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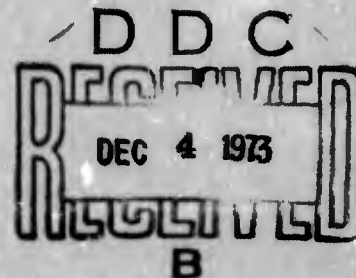
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RADC-TR-73-247, Vol I  
Final Report  
August 1973



TIME DOMAIN ANALYSIS

Pattern Analysis & Recognition Corporation



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GAFB, NY 13441.

Rome Air Development Center  
Air Force Systems Command  
Griffiss Air Force Base, New York

TIME DOMAIN ANALYSIS, VOL. 1

AD 915096

**TIME DOMAIN ANALYSIS**

**Michael S. Crone  
Dr. Donald H. Foley**

**Pattern Analysis & Recognition Corporation**

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FOREWORD

This final report was prepared by Pattern Analysis and Recognition (PAR) Corporation, 128 East Dominick Street, Rome, New York, under Contract F30602-73-C-0070, Job Order Number 692B02B1, for Rome Air Development Center, Griffiss Air Force Base, New York. The contractor's identification number for this two volume report is PAR Report Number 73-17. The work was accomplished during the period September 1972 to June 1973. Mr. John F. Dove (OCDE) was RADC Project Engineer for Volume I and Captain Roy F. Schering (DCIT) was RADC Project Engineer for Volume II.

This technical report has been reviewed and is approved.

APPROVED:

*John F. Dove*  
JOHN F. DOVE

Sensor Development Section  
Surveillance Equipment Development Branch

APPROVED:

*William T. Pope*  
WILLIAM T. POPE  
Assistant Chief  
Surveillance and  
Control Division

FOR THE COMMANDER:

*Carlo P. Crocetti*  
CARLO P. CROCETTI  
Chief, Plans Office

### ABSTRACT

Under Contracts F30602-72-C-0227 and F30602-73-C-0070, Pattern Analysis and Recognition (PAR) Corporation has designed and simulated a six-class classifier for identifying targets of tactical interest based on their acoustic signatures. The classes are: wheeled vehicles, tracked vehicles, propeller aircraft, rotary aircraft and jet-powered aircraft. Background is rejected to prevent false alarms. Design or training set recognition rates on data collected by RADC/OCDE under a wide variety of environmental conditions was 100%. Limited preliminary testing of the simulated classifier has also yielded 100% results.

Project No: 692B

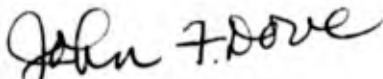
Effort Title: Time Domain Analysis

Contract No: F30602-73-C-0070

Contractor: Pattern Analysis &  
Recognition Corp.

#### EVALUATION

This report presents the results of an effort to meet certain aspects of the tactical surveillance requirements as delineated in TPO-7. Under this effort a six-class feature extractor/classifier has been designed and simulated for identifying targets of tactical interest based on acoustic signatures. The simulated classifier of this design has performed with a 100% correct classification rate on the targets for which it was designed. This classifier will be further tested against a variety of signatures from different transducers and geographical locations. If satisfactory performance is achieved then the classifier design will be bread-boarded and tested in-house.



JOHN F. DOVE

Sensor Development Section  
Surveillance Equipment Development Branch

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## INTRODUCTION

The feature extraction and classification logic is simulated on a PDP-9 computer at the RADC West Lee Test Annex. The input to the simulated classifier may be either (1) the output of an acoustic transducer (microphone) which is deployed on the test range, or (2) the output of analog tapes on which tactical data from world-wide test sites has been stored.

In designing the classifier, PAR used a two-staged approach. The first stage of the approach involved the use of PAR's sensor analysis facility for analyzing the data and selecting the features. The features chosen for the classifier were based upon both apriori physical knowledge and visual analysis of real data as opposed to abstract mathematical features based on a limited data set. For example, the U-21 propeller aircraft is a turbo-prop with a nominal propeller shaft speed of 2200 rpm. Visual analysis of the data indicates that the energy is concentrated at certain frequencies. Analysis has verified that these peaks in energy occur at the propeller-blade-passage frequency and its associated harmonics. One of the features designed for the classifier involves measuring the presence of harmonic series. Parameters involved can be set so that variations caused by Doppler shifts can be accommodated.

The second stage of this approach made use of many of the state-of-the-art statistical and/or mathematical routines available in RADC's On-Line Pattern Analysis and Recognition System (OLPARS) to design the logic for the classifier based on the features designed and extracted in stage one.

The understanding of the physical sources of the acoustic excitation coupled with a parameterized feature set is important for projecting the success of the classifier on new types of tactical vehicles and aircraft. Based on design specifications, one can attempt to predict the success of the present classifier. The parameterized feature set will permit fine tuning of the classifier if such changes are dictated by new data.

Further plans in the acoustic sensor development program involve the use of the simulation facility to thoroughly test the classifier on an even larger data base. In addition to the simulated acoustic classifier, display routines have been implemented on the PDP-9 computer so that the cause of any future errors may be analyzed, isolated and corrected.

The remainder of this report discusses the features, logic and software actually used in the acoustic classifier simulation at West Lee. The earlier report, RADC-TR-72-292, Vol. II, entitled "Acoustic Signature Analysis, discusses how the data was analyzed and the approach taken in the design of the classifier. Despite the fact that this earlier report is based on a limited data set collected in Panama (as opposed to the more extensive data base used in the West Lee simulation), the reader can obtain an appreciation for the detailed analysis which has taken place.

SECTION 1  
SYSTEM OVERVIEW

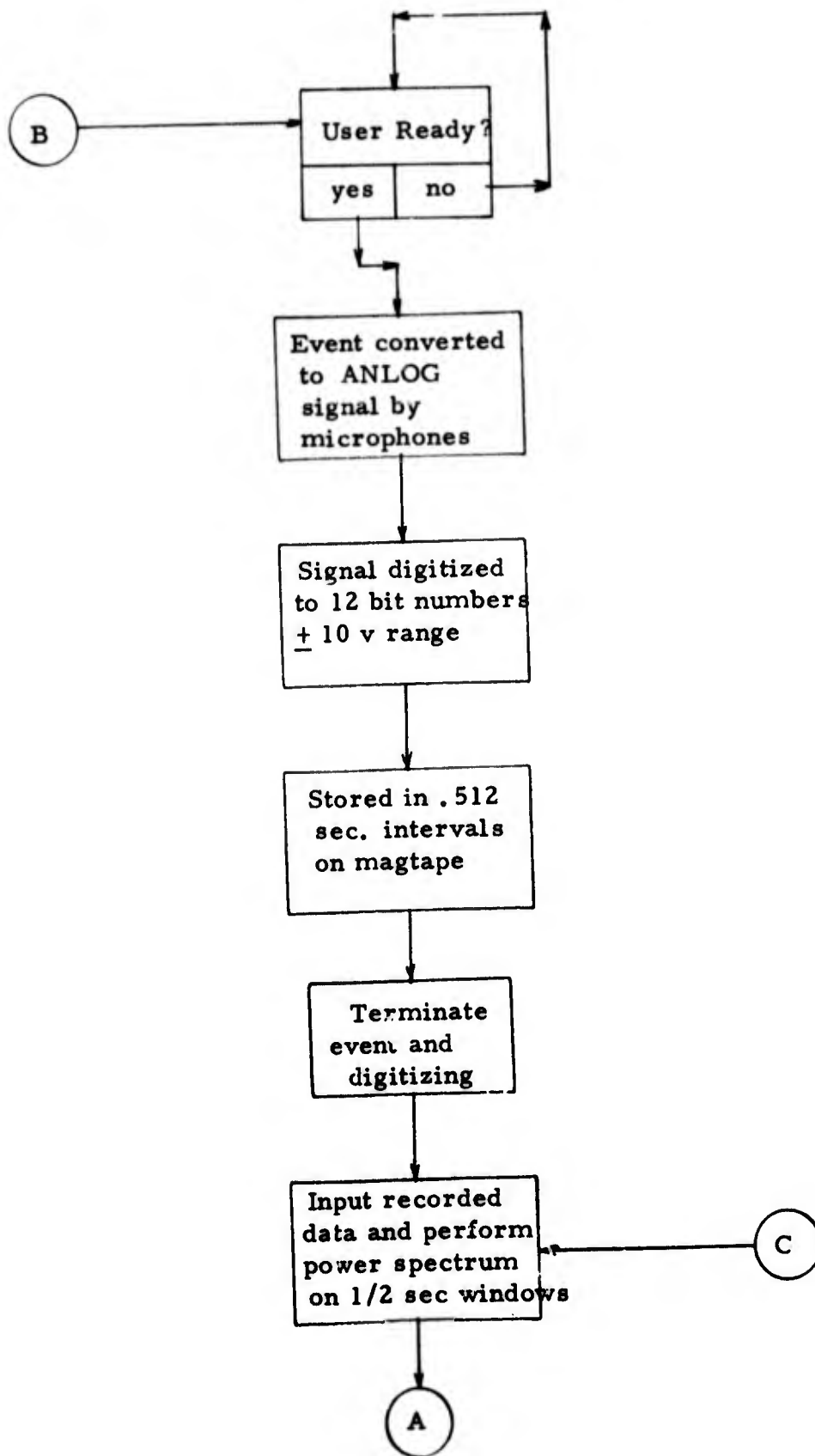
The solution to the problem of on-line classifier simulation can be divided into three main sections: (1) conversion of a real-time analog signal to a time sampled digital signal; (2) extraction of a feature set to define the signatures; and (3) logic evaluation to designate a class for output to a user. Reference Figure 1-1 for system organization.

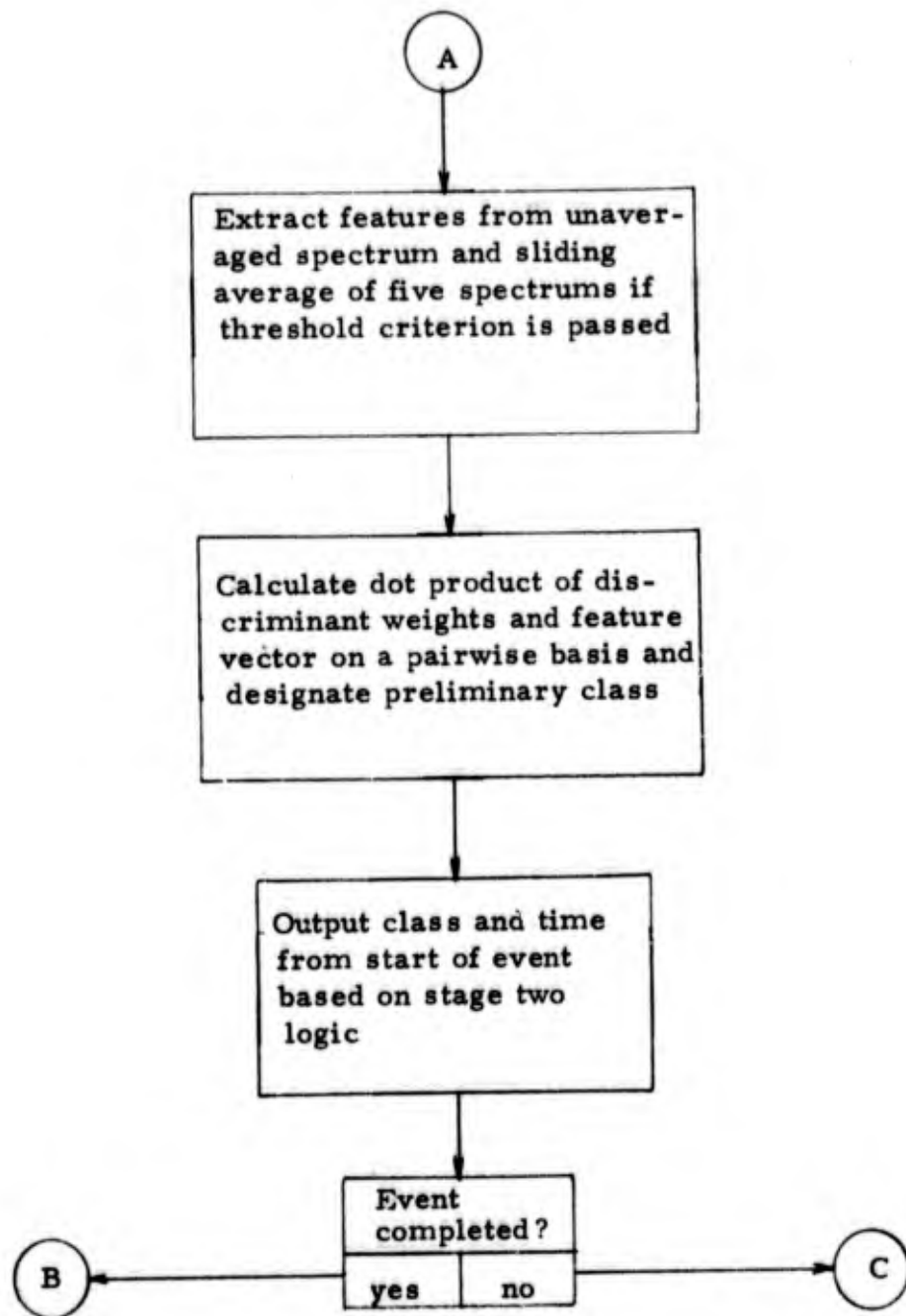
Since all feature extraction is performed in the frequency domain, the input data must be transformed. The method used was the fast Fourier transform, which requires approximately 1 sec for computation. Since the time window is .5 sec, the digitizing of an event must be completed before feature extraction can begin. With the use of a hardware FFT unit this could be accomplished in real-time.

When the user indicates the beginning of an event, digitizing and storing of data on mag tape begins. When the user indicates the end of an event the digitizing ceases, the mag tape is rewound and the event is essentially restarted with the input coming from the mag tape in digital form.

Each logical record on mag tape represents 1/2 second of digitized data from which a power spectrum is computed. The feature extraction is performed on each individual spectrum and upon an average of five spectrums, + 1 sec around the individual spectrum under consideration. Therefore, the first feature vector is not extracted for 2 1/2 seconds. Succeeding vectors are extracted every 1/2 sec as the sliding average of five spectrums is updated.

The feature vector is then tested by Stage One logic, which outputs a preliminary decision. This decision is then passed through Stage Two logic. State Two logic requires 3.5 seconds of decisions for a particular class before outputting a decision to a user. The first possible decision output to the user, therefore, occurs after 5.5 seconds. This decision is updated every 1/2 second until all digitized data has been texted.





## SECTION 2

### ACOUSTIC FEATURES

Each feature vector extracted consists of 42 features. The first seventeen features of the vector are obtained from an individual 1/2 second spectrum. The next seventeen features are identical to the first seventeen but are extracted from the average of five spectrums. This average represents  $\pm 1$  sec around the individual spectrum under consideration. The remaining eight features are extracted from the averaged spectrum only.

#### Features

1 & 18	10 x % energy between 0 - 20 Hz (i. e. , $0 \leq f < 20$ )
2 & 19	10 x % energy between 20 - 40 Hz
3 & 20	10 x % energy between 40 - 120 Hz
4 & 21	10 x % energy between 120 - 1000 Hz
5 & 22	Frequency of the maximum peak

Before discussing the next feature, the peak detection routine will be described. A series of peaks is defined as follows:

- a. Find the maximum peak
- b. Slide down each side until either:
  - 1) spectrum is zero, or
  - 2) spectrum jumps up at least 2% of the previous point.
- c. Eliminate these points from further consideration for the next peak; the energy associated with a peak is defined to be the energy of these "eliminated" points.
- d. If zero magnitude was reached, eliminate points from consideration which are less than or equal to the minimum allowable frequency between peaks.

The peak detection routine is a function of two parameters: (a) the number of peaks desired; and (b) the minimum allowable separation between peaks.

## Features

6 & 23 Average of the four largest peaks (6 Hz minimum separation between peaks)

7 & 24 Consider the four largest peaks. Let  $f_i$  be the frequency of the  $i^{\text{th}}$  largest peak (6 Hz separation). Then measure the deviation in frequency of these peaks from the frequency of the largest peak, i. e. ,

$$\sum_{i=2}^4 (f_i - f_1)$$

8 & 25 Next, measure the number of peaks above the maximum minus the number below, i. e. ,

$$\sum_{i=2}^4 \mathcal{U}(f_i - f_1) - \sum_{i=2}^4 \mathcal{U}(f_1 - f_i)$$

$$\text{where } \mathcal{U}(x) = \begin{cases} 0 & x < 0 \\ 1 & x \geq 0 \end{cases}$$

Note that this is a discrete variable with possible values of only -3, -1, 1, or 3.

9 & 26 Number of peaks from 120 - 600 Hz above 5% of the overall maximum (6 Hz minimum separation between peaks).

10 & 27 Number of peaks from 0 - 60 Hz above 5% of the overall maximum (6 Hz minimum separation).

11 & 28 Number of peaks from 20 - 60 Hz above 75% of overall maximum (6 Hz minimum separation)

12 & 29 Number of peaks from 60 - 90 Hz above 20% of overall maximum (6 Hz minimum separation)

For features 13 - 15, find the largest peak between 55 - 120 Hz.

13 & 30  $10 \times$  (energy below this peak) divided by (the sum of the energy above and below this peak).

- 14 & 31      10 x (energy above the peak) divided by (the sum of the energy above and below this peak).
- 15 & 32      10 x % energy associated with this peak
- 16 & 33      10 x % energy associated with the major peak between 20 - 40 Hz.
- 17 & 34      10 x % energy in the first 6 peaks. (Min. separation = 6 Hz.)

The harmonic content algorithm considers all positive differences in the frequencies of the first  $N_p$  peaks at least  $\Delta_{\min}$  Hz wide, but less than  $\Delta_{\max}$  Hz wide. Consider only those peaks above  $f_{\min}$  Hz. Minimum separation between peaks is given by  $f_{\text{sep}}$ . The allowable tolerance in comparing deltas is  $\pm$  TOL. A set of at least  $N_{\Delta}$  similar differences is called a series. In any one series, no difference can have its lower frequency between another difference, e.g., peaks at 100 - 200 and 106 - 206 do not constitute a legitimate series even though both the differences are 100 (refer to Figure 2-1). It is possible to demand that  $N_c$  deltas be consecutive, i.e., the higher frequency of one delta is the lower frequency of the next delta. We can ask that no peaks lie between the lower and upper frequencies of any delta in either the consecutive series or with the minimum number of deltas (i.e.,  $N_{\Delta}$ ). Finally, it is possible to restrict any peak in one series from being the first peak of another series.

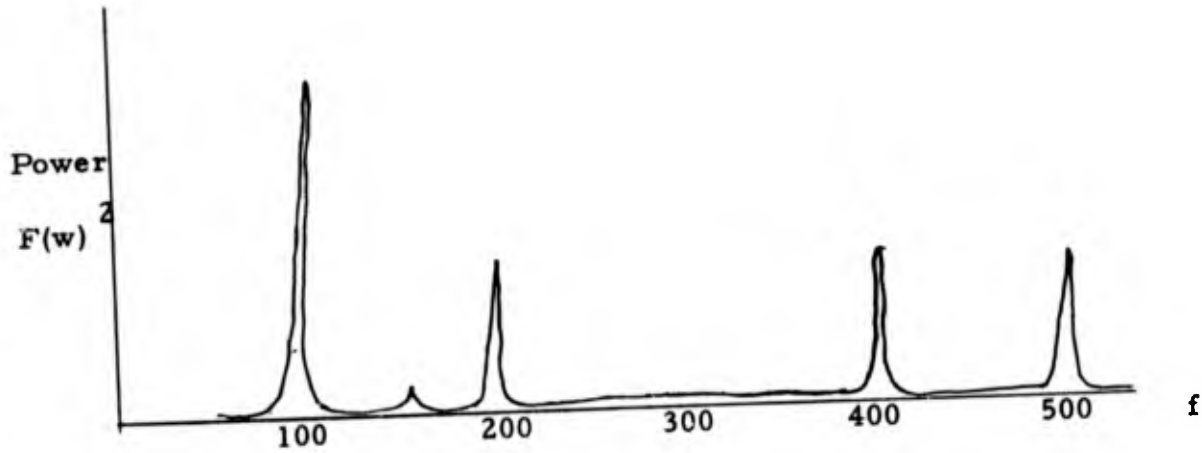
If there is more than one series, the series with the greatest number of deltas is used. If two series have the same number of deltas, then the series with the fewest number of frequencies is used.

