DO 220 I=1,12
C read the user records
        READ(4,210) USER(I)
210     FORMAT(4X,A64)
220   CONTINUE
DO 300 I=1,NUMCHN,5
C read the spectrum data into a temporary buffer
        READ(4,270) K,(SPCTMP(J),J=1,5)
270     FORMAT(4X,I6,5I10)
C check to see if the records are in the right order
      IF(K.NE.(I-1)) THEN
C and tell if they are not in the right order
      WRITE(0,280) I-1,K
280     FORMAT(' Channel number not in sequence at ',I5,' S/B
',I5)
      ENDIF
C put the spectrum data in the final array according to the
channel
C number on the record.
      DO 290 J=1,5
      SPECTR(K+J)=SPCTMP(J)
290   CONTINUE
300   CONTINUE
C the rest of your program to use the data is here
```

Annex B
Example BASIC program to read data

(informative)

```
10 DIM USER$(12)
20 DIM SPECTR(8192)
30 DIM EFFENG(24)
40 DIM ENGCHN(24)
50 DIM FWHENG(24)
60 DIM EFFVAL(24)
70 DIM ENGVAL(24)
80 DIM FWHVAL(24)
90 OPEN "test.iec" FOR INPUT AS #1
100 REM read the first record
```


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```
110 INPUT #1,A$
120 SYSNAM$=MID$(A$,5,16)
130 MCA=VAL(MID$(A$,21,4))
140 SEG=VAL(MID$(A$,25,4))
150 DIGOFF=VAL(MID$(A$,29,6))
160 REM read the second record
170 INPUT #1,A$
180 LVETIM=VAL(MID$(A$,5,14))
190 RELTIM=VAL(MID$(A$,19,14))
200 NUMCHN=VAL(MID$(A$,33,6))
210 REM read the acquisition time and the sample time
220 INPUT #1,A$
230 DATTIM$=MID$(A$,5,18)
240 SAMTIM$=MID$(A$,23,18)
250 REM read the energy calibration coefficients
260 INPUT #1,A$
270 ENGA=VAL(MID$(A$,5,14))
280 ENGB=VAL(MID$(A$,19,14))
290 ENGC=VAL(MID$(A$,33,14))
300 ENGD=VAL(MID$(A$,47,14))
310 INPUT #1,A$
320 REM read the shape calibration coefficients
330 FWHMA=VAL(MID$(A$,5,14))
340 FWHMQ=VAL(MID$(A$,19,14))
350 FWHMR=VAL(MID$(A$,33,14))
360 FWHMW=VAL(MID$(A$,47,14))
370 FWHMI=VAL(MID$(A$,61,4))
380 REM read the sample description
390 INPUT #1,SAM1$
400 INPUT #1,SAM2$
410 INPUT #1,SAM3$
420 INPUT #1,SAM4$
430 INPUT #1,A$
440 I=1
450 REM read the energy channel pairs
460 INPUT #1,A$
470 ENGCHN(I)=VAL(MID$(A$,5,14))
480 ENGVAL(I)=VAL(MID$(A$,21,14))
490 ENGCHN(I+1)=VAL(MID$(A$,36,14))
500 ENGVAL(I+1)=VAL(MID$(A$,52,14))
510 I=I+2
520 IF I < 25 THEN GOTO 460
530 REM read the energy FWHM pairs
540 INPUT #1,A$
550 FWHENG(I)=VAL(MID$(A$,5,14))
560 FWHVAL(I)=VAL(MID$(A$,21,14))
570 FWHENG(I+1)=VAL(MID$(A$,36,14))
580 FWHVAL(I+1)=VAL(MID$(A$,52,14))
590 I=I+2
600 IF I < 25 THEN GOTO 540
610 REM read the efficieny pairs
620 INPUT #1,A$
630 EFFENG(I)=VAL(MID$(A$,5,14))
640 EFFVAL(I)=VAL(MID$(A$,21,14))
```