Features 35 and 36 measure the delta and number of deltas found in the best series with the following parameters:

- $N_p$       =      number of peaks = 8
- $N_c$       =      number of consecutive deltas = 2
- $N_{\Delta}$       =      number of deltas = 2



Figure 2-1  
HARMONIC CONTENT EXAMPLE



Peaks at:

$f_1$	=	100
$f_2$	=	161 (extraneous peak due to noise)
$f_3$	=	200
$f_4$	=	403
$f_5$	=	504

Harmonic Content Extracted

$$\Delta = 100 \pm \text{tolerance}$$

Two  $\Delta$ 's are involved, i. e., 100 - 200 and 403 - 504

$f_{\min}$	=	minimum frequency of any peak considered = 60 Hz
$f_{\text{sep}}$	=	minimum frequency separation of peaks = 2 Hz
TOL	=	tolerance in matching deltas = 2 Hz
$\Delta_{\min}$	=	minimum delta = 60 Hz.
$\Delta_{\max}$	=	maximum delta = 180 Hz.

Peaks may be between the two frequencies associated with any delta and any peak in one series may be used again in another series. These features are primarily for a turboprop.

Features 37 and 38 measure the delta and number of deltas using the following parameters:

$N_p$	=	10
$N_c$	=	4
$N_{\Delta}$	=	6
$f_{\min}$	=	10
$f_{\text{sep}}$	=	2
TOL	=	2
$\Delta_{\min}$	=	8
$\Delta_{\max}$	=	16

No peaks may be between any of the deltas in the consecutive series, nor may any peaks be between at least six deltas. If a peak is associated with one series it may not be used as the first peak in another series.

In addition, a series is disallowed if the frequency of the maximum overall peak is greater than 100 Hz or if the minimum frequency associated with any delta is not less than or equal to 50. These two features are primarily for a helicopter.

Features 39 and 40 measure the delta and number of deltas using the following parameters:

$N_p$	=	10
$N_c$	=	2
$N_{\Delta}$	=	3
$f_{\min}$	=	40
$f_{\text{sep}}$	=	2
TOL	=	2
$\Delta_{\min}$	=	14
$\Delta_{\max}$	=	44

No peaks may be between the frequencies associated with any delta in the consecutive series. However, peaks may lie between the frequencies associated with any other delta used. A peak in one series may be used as the first peak of another series. These two features are primarily for a piston-driven propeller aircraft.

Feature 41 measures the percentage energy associated with the smallest 4 peaks out of the largest 6 peaks over 40 Hz. Minimum separation between peaks is 2 Hz.

Feature 42 counts the number of peaks out of the largest 10 peaks that are: (1) above 120 Hz; and (2) above 5% of the overall maximum. Minimum separation between peaks is 2 Hz.

### SECTION 3

#### CLASSIFICATION LOGIC

In many pattern recognition problems each individual feature vector is unrelated from the next. For example, in recognizing a string of handwritten numbers there is no reason to believe that the  $(i + 1)^{\text{th}}$  vector is related to the  $i^{\text{th}}$  vector. However, in this acoustic recognition problem each vector represents 1/2 second of data and each succeeding vector represents the next 1/2 second of data.

Consequently, a two-stage classification logic using this time-continuity constraint can be developed. In fact, this two stage logic permits the identification of multiple classes as long as each class is dominant at some point in time. A reject strategy allows for periods of confusion when the acoustic signature represents the transition between two events.

The first stage uses pairwise Fisher linear discriminant logic derived using the On-Line Pattern Analysis and Recognition System (OLPARS). Sammon<sup>(1)</sup> gives the mathematical description of the discriminant and the criteria it maximizes. For our purposes, we need only treat the Fisher linear discriminant as a set of weights for each input feature.

Figure 3-1 shows the logical operation of the first stage of the logic. A brief description follows:

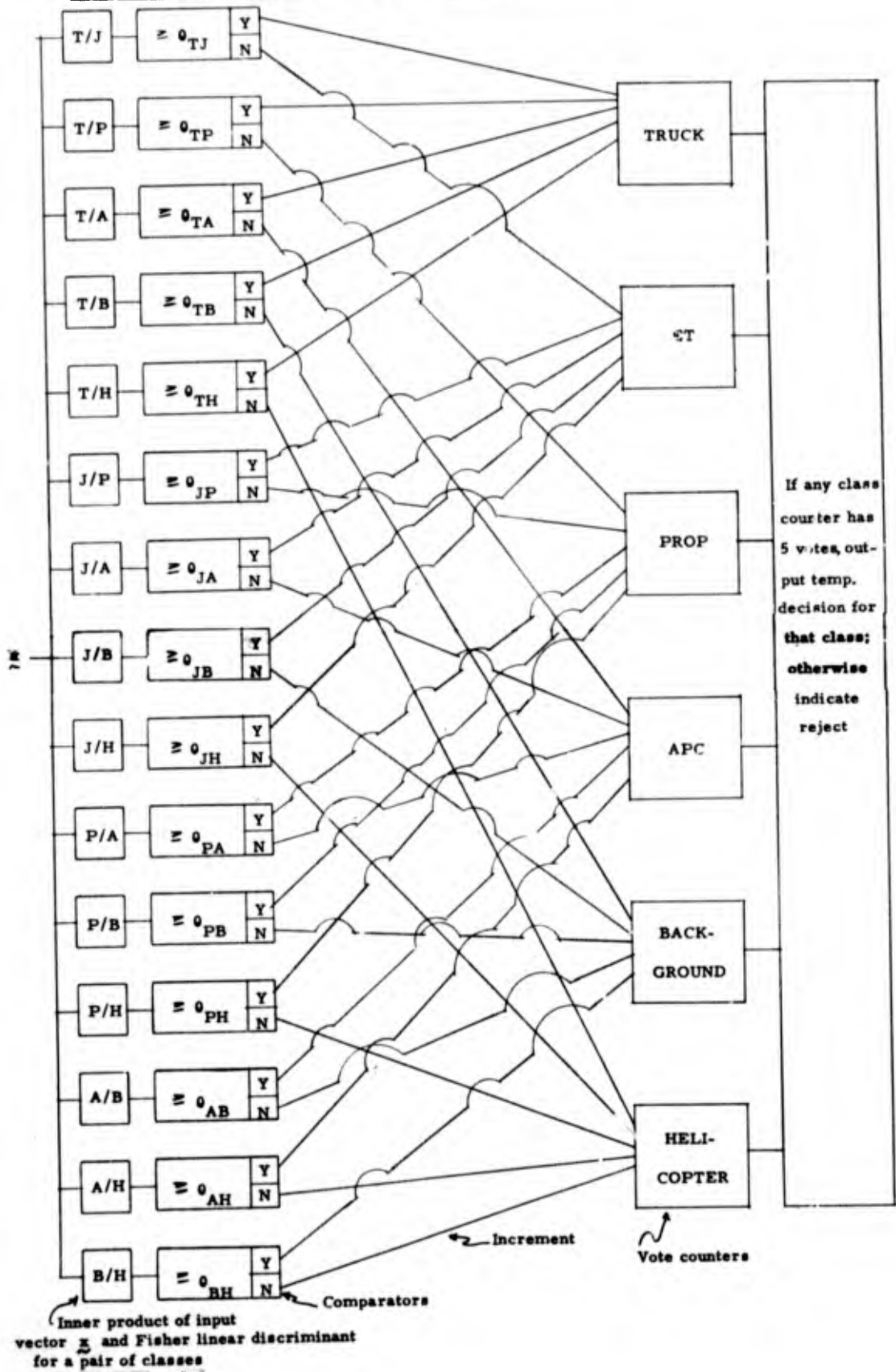
The inner product of an input feature vector,  $\underline{x}$ , is taken with the Fisher linear discriminant  $d_{TJ}$  for the pair of trucks and jets, and compared with the threshold  $\theta_{TJ}$  for the pair of trucks and jets, i. e.,

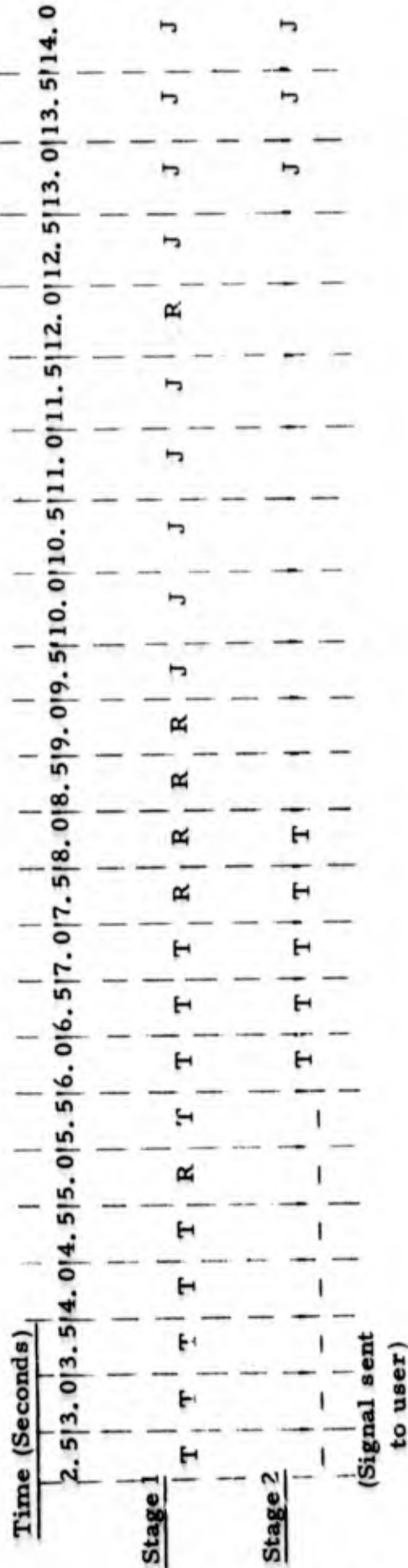
if  $\langle d_{TJ}, \underline{x} \rangle = \sum_{i=1}^{45} x_i d_{TJ_i} > \theta_{TJ}$  increment counter for the class of trucks

if  $\langle d_{TJ}, \underline{x} \rangle = \sum_{i=1}^{45} x_i d_{TJ_i} < \theta_{TJ}$  increment counter for the class of jets

if  $\langle d_{TJ}, \underline{x} \rangle = \sum_{i=1}^{45} x_i d_{TJ_i} \approx \theta_{TJ}$  assign to the class counter with the larger number of samples in the design set.

Figure 3-1: Stage I Logic: Pairwise Fisher Linear Discriminant





T: Truck

J: Jet

R: Reject or no decision made for this particular  $\frac{1}{2}$  second of data

Figure 3-2: Example of the Logical Operation of The Stage II Sequential Logic

This same procedure is carried out for all possible pairs of classes as shown in Figure 3-1. If any class receives a total of five votes (this is the largest number of votes possible) then the input vector  $x$  is temporarily assigned to that class. If no class receives 5 votes, then that vector is temporarily called a reject.

The second stage of the classification logic is a sequential technique which capitalizes on the fact that each input vector represents features centered about the next 1/2 second of the acoustic signature. The OLPARS logic (stage one) outputs a string of temporary decisions as shown in Figure 3-2. We require that out of the last 10 temporary decisions, at least 7 represent the same class before a final decision is sent to the user.

It requires 2.5 seconds to generate the first vector and 1/2 second for each succeeding one. Since 7 temporary decisions are required before a final decision can be output to the user, an additional 3.5 secs are required. Consequently, it takes 5.5 seconds after the beginning of an event before the event is recognized. However, this decision can be updated with every 1/2 second spectrum.

The second stage of the classification logic has at least two advantages. First, the strategy eliminates periods of confusion when an event is transitioning into another. Secondly, it eliminates some incorrect disturbances due to the random nature of the received signal and noise.

## SECTION 4

### COMPUTER HARDWARE REQUIREMENTS

1. PDP-9 computer with dectape operating system DEC-15.
2. Core Size - 24K
3. Peripherals:
  - a. TTY
  - b. VPAO Storage Tube
  - c. AF01B A/D Converter
  - d. TC59 Magtape control and two magtape drives
  - e. 10 KHz real-time clock



## SECTION 5

### OPERATING INSTRUCTIONS

The simulation system, SIMUL, is stored on DEC tape in the upper Q area of the tape. The user must first bootstrap the system using the paper tape bootstrap program with the address switches set at 57737. The TTY will respond with a "\$". The user must mount magnetic tapes with write rings on units 0 and 1. The A/D converter must be set to 12 bits and the real-time clock to 10 KHz. The input signal must be passed through the filter bank with a gain of 13 db. The high pass setting must be 16 Hz. and the low pass setting 1000 Hz.

The DEC tape labeled SIMUL can be mounted on either deck. The user then types GET N, where N represents the deck number. When the tape halts, he types a control P and control is transferred to the simulation system. All accumulator switches must be down. He then must respond to a series of questions. In response to "THRESHOLD=", he types 23 in integer format. In response to "TESTING?", 1 - Y, 0 - N" he types "1" if testing and "0" if not. If he is testing he must type in the TCN and RUN numbers for use in the output FFT tape. The next instruction will tell him to lower AC0 and raise AC1 to begin digitizing. To end digitizing he is told to lower AC1 and raise AC0.

After completing the event, the digitized tape is rewound and classification begins. The decisions are output to the VPA0 and he may obtain a hardcopy if he wishes. If not, he presses the erase button on the VPA0 when the screen is full.

After the classification sequence is completed, tape 0 is rewound and program returns to ask user questions as above. If he is finished, he must type control C and the monitor will return with a "\$".

If the user were testing, the power spectrums of each run were output to mag tape 1 for future use.

SECTION 6

PROGRAM DOCUMENTATION

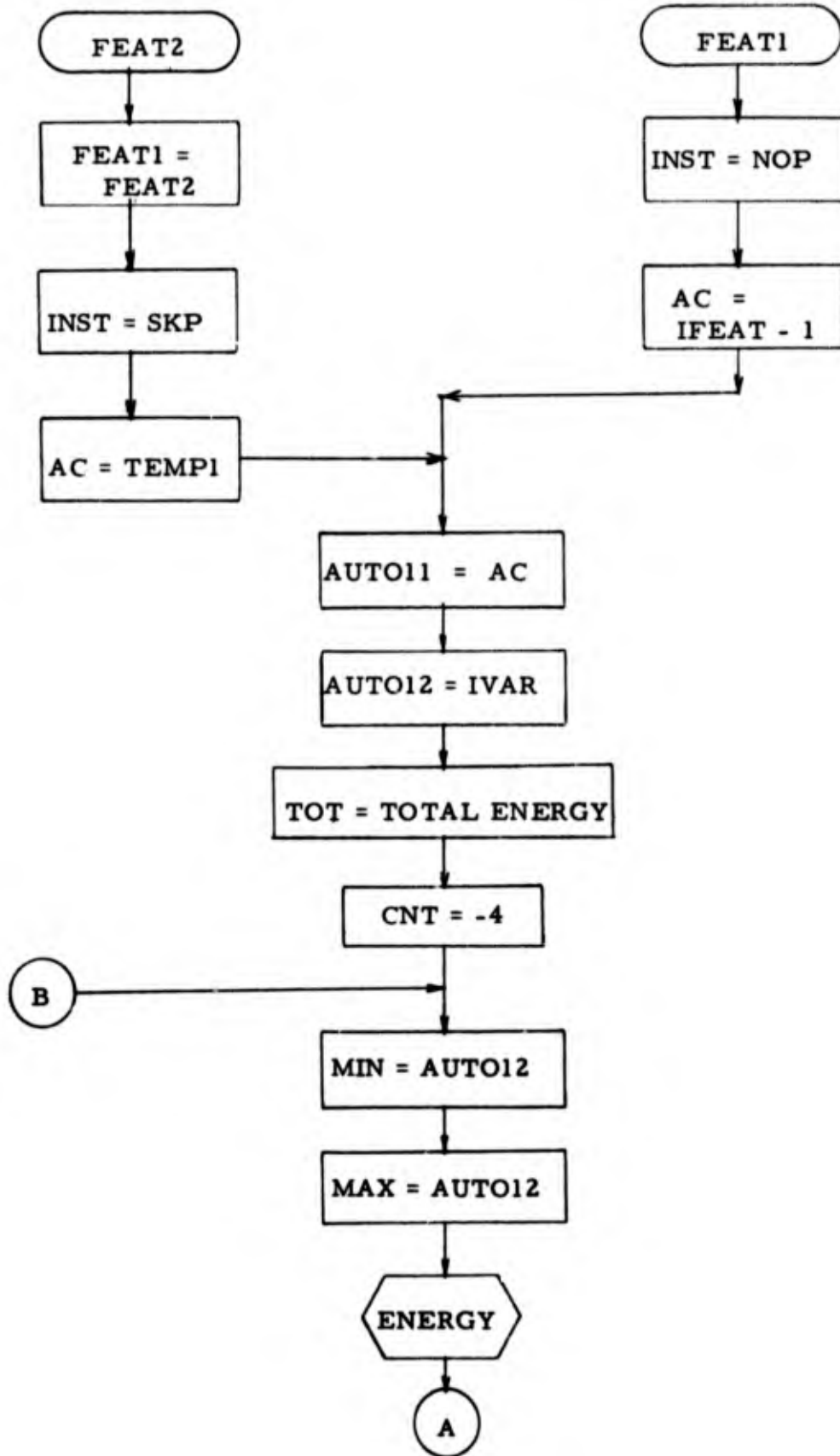
1. Program Name: FEATUR
2. Language: MACRO
3. Summary: Routine controls flow of feature extraction on both the unaveraged and averaged power spectrums.
4. Requirements: None
5. Routines Required: CPEAKS, FPEAKS, ENERGY, REVER, HARMON
6. Arrays: IMAG, IFEAT, JVAR, REVAR, REVARi, INRAY
7. GLOBLs: FEAT1, FEAT2, IMAG, IFEAT, CPEAKS, FPEAKS, JVAR, MIN, MAX, SEP, NPEAKS, LF, HF, ENERGY, PMAX, TEMP, SLIDE, CLEAN, REVER, HARMON, TOLER, FREQ, PCBET, MINDEL, MAXDEL, CONSEC, PBET, INDEP, MINDL, FIRST, NDELTS, FREQS, DELTAS, REVAR, REVARi, FAKEF, INRAY, PERI

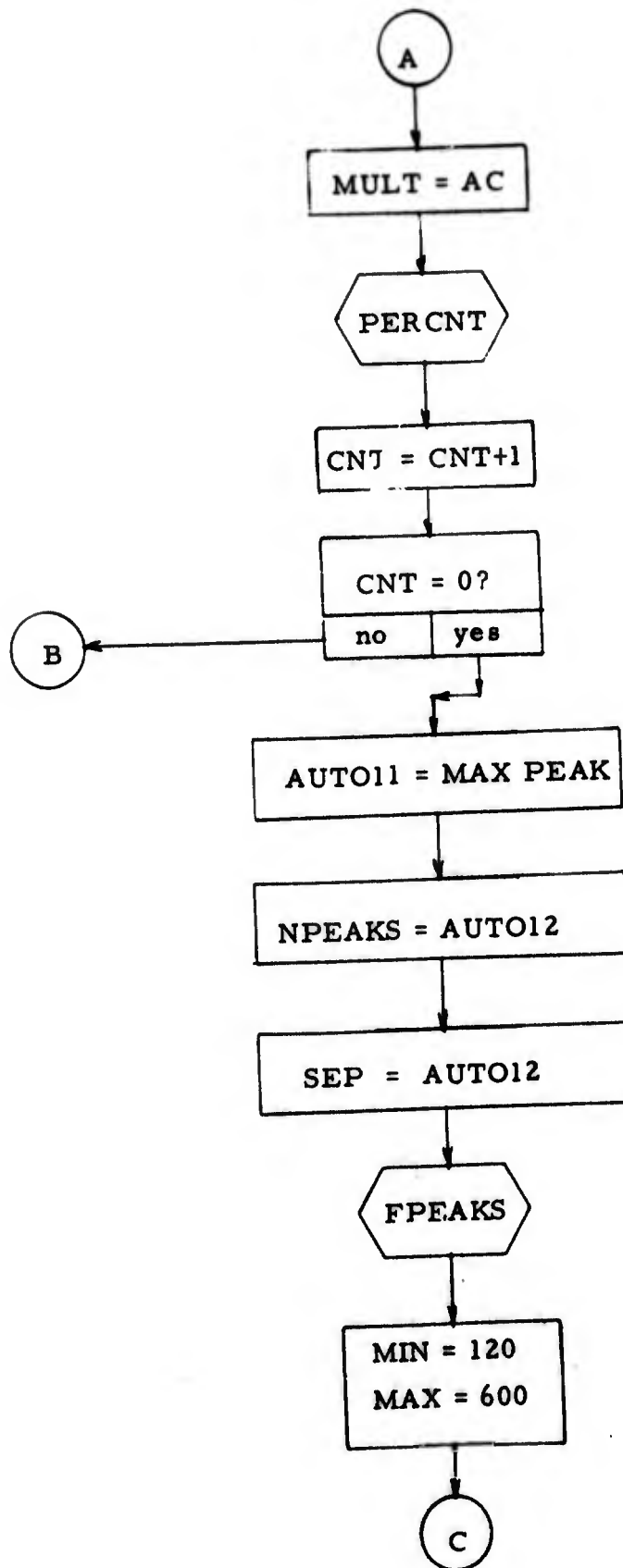
8. Description:

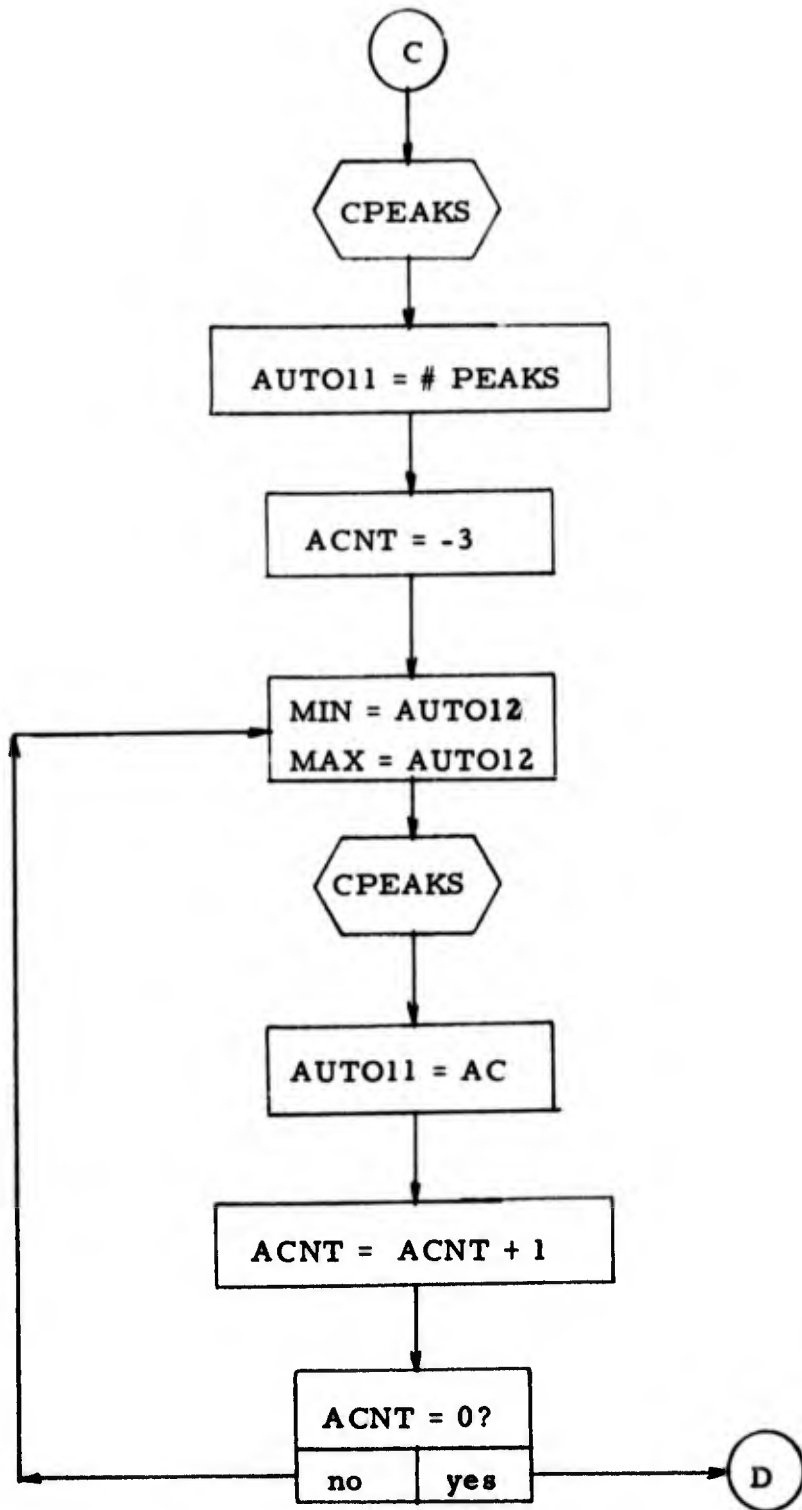
The feature vector consists of 42 features, 17 of which are extracted from both the unaveraged power spectrum and the averaged of five spectrums. The remaining eight features are extracted from the averaged spectrum. The entry point for the unaveraged extraction is called FEAT1. Upon entry at FEAT1, the feature vector and variable vector are initialized into auto-index registers 11 and 12 respectively. The appropriate feature routines are called to extract the first 17 features which are explained in detail in the feature extraction section.

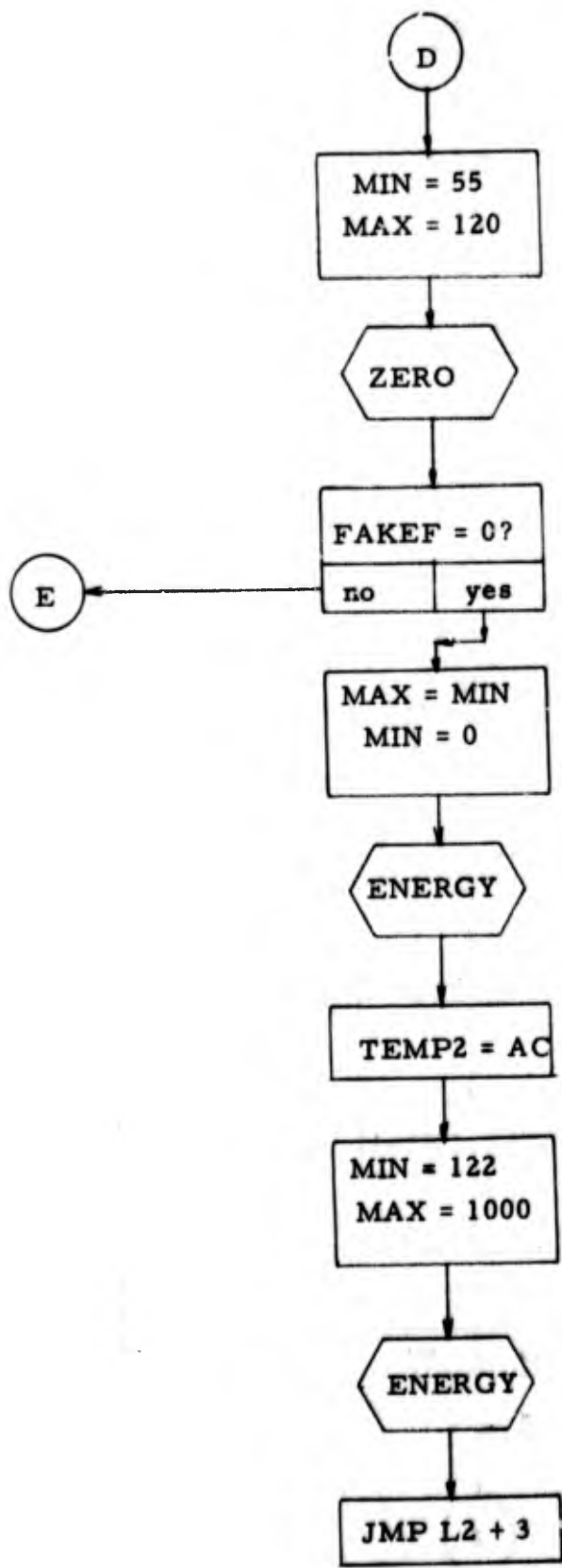
The average of five spectrums is performed and FEAT2 is called. The same 17 features are extracted and then the remaining 8 features are extracted from the averaged spectrum. The routine returns with the feature vector IFEAT completed.