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```
650 EFFENG(I+1)=VAL(MID$(A$,36,14))
660 EFFVAL(I+1)=VAL(MID$(A$,52,14))
670 I=I+2
680 IF I < 25 THEN GOTO 620
690 REM read the user records
700 FOR I=1 TO 12
710 INPUT #1,USER$(I)
720 NEXT I
730 I=0
740 REM read the spectrum
750 INPUT #1,A$
760 K=VAL(MID$(A$,5,6))
770 SPECTR(I+1)=VAL(MID$(A$,11,10))
780 SPECTR(I+2)=VAL(MID$(A$,21,10))
790 SPECTR(I+3)=VAL(MID$(A$,31,10))
800 SPECTR(I+4)=VAL(MID$(A$,41,10))
810 SPECTR(I+5)=VAL(MID$(A$,51,10))
820 I=I+5
830 IF I < 8192 THEN GOTO 750
840 REM
850 REM Put the rest of the spectrum here
860 REM
```

Annex C
Example C program to read data

(informative)

```
#include <stdio.h>
main(argc, argv)
int argc;
char *argv[];
{
   static char system_id[9], subsystem_id[9];
   static char acq_date[9], acq_time[9], samp_date[9],
samp_time[9];
   static char samp_desc1[65], samp_desc2[65], spare[65],
user[12][65];
   static char spc_buffer[71];
   static int i, j, spc_chan, adc_number, segment_number,
number_of_chans;
   static long digital_offset;
   static float livetime, realtime, energy_cal[4], fwhm_cal[4],
fwhm_exp;
   static float spc_tmp[5], spectrum[8192];
   struct {
      float energy;
      float efficiency;
   } eff[24];
   FILE *spc_fp;
```

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```
/* Open the Interchange Format spectrum for input */
   spc_fp = fopen("test.iec","r");

/* Read IDs, ADC number, segment number and digital offset */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%8c%8c%4d%4d%6ld",
      system_id,subsystem_id,&adc_number,&segment_number,
&digital_offset);
   system_id[9] = NULL;
   subsystem_id[9] = NULL;

/* Read live time, real time and number of channels */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%14f%14f%6d",&livetime,&realtime,
&number_of_chans);

/* Read acquisition and sample collection dates and times */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%8c %8c %8c %8c ",
      acq_date,acq_time,samp_date,samp_time);
   acq_date[9] = NULL;
   acq_time[9] = NULL;
   samp_date[9] = NULL;
   samp_time[9] = NULL;

/* Read energy calibration coefficients */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%14f%14f%14f%14f",

&energy_cal[0],&energy_cal[1],&energy_cal[2],&energy_cal[3]);

/* Read peak FWHM calibration coefficients */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%14f%14f%14f%14f%4f",

&fwhm_cal[0],&fwhm_cal[1],&fwhm_cal[2],&fwhm_cal[3],&fwhm_exp);

/* Read two records of 64 character sample description */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%64c",samp_desc1);
   samp_desc1[65] = NULL;

   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%64c",samp_desc2);
   samp_desc2[65] = NULL;

/* Read the first spare record */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%64c",spare);
   spare[65] = NULL;

/* Read the second spare record */
   fgets(spc_buffer,71,spc_fp);
   sscanf(spc_buffer,"A004%64c",spare);
```

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```
   spare[65] = NULL;

/* Read the 12 energy & efficiency pairs records (24 pairs) */
   for(i=0; i<24; i+=2) {
      fgets(spc_buffer,71,spc_fp);
      sscanf(spc_buffer,"A004%16f%16f%16f%16f",&eff[i].energy,
&eff[i].efficiency,&eff[i+1].energy,&eff[i+1].efficiency);
   }

/* Read the user defined records */
   for(i=0; i<12; i++) {
      fgets(spc_buffer,71,spc_fp);
      sscanf(spc_buffer,"A004%64c",&user[i][0]);
      user[i][65] = NULL;
   }

/* Read the spectral data. Report if any records are out of
order*/
/* but always put the data in the proper location in the array */
   for(i=0; i<number_of_chans; i+=5) {
      fgets(spc_buffer,71,spc_fp);
      sscanf(spc_buffer,"A004%6d %10f %10f %10f %10f
%10f",&spc_chan,
&spc_tmp[0],&spc_tmp[1],&spc_tmp[2],&spc_tmp[3],&spc_tmp[4]);
      if(i != spc_chan) {
printf("Channel number not in sequence at %d S/B %d\n",
   i,spc_chan);
      }
      for(j=0; j<5; j++){
spectrum[spc_chan+j] = spc_tmp[j];
      }
   }

/* Close the interchange format spectrum file */
   fclose(spc_fp);

/*********************************************************/
/*                                                       */
/* Place the rest of your program to use the data here */
/*                                                       */
/*********************************************************/

}
```


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