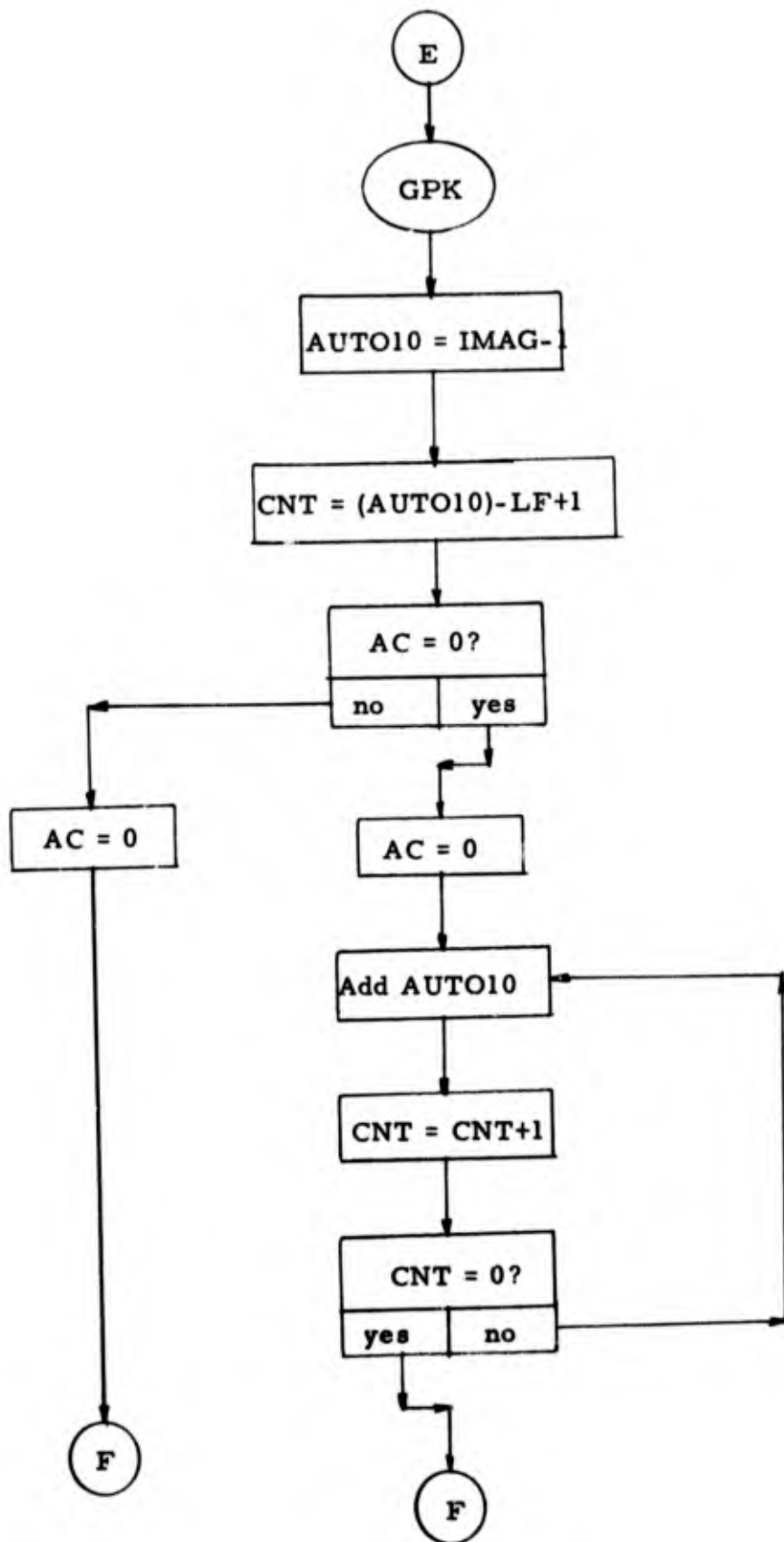
FEATUR



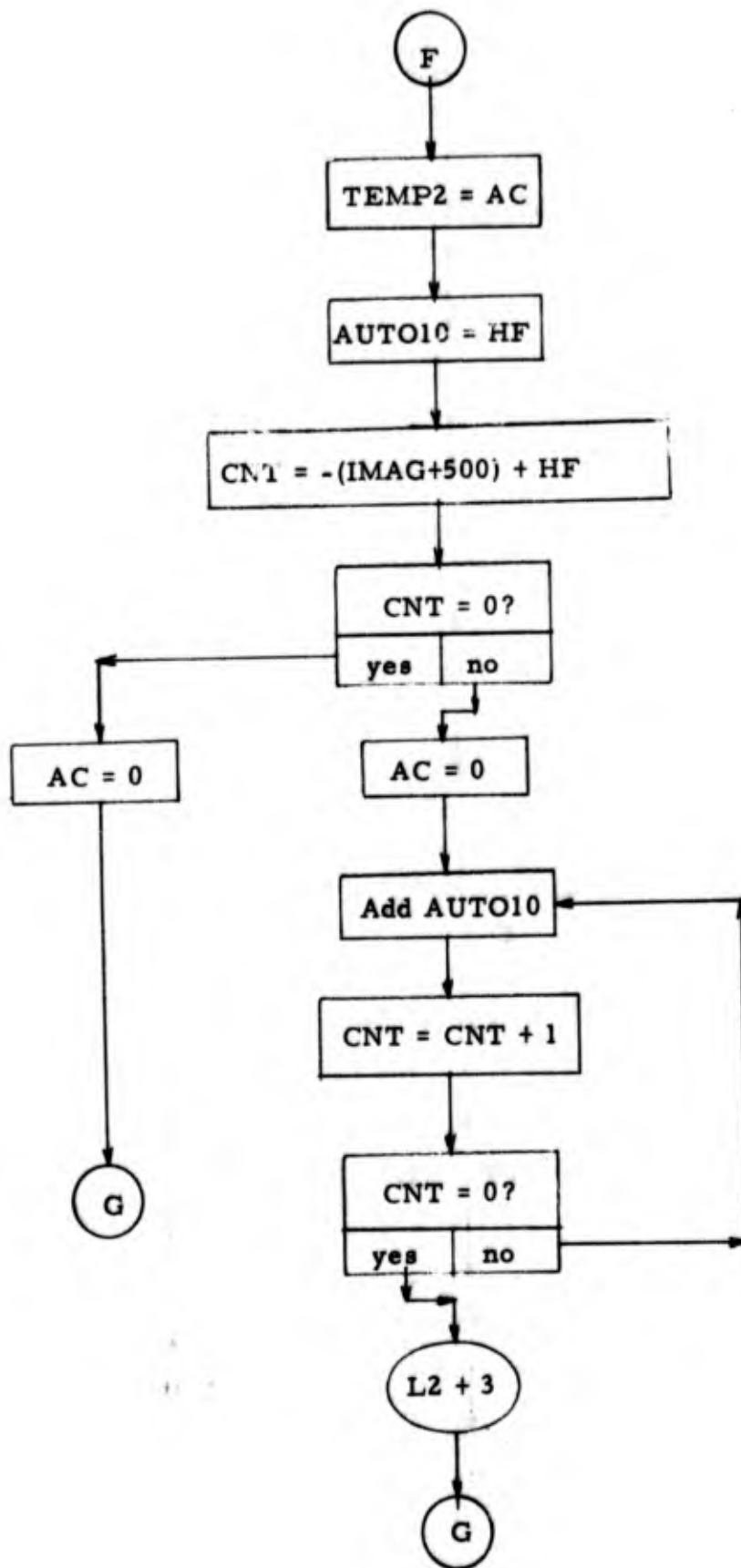


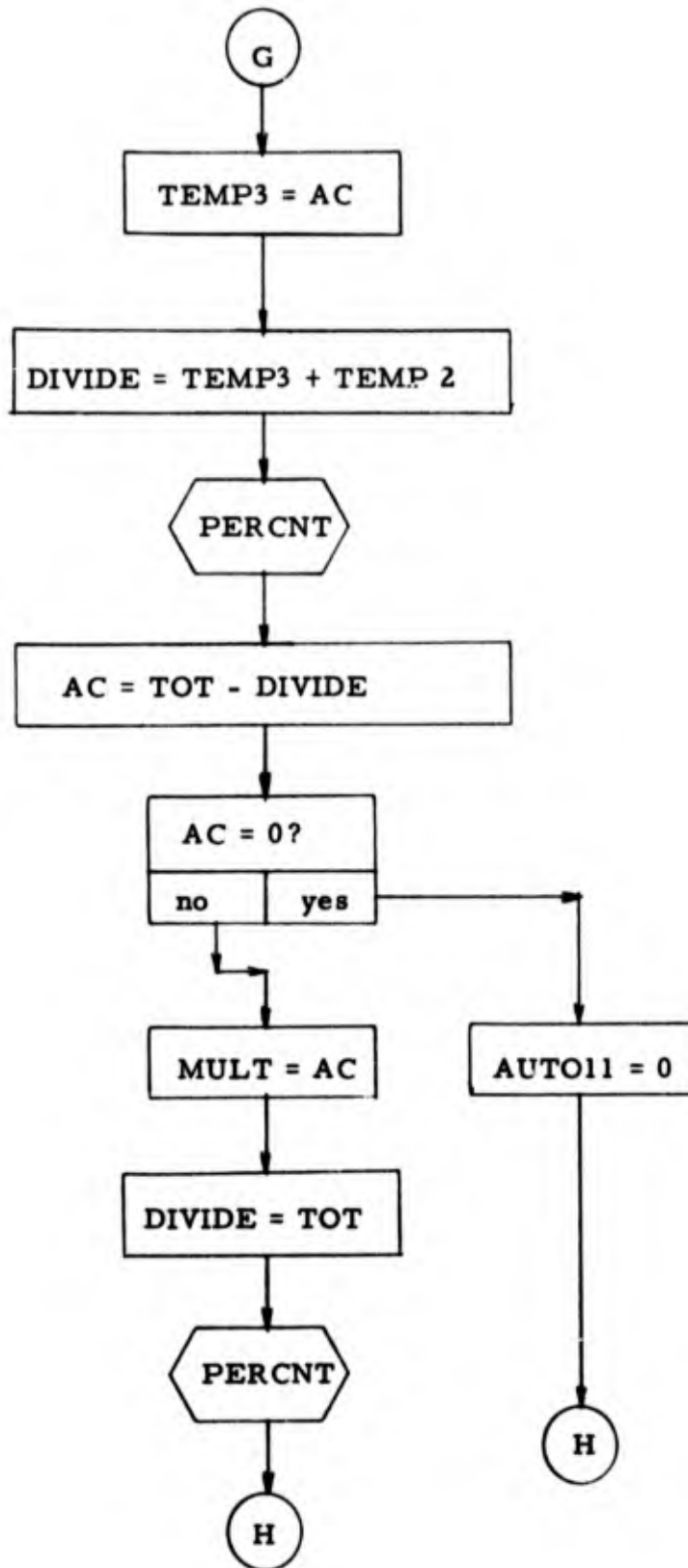


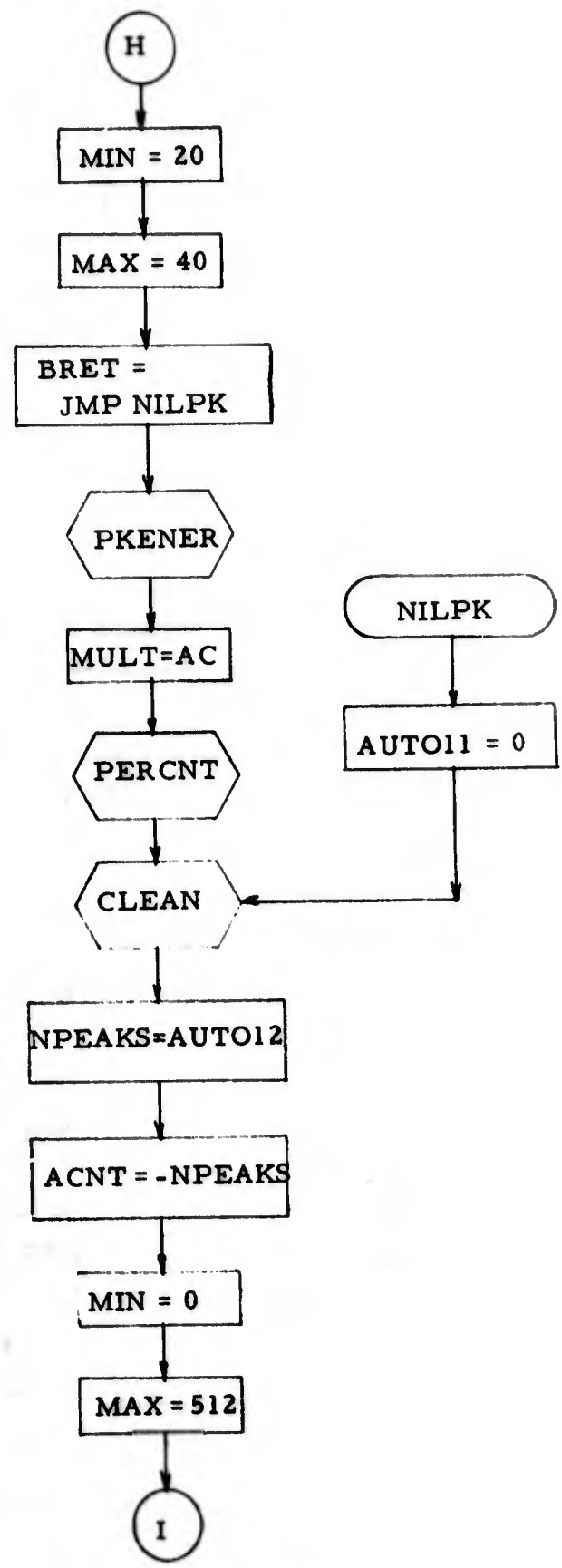
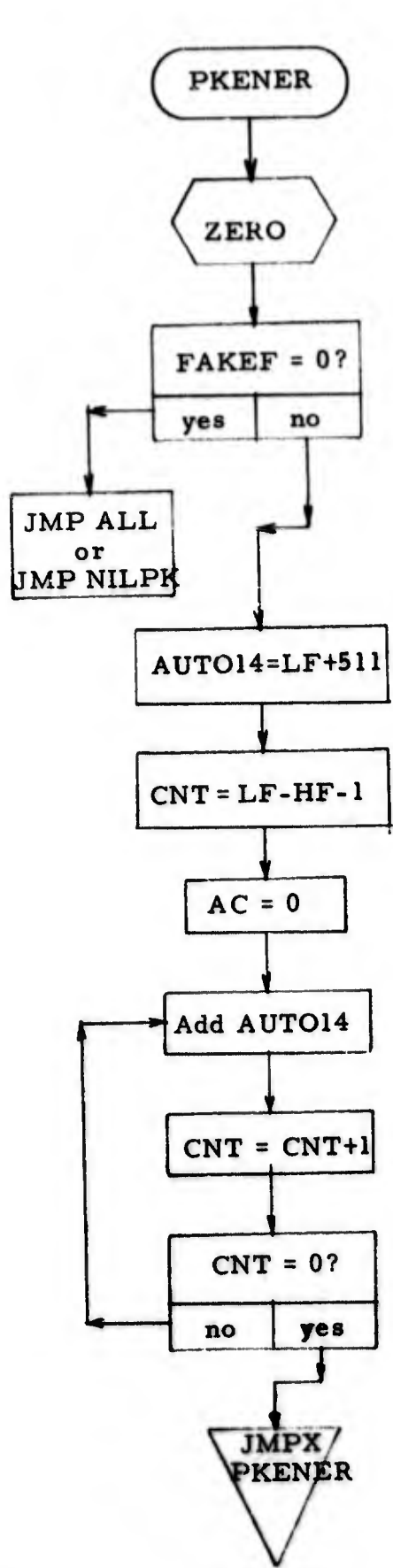


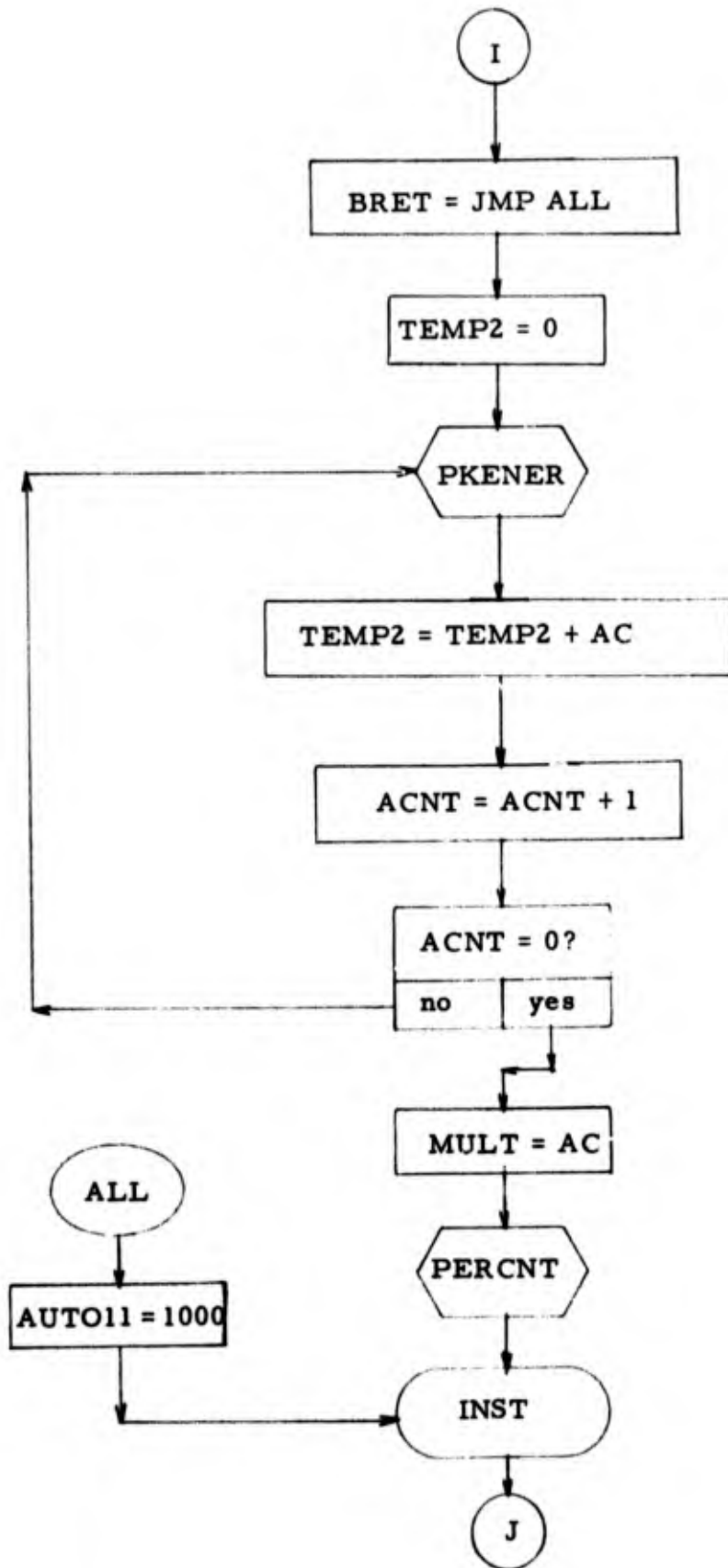


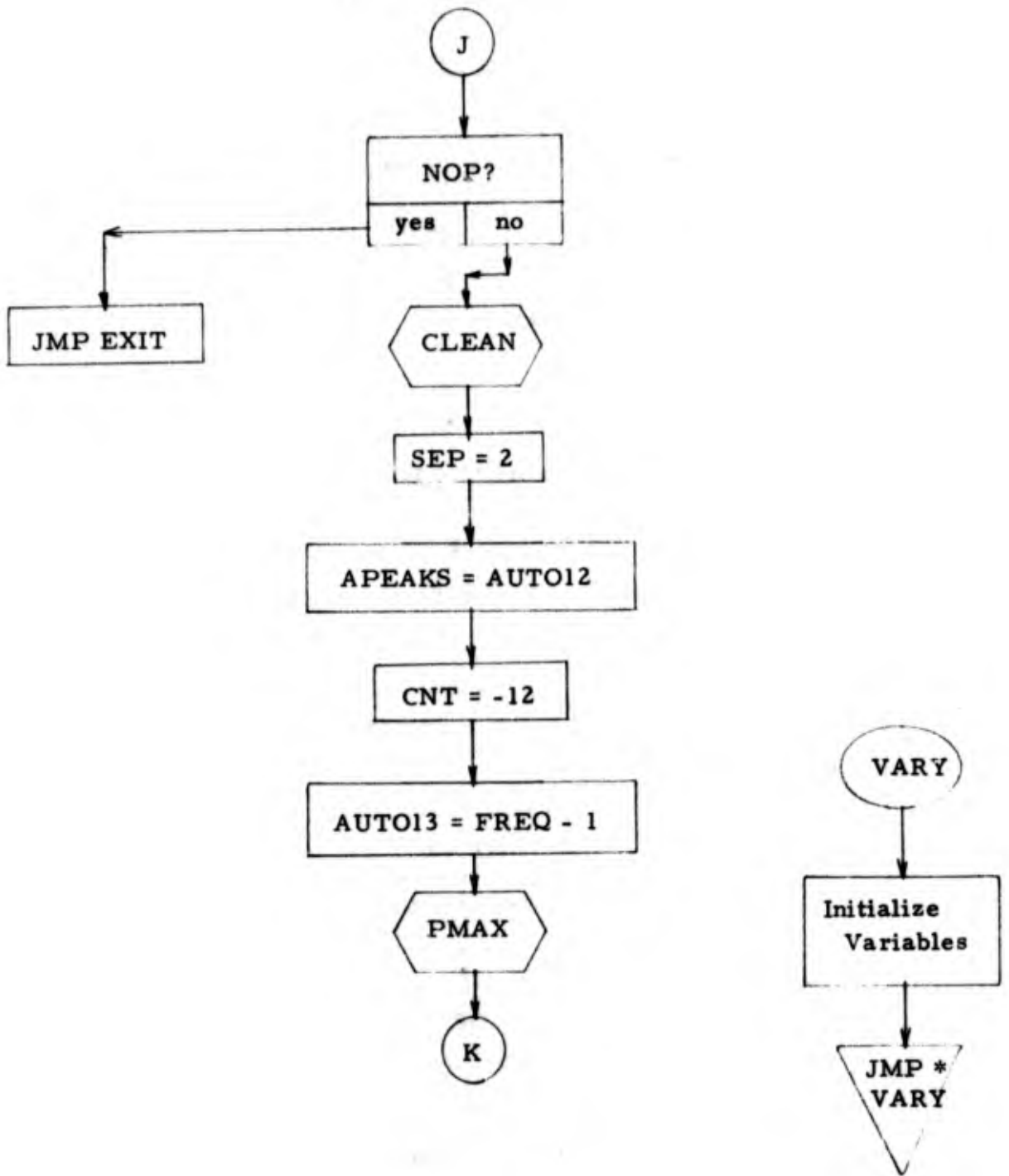


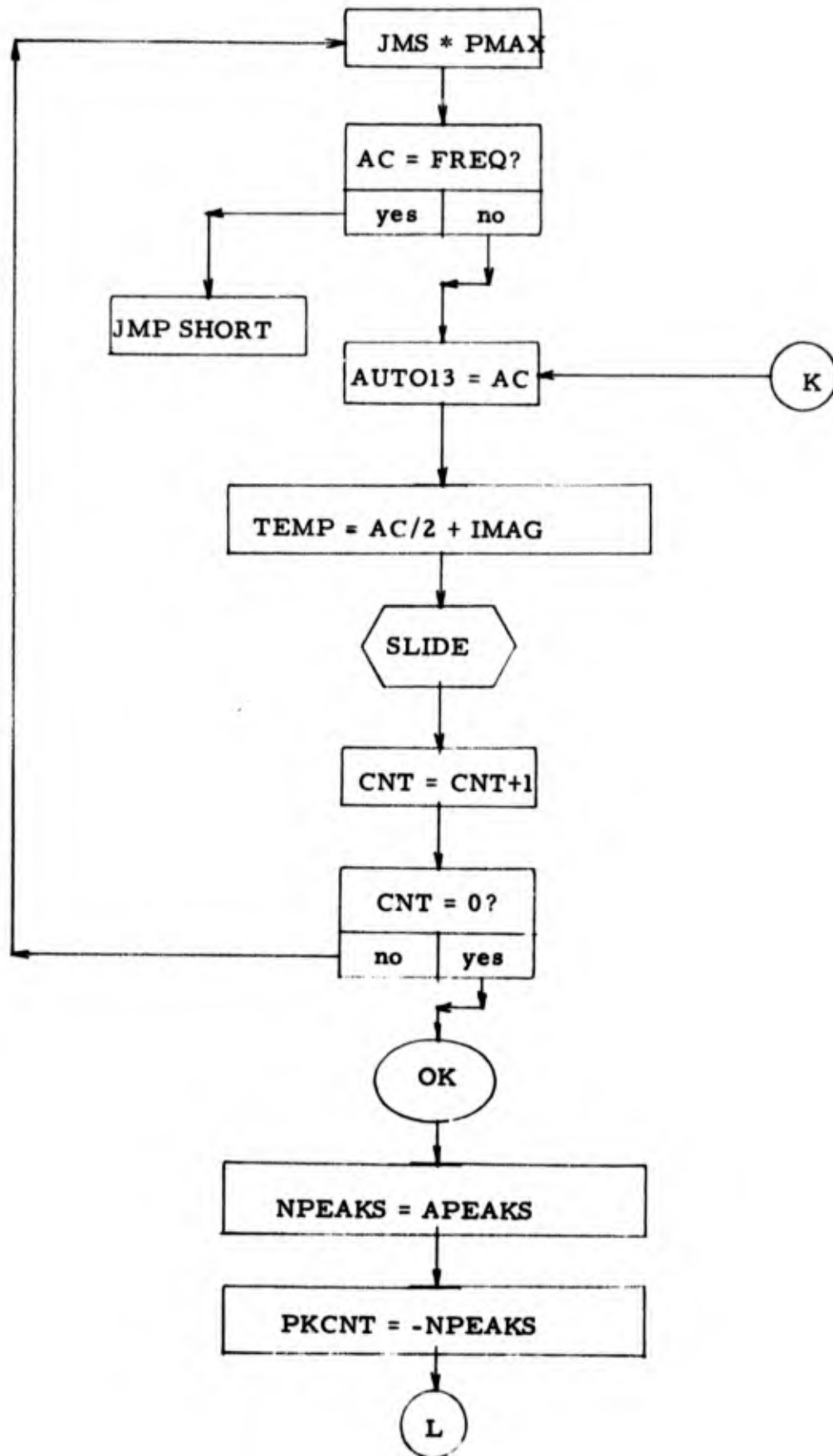


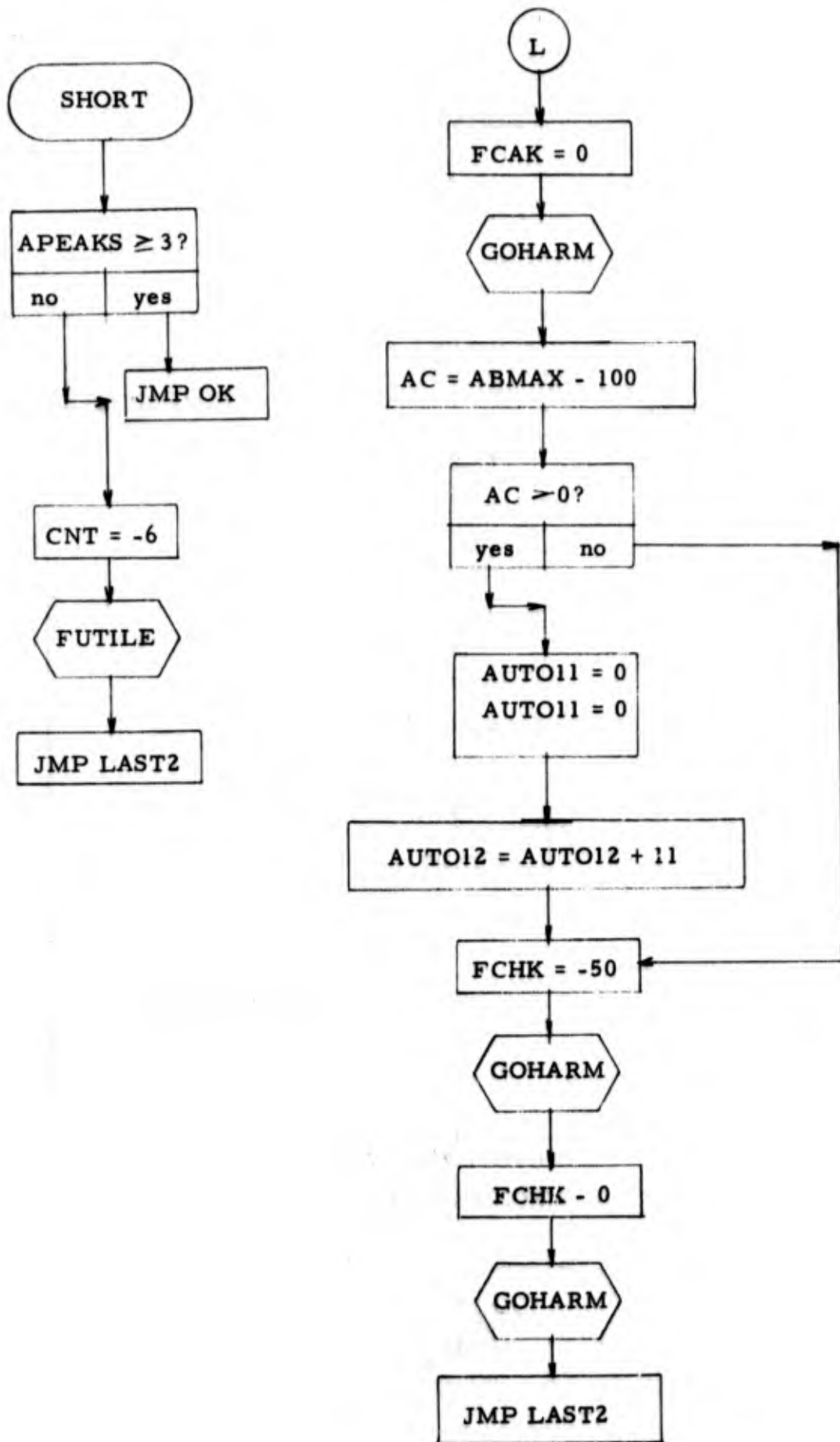


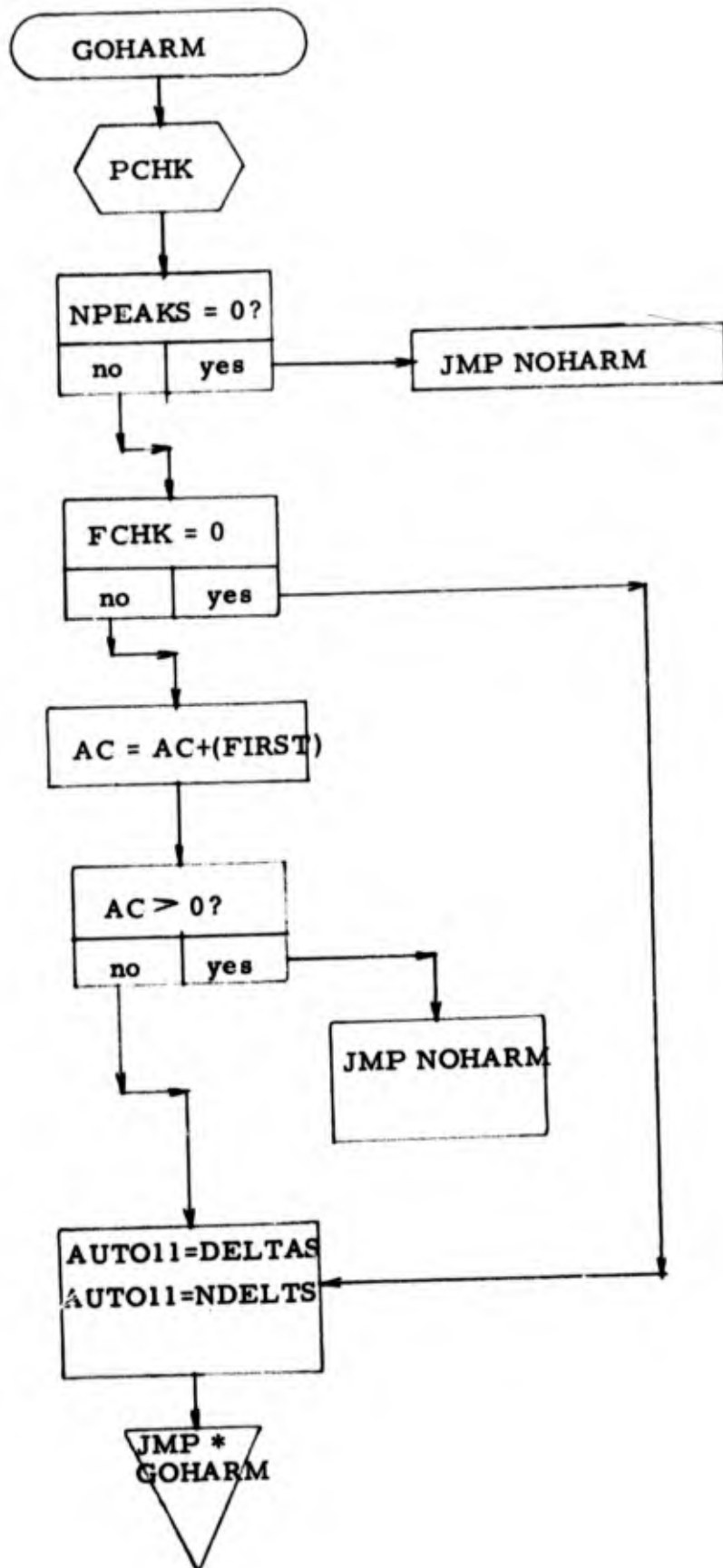




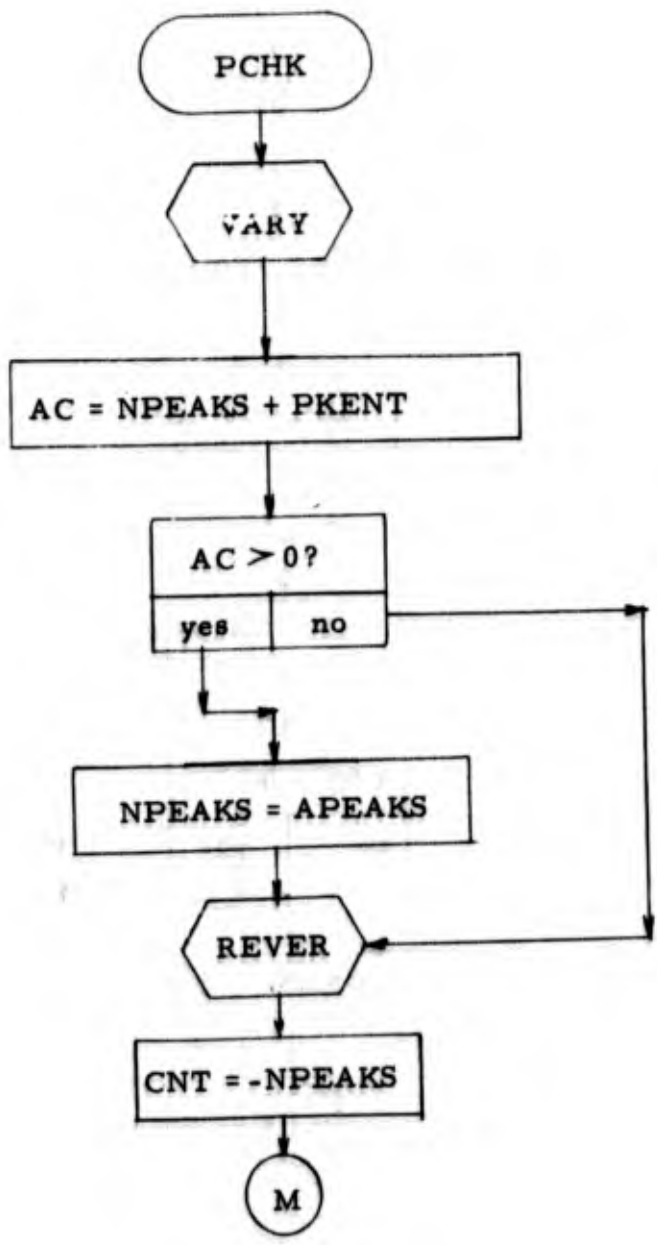
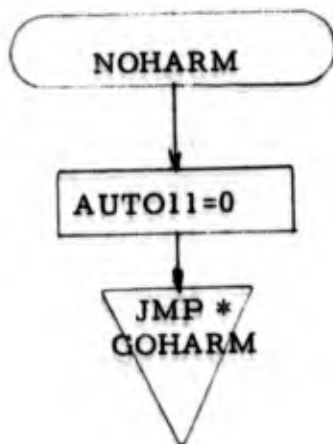


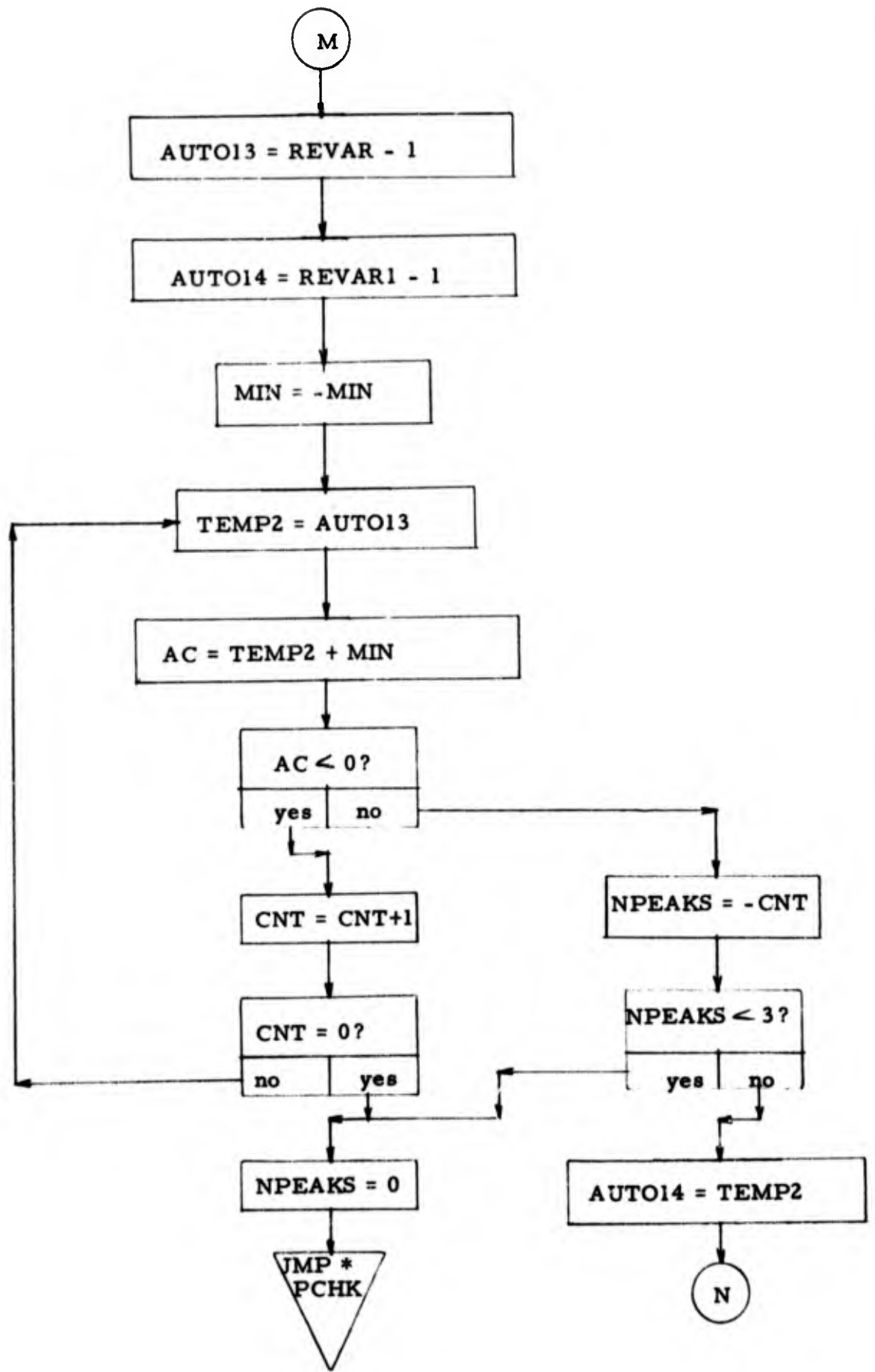


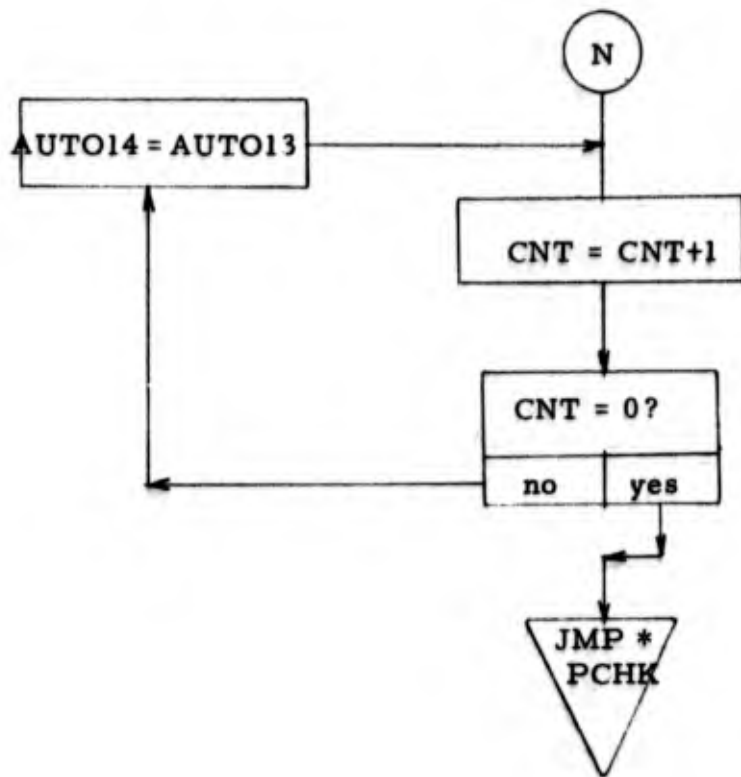


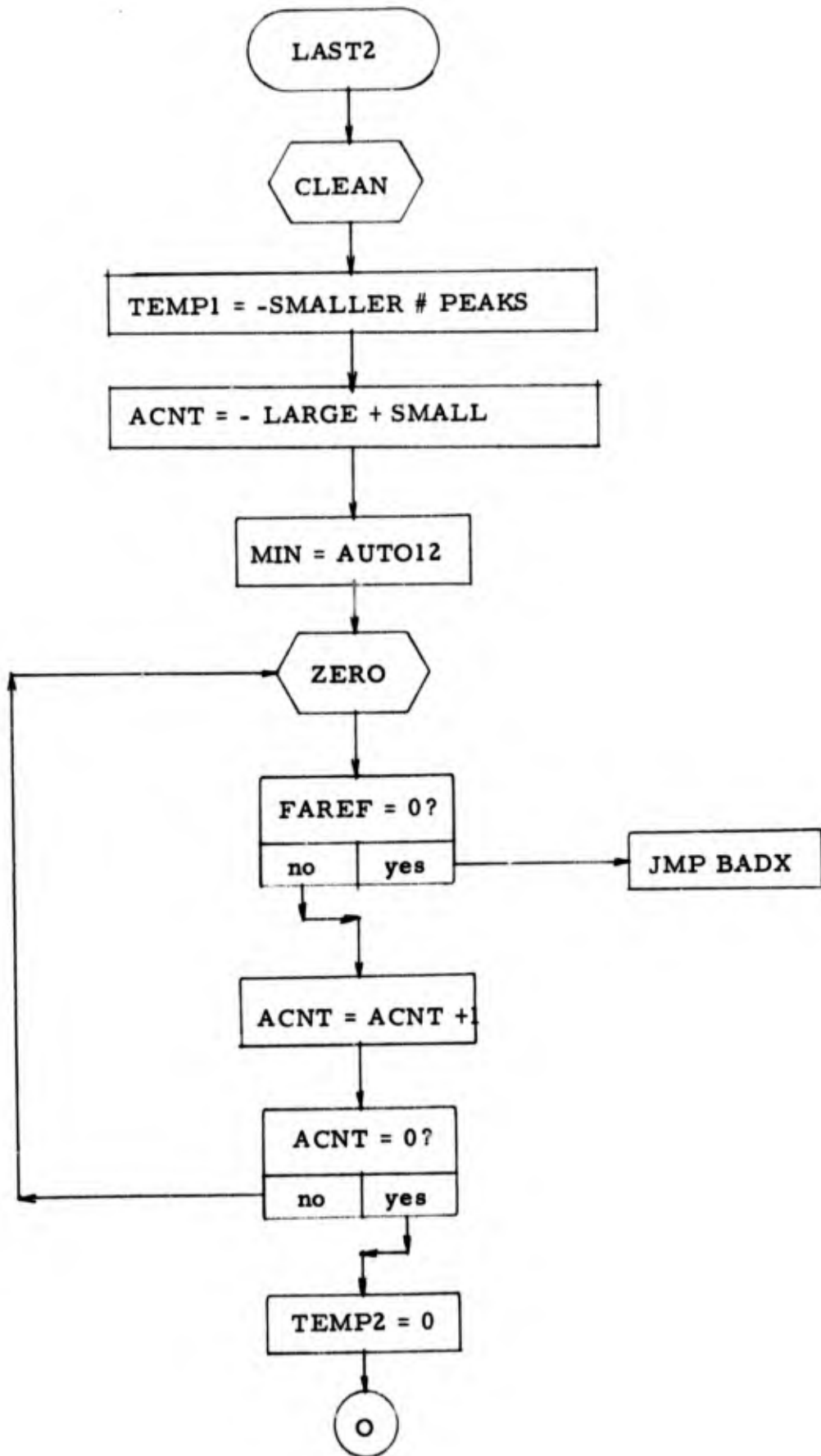


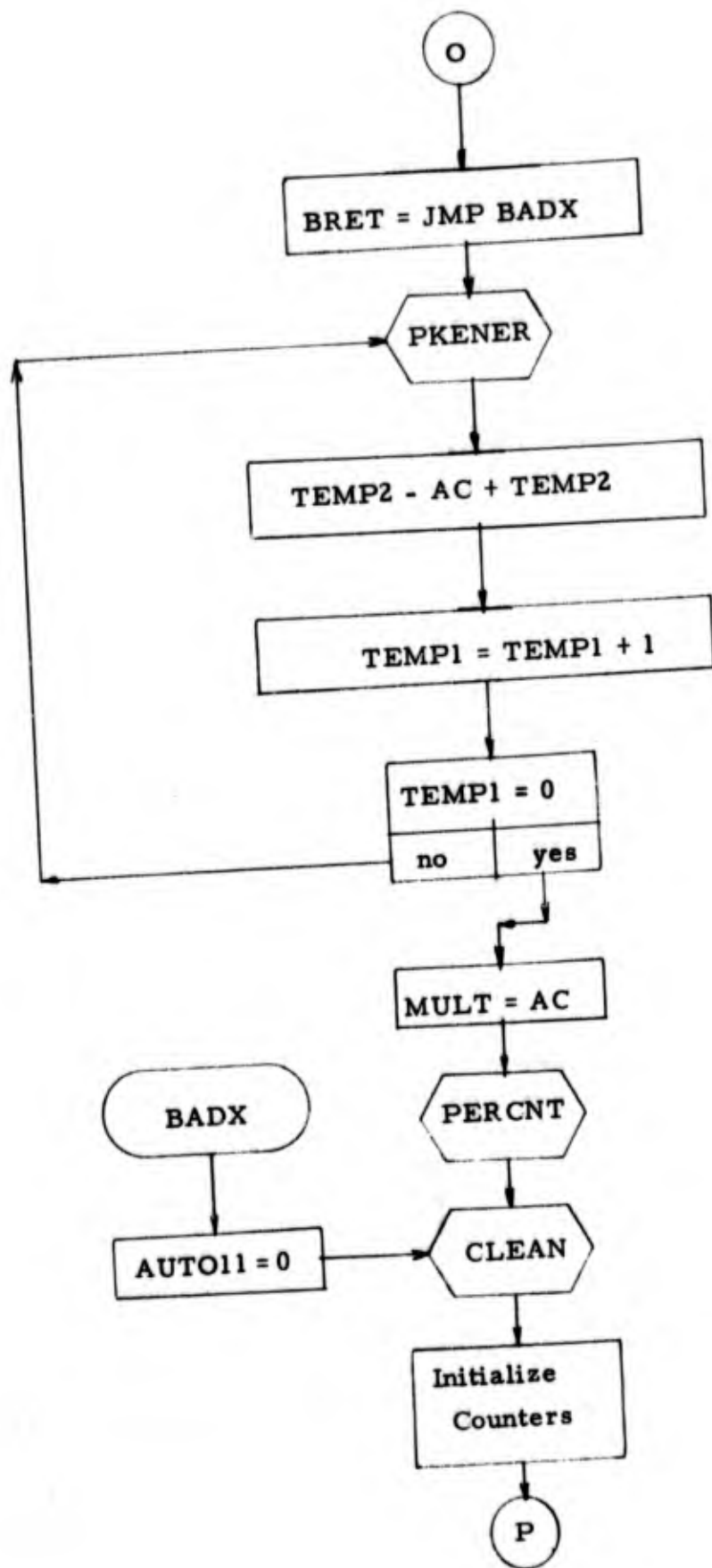


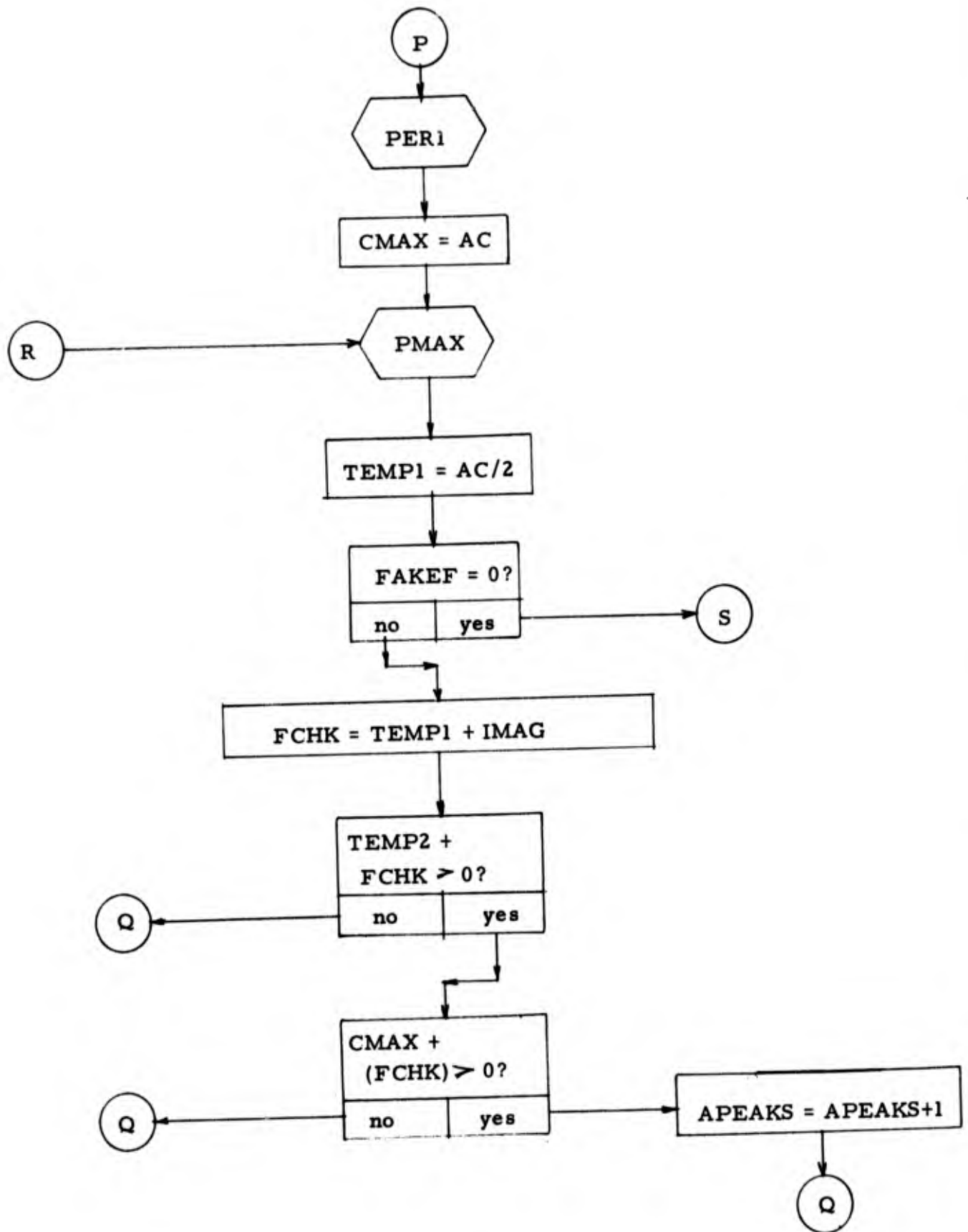


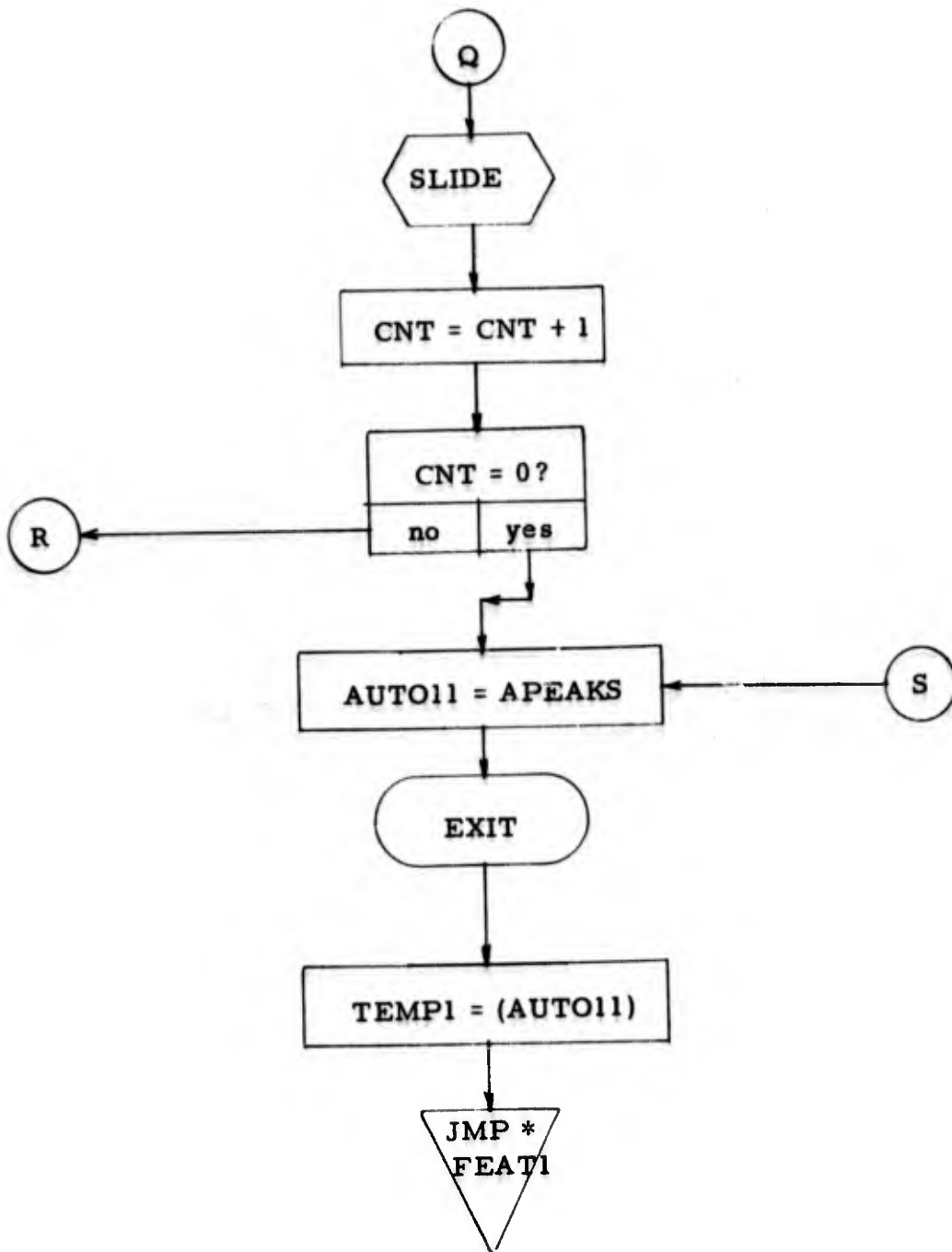


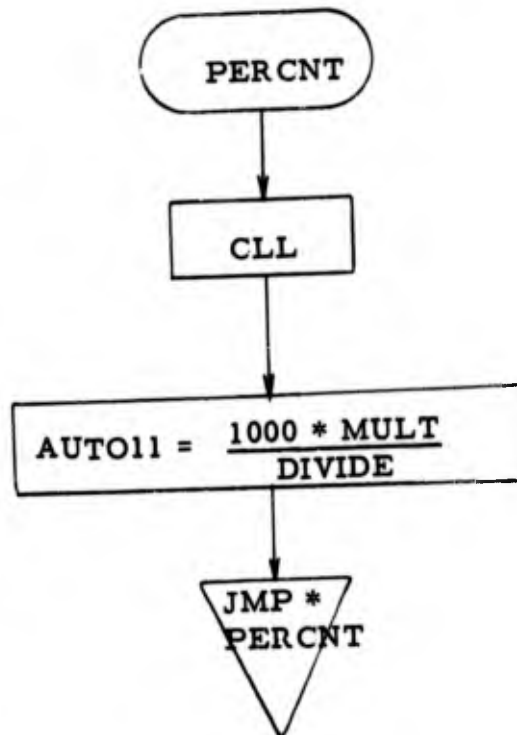
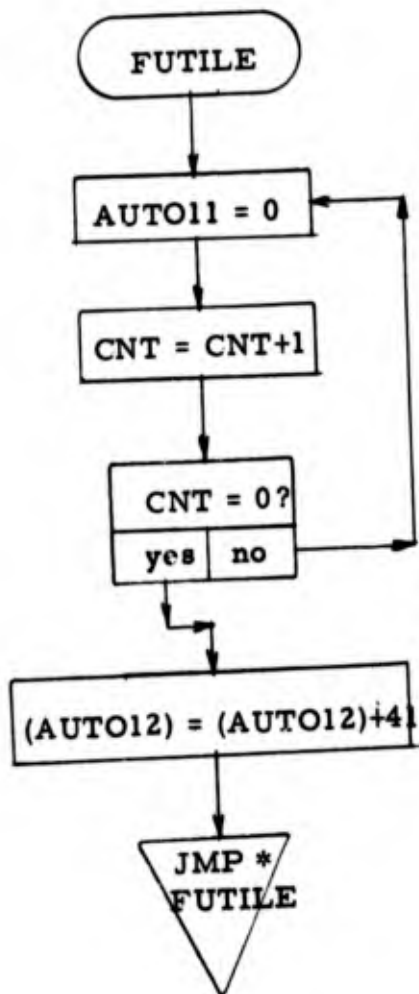














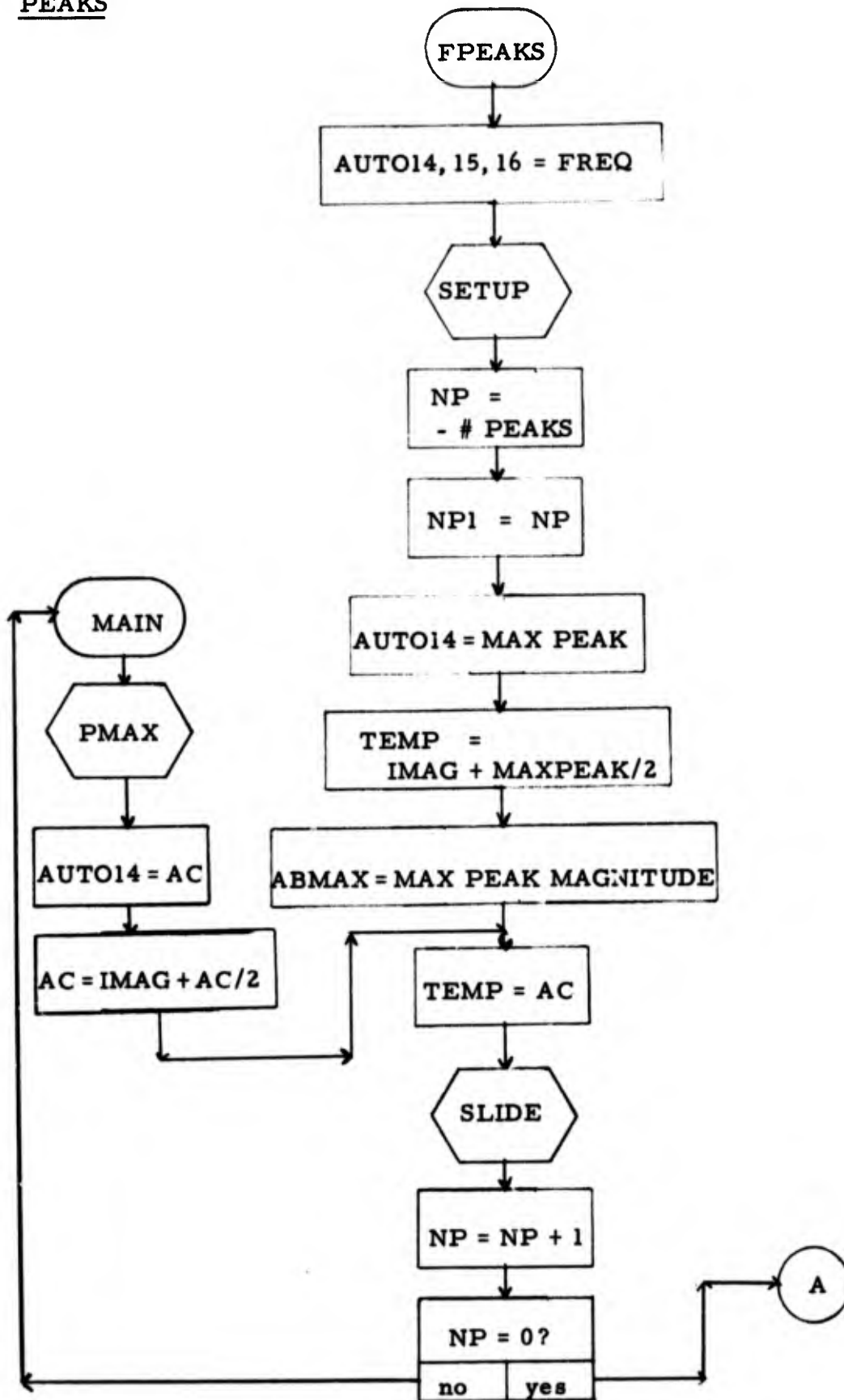
1. Program Name: PEAKS
2. Language: MACRO
3. Summary: A routine to either count number of peaks in energy bin or find "N" largest peaks in energy bin.
4. Requirements: None
5. Routines Required: ENERGY
6. Arrays: IMAG, FREQ
7. GLOBS: CPEAKS, FPEAKS, TEMP, PMAX, SLIDE, MIN, MAX, SEP, NPEAKS, IMAG, LF, HF, FREQ, CLEAN, PERI
8. Description:

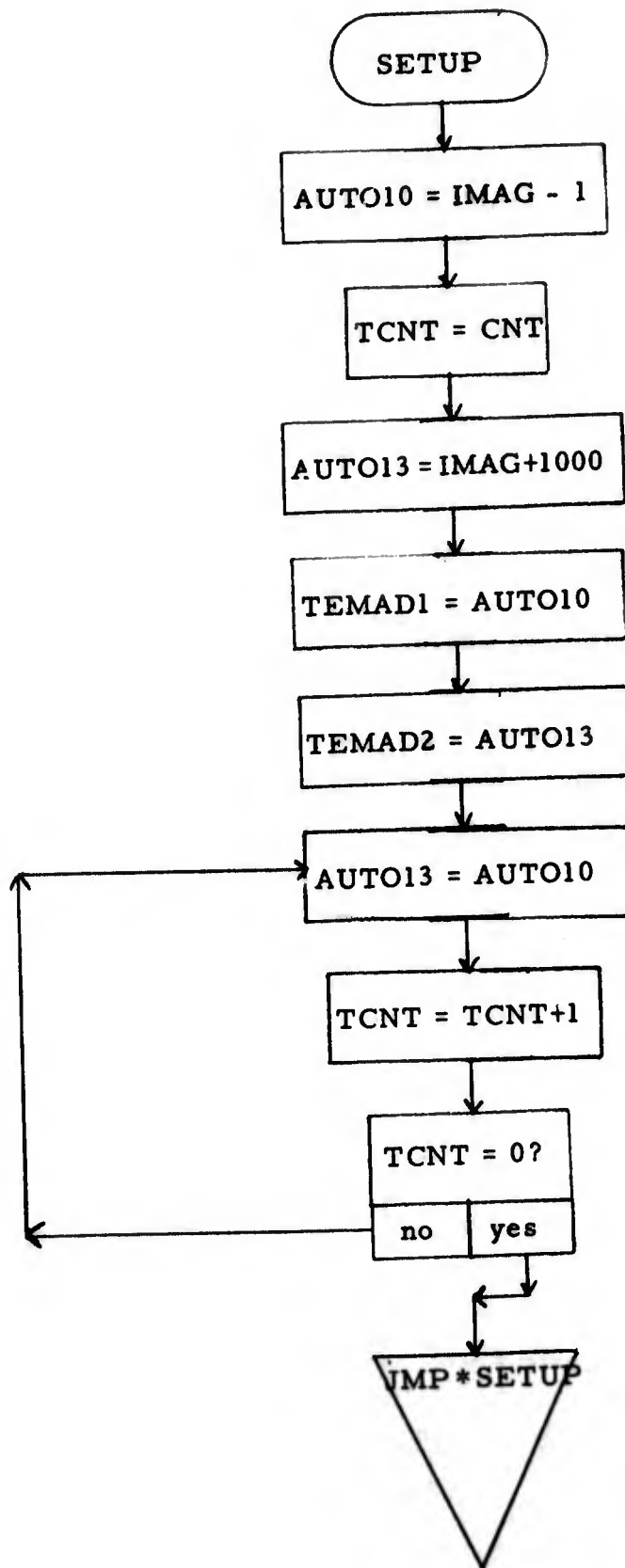
The PEAK routine has two entry points; "FPEAKS" and "CPEAKS". If the former is called, the variables are separation between peaks and the number of peaks to be found between a minimum and a maximum frequency. The largest peak is located and the frequency of this peak is recorded in the FREQ array. This peak is then zeroed out and the process is repeated until "N" peaks are located.

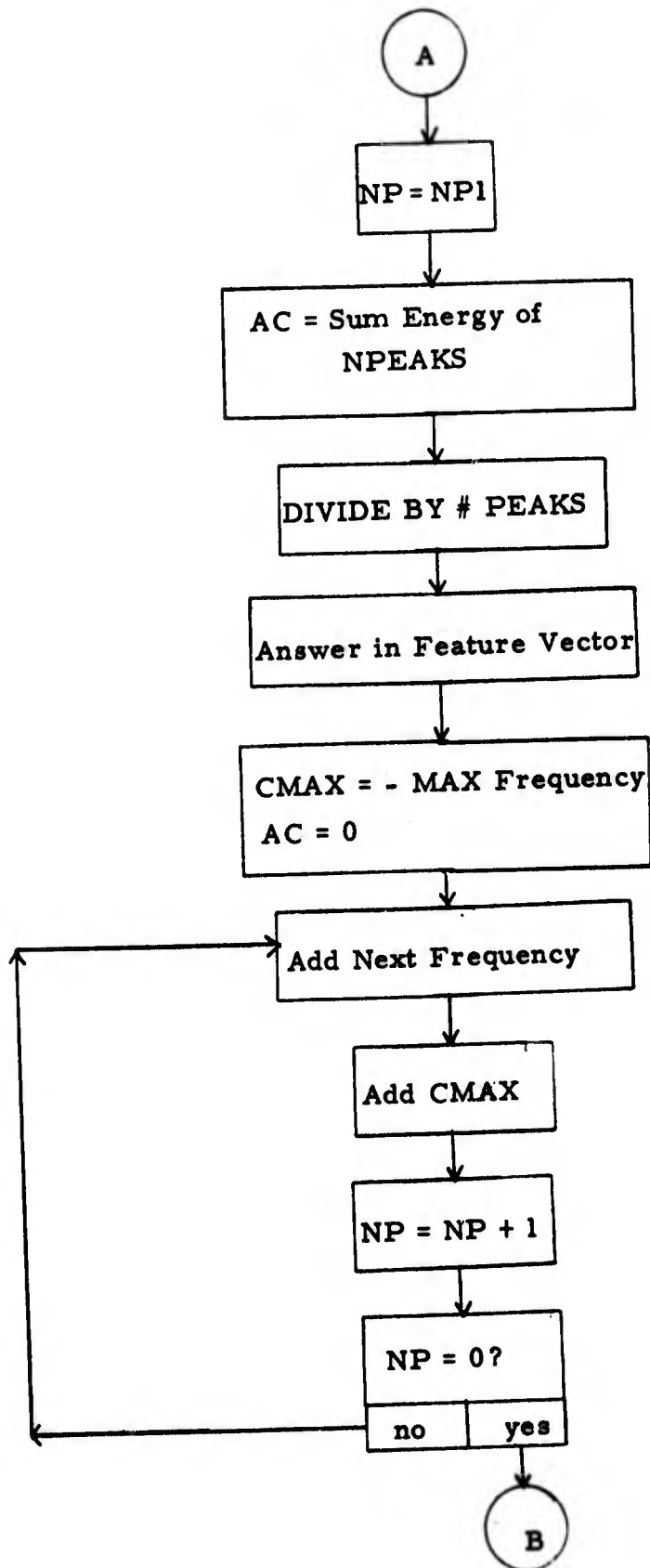
Certain features are then extracted from the "N" peaks. These are: average of peaks; frequency deviation from maximum peak; and number of frequencies above the maximum peak minus the number below the maximum peak.

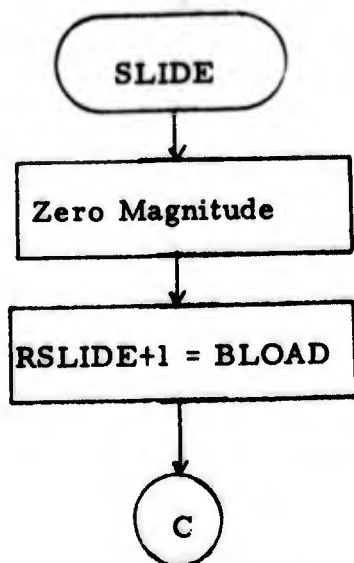
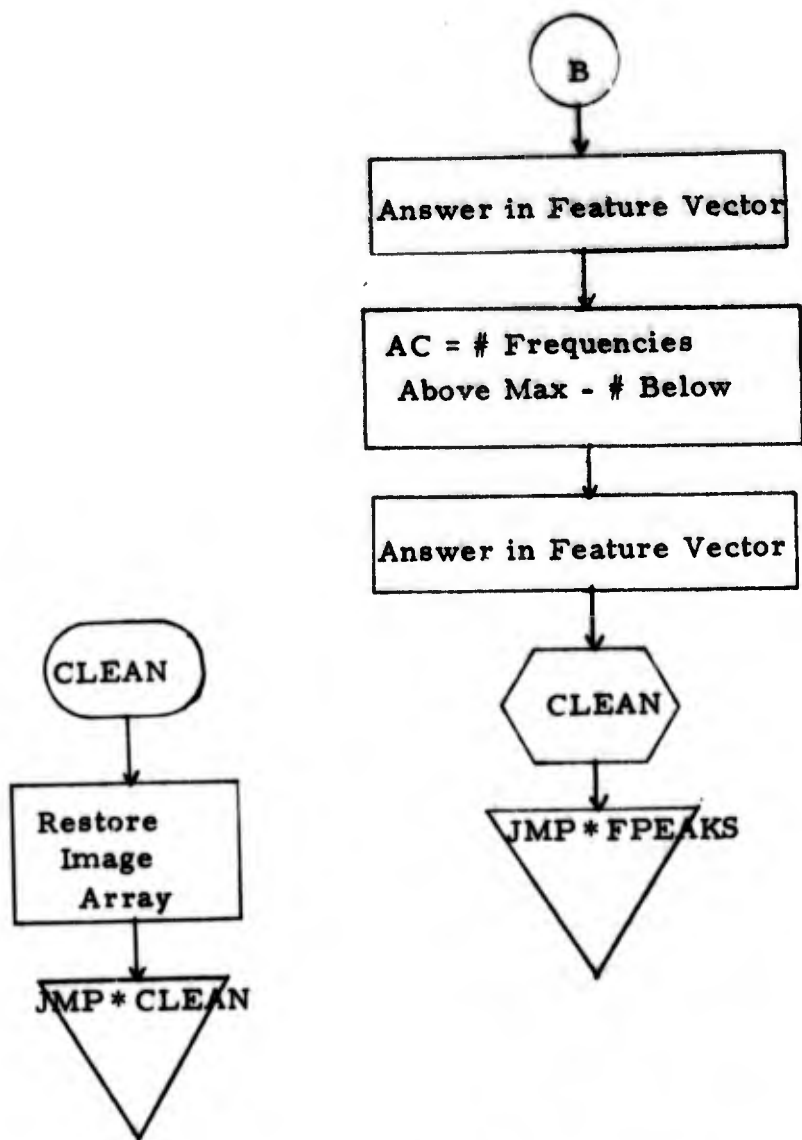
The "CPEAKS" entry point is used to count the number of peaks above a specified percent of the maximum peak. The variables are separation between peaks, minimum and maximum frequency, and percent of maximum peak. The largest peak is found and compared to a percent of the maximum peak. If it is greater than this level a peak counter is incremented. If it is less than or equal to this level the program returns with the peak count in the accumulator.

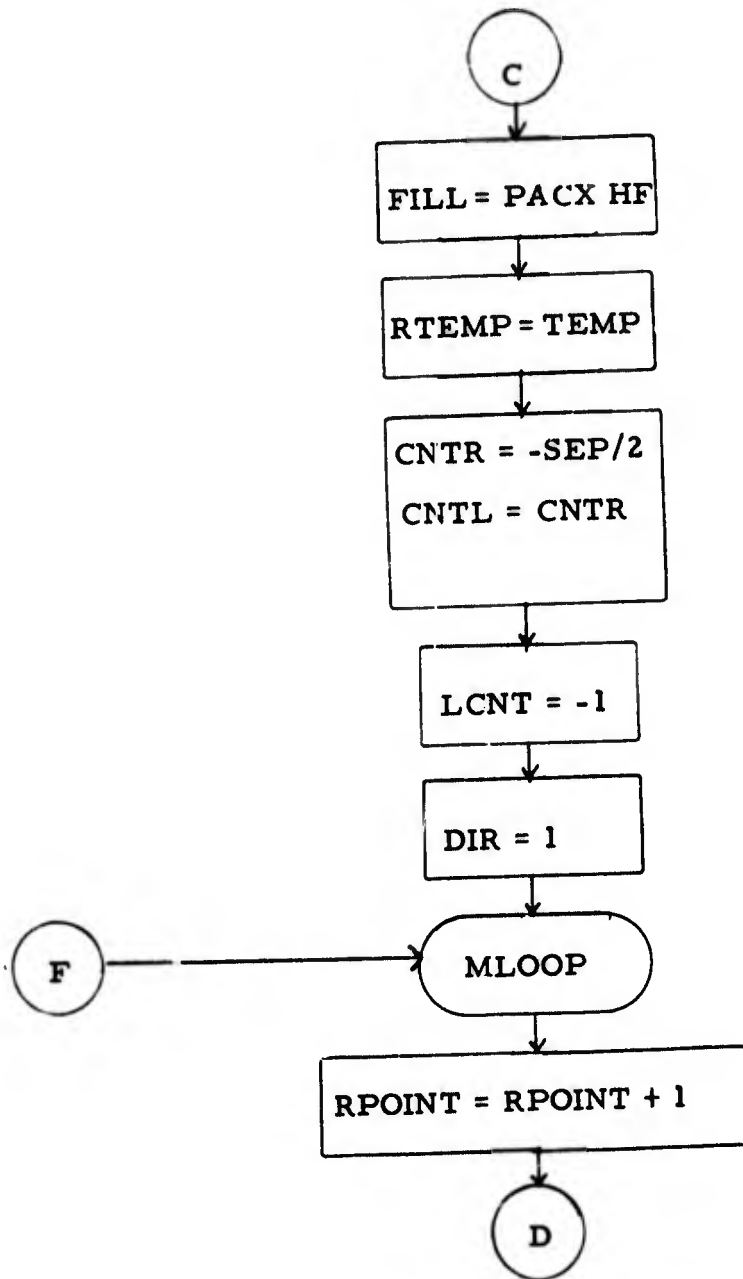
PEAKS

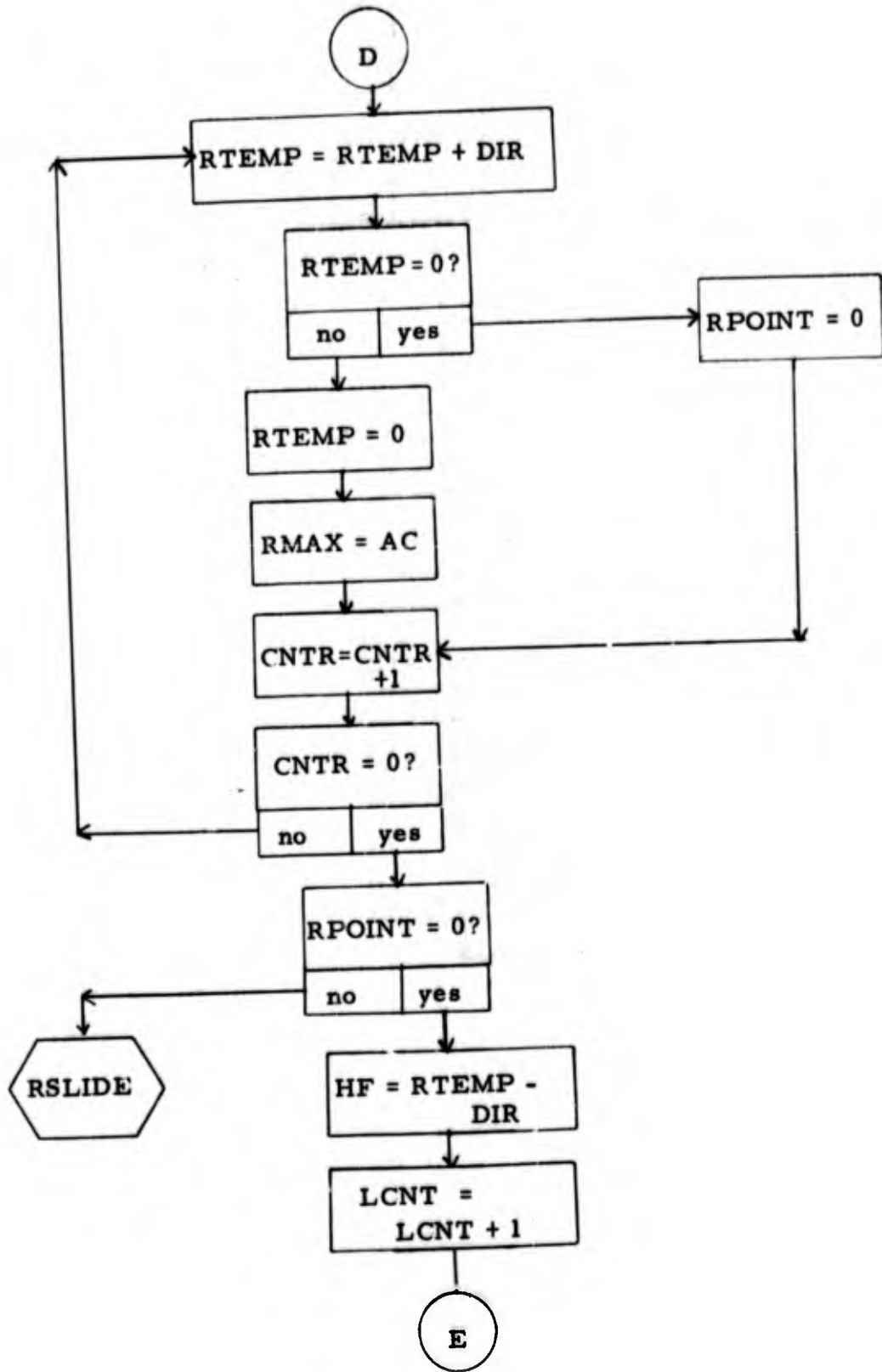


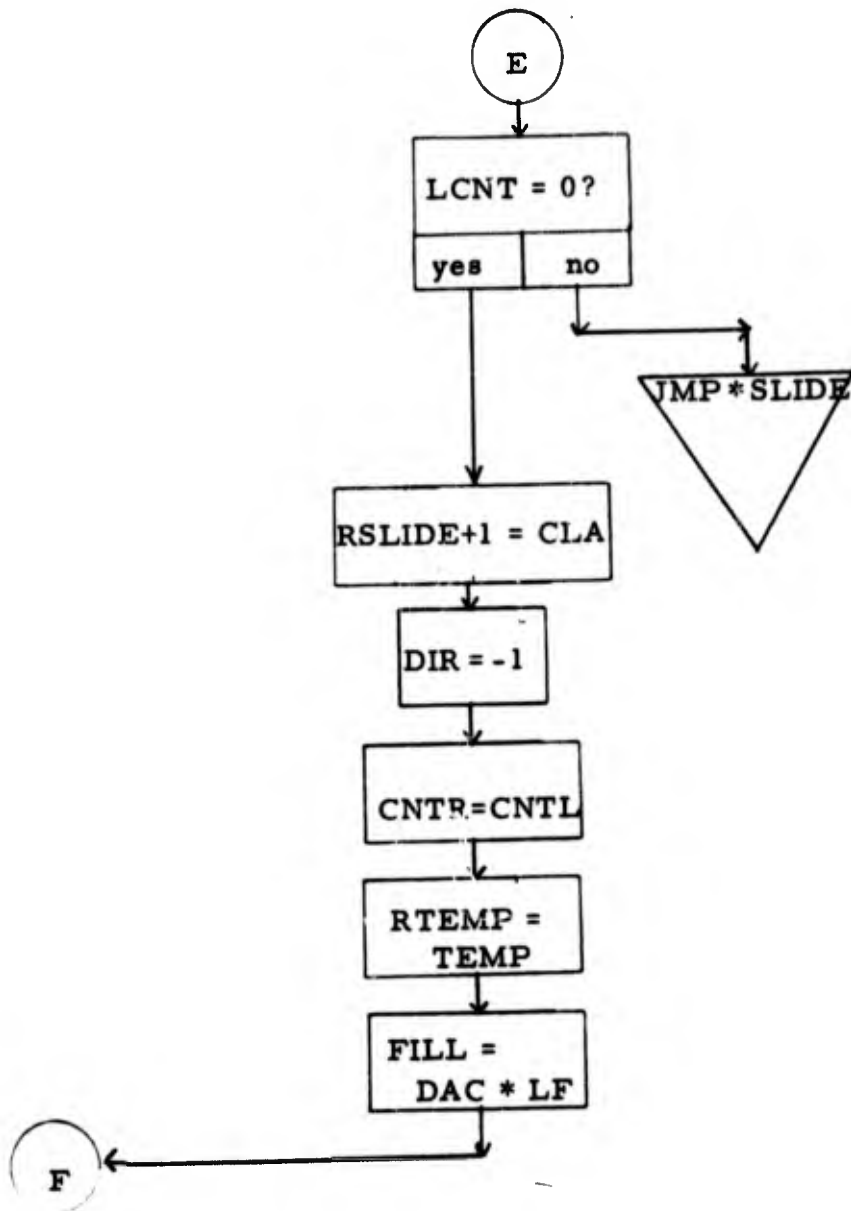




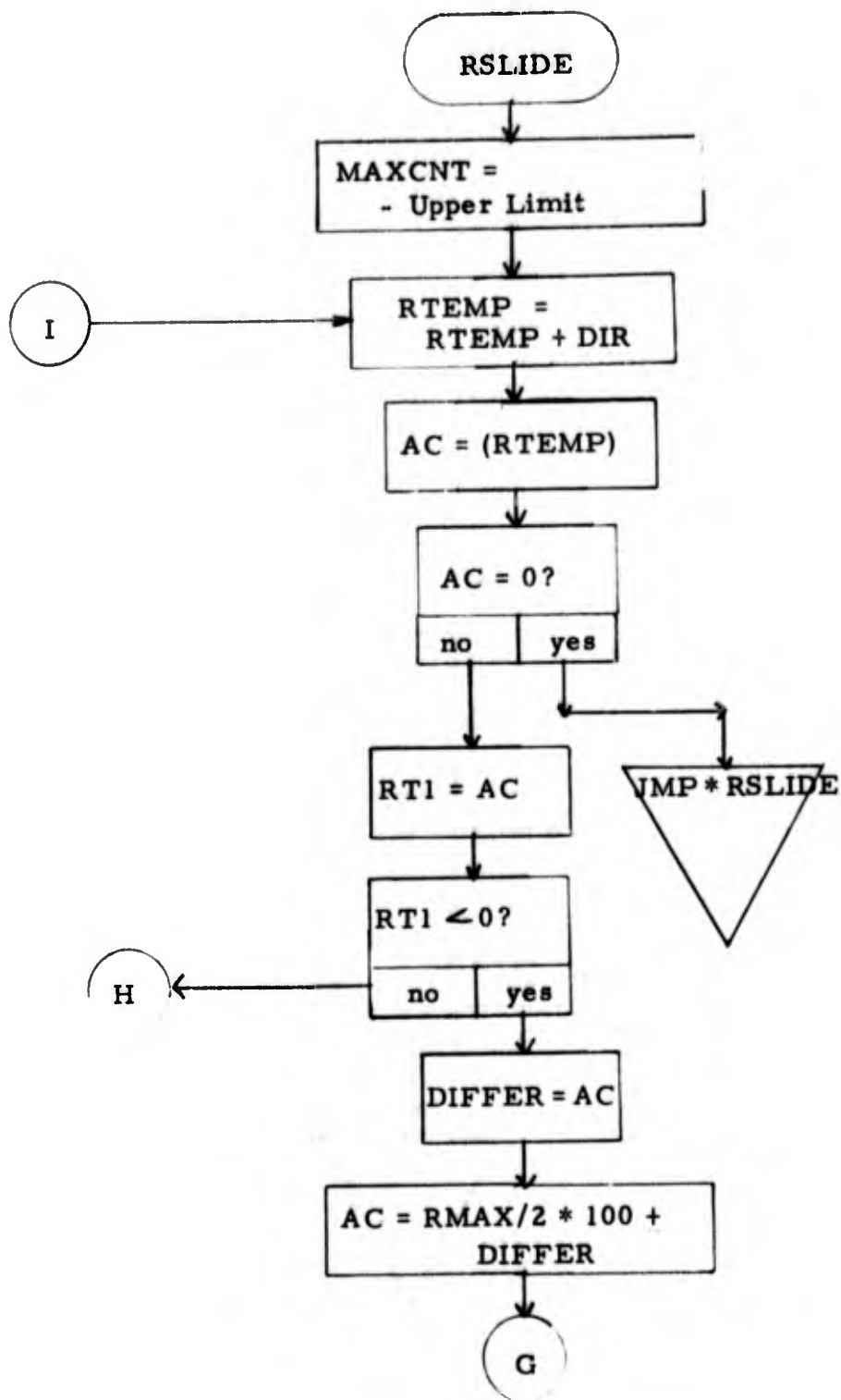


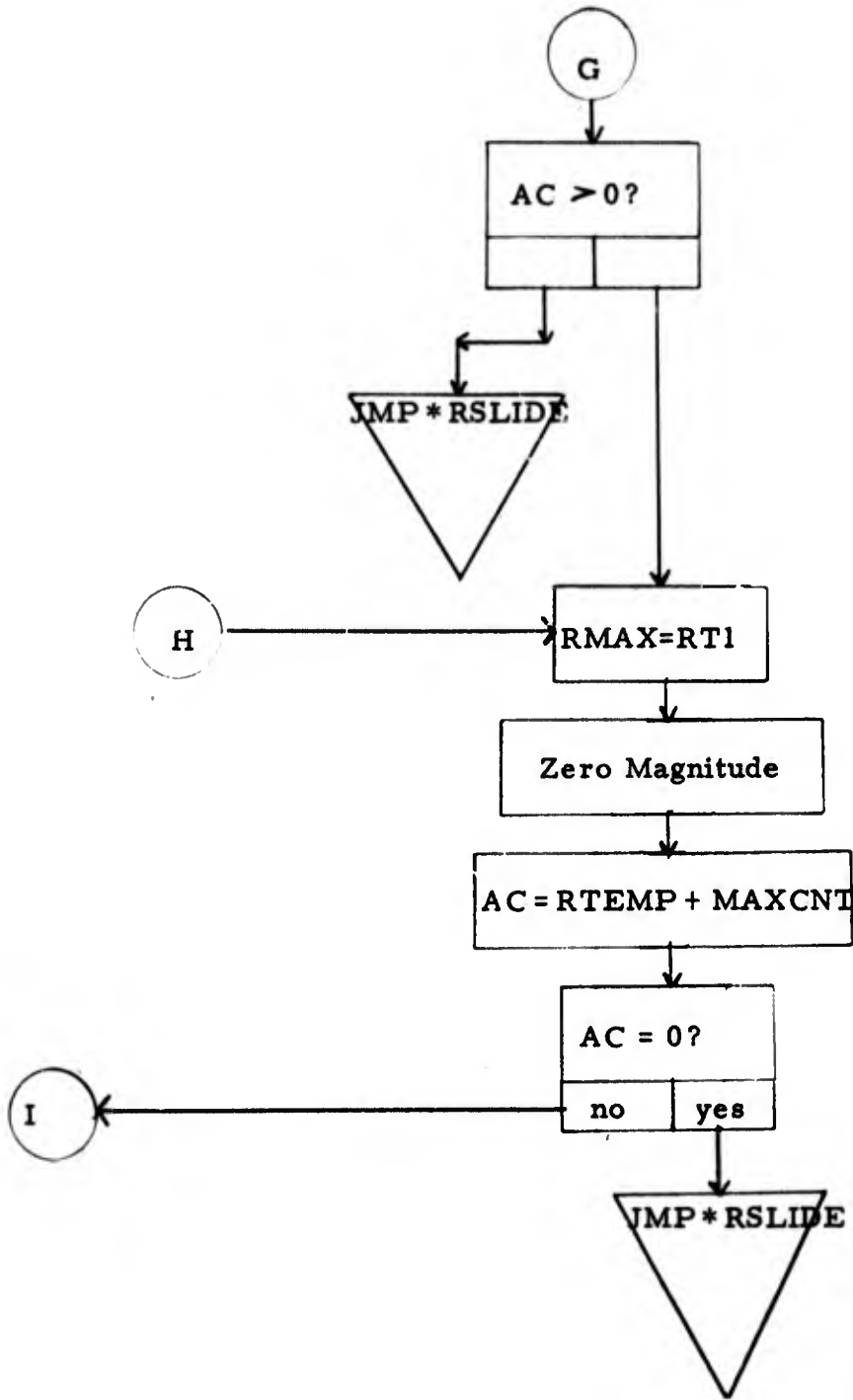


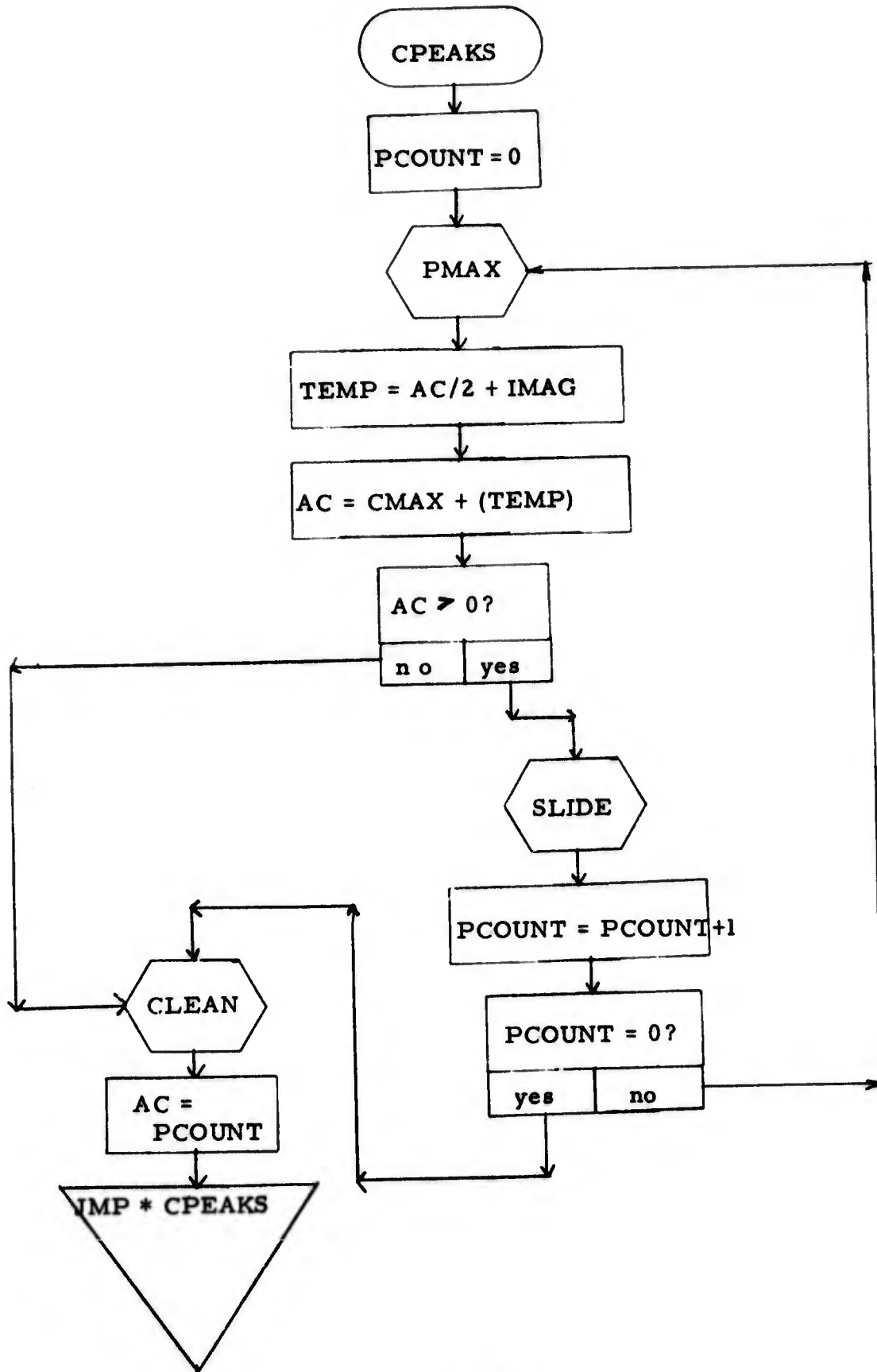








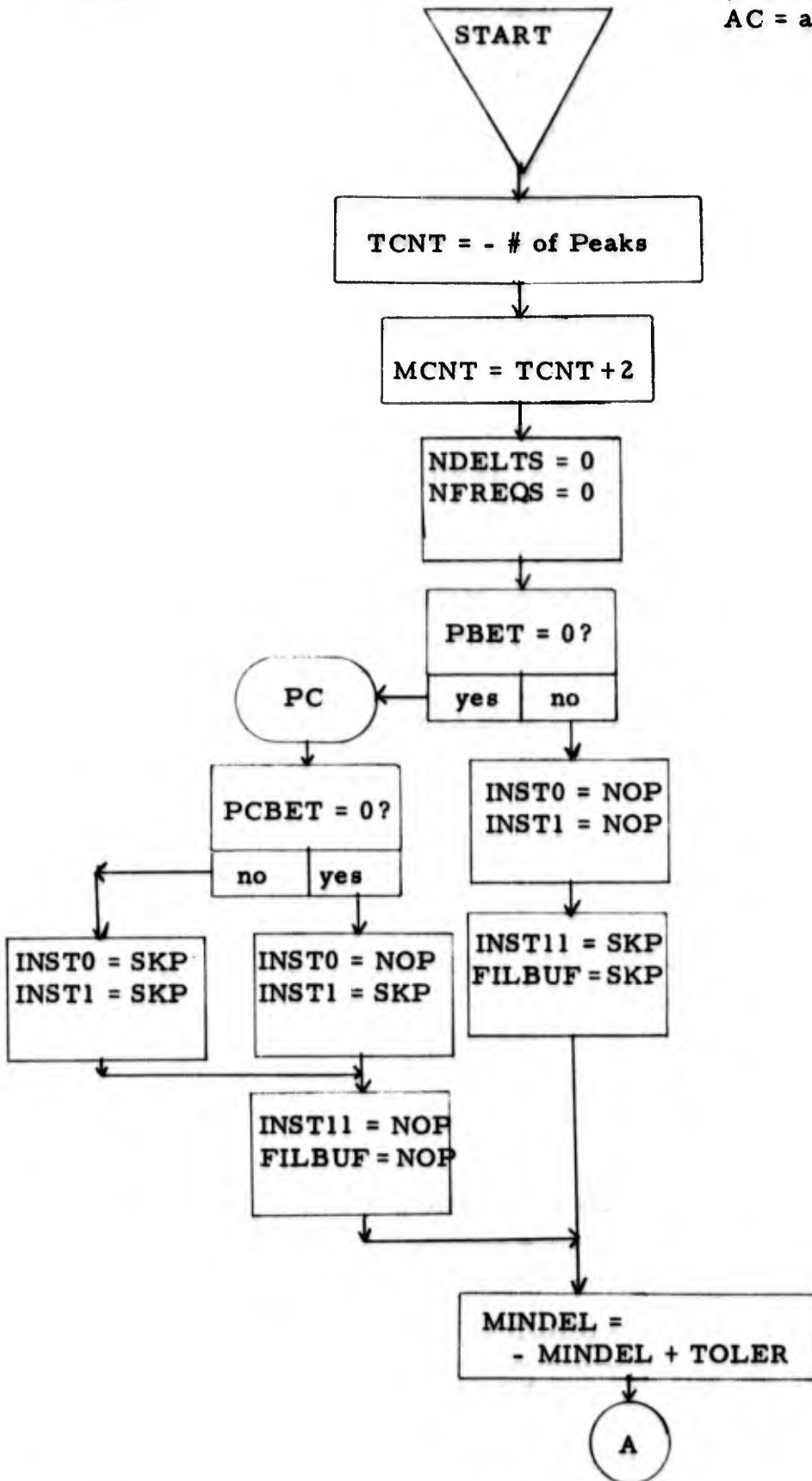


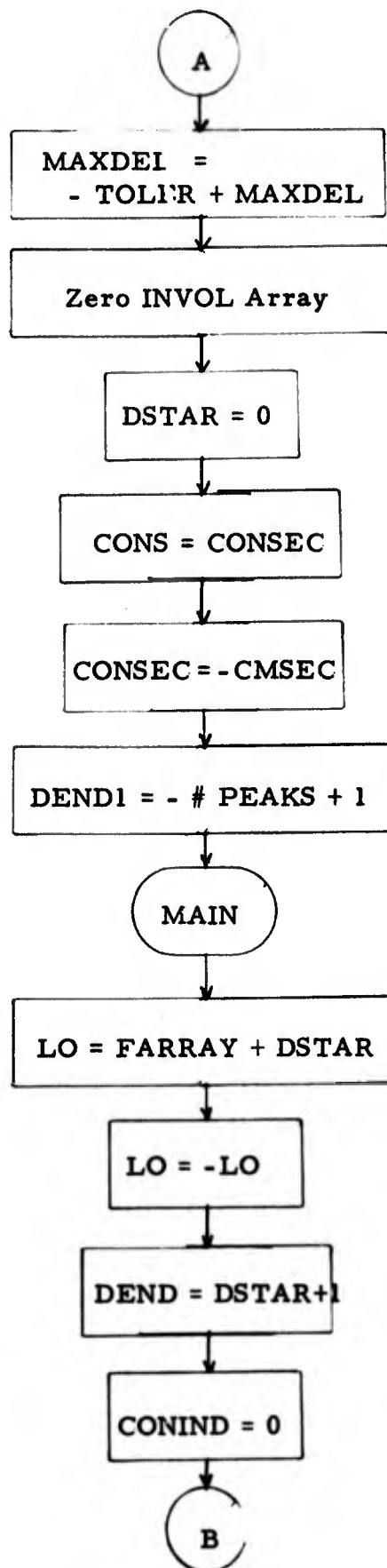


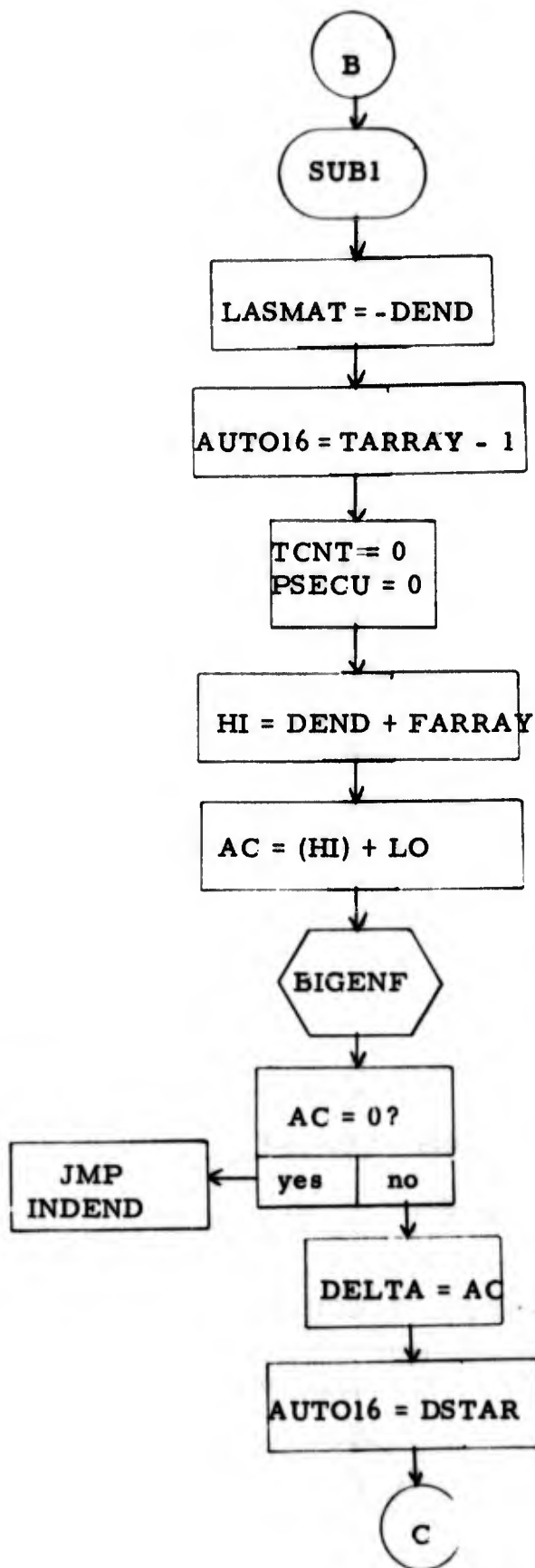
1. Program Name: HARMON
2. Language: MACRO
3. Summary: A routine to extract harmonic content from averaged power spectrums.
4. Requirements: Execution of REVER must precede this routine.
5. Routines Required: None
6. Arrays: REVAR1, INVOL, TARRAY
7. GLOBS: HARMON, TOLER, REVAR1, NPEAKS, MINDEL, MAXDEL, CONSEC, PBET, PLBET, INDEP, MINDL, DELTAS, NFREQS, NDELTS, FIRST
8. Description:

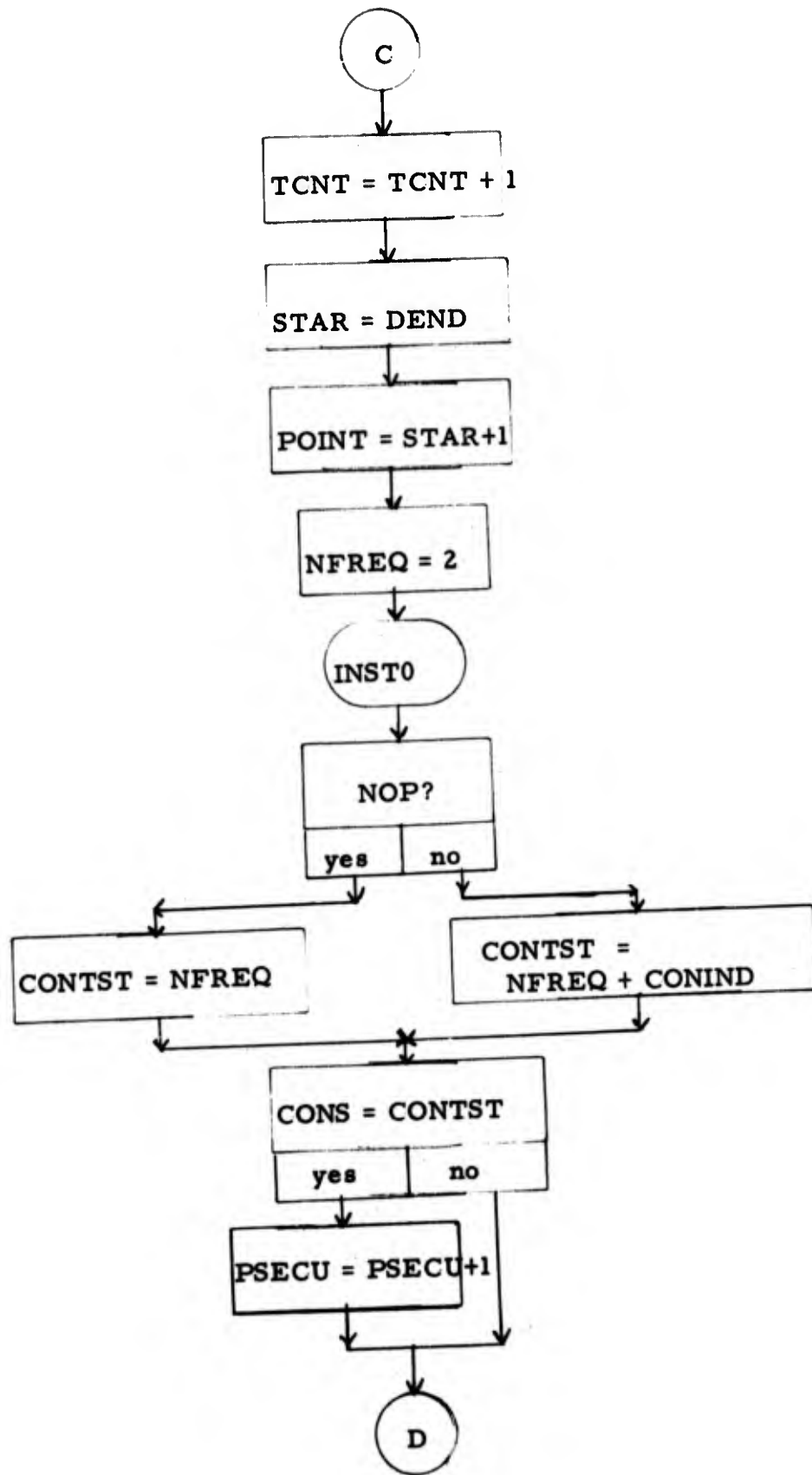
The Harmonic routine extracts harmonic series under varying constraints. It returns the value of the delta, the number of deltas and the lowest frequency of series with the greatest number of deltas. In case of a tie, the series with the minimum number of frequencies is chosen. The constraints which can be applied are as follows: (1) MINIMUM SEPARATION OF PEAKS, (2) MIN DELTA, (3) MAX DELTA, (4) MAX MEVIATION, (5) MIN CONSECUTIVE FREQUENCIES, (6) PEAKS BETWEEN CONSECUTIVE FREQUENCIES, (7) PEAKS BETWEEN ANY FREQUENCIES, (8) ALLOW PEAKS INVOLVED IN PREVIOUS SERIES TO BE USED AS FIRST FREQUENCY IN A SERIES, (9) MINIMUM NUMBER OF DELTAS REQUIRED. The usage of these constraints and a detailed explanation of the harmonic algorithm are explained in the section on Features.

( ) = indirect addressing  
 AC = accumulator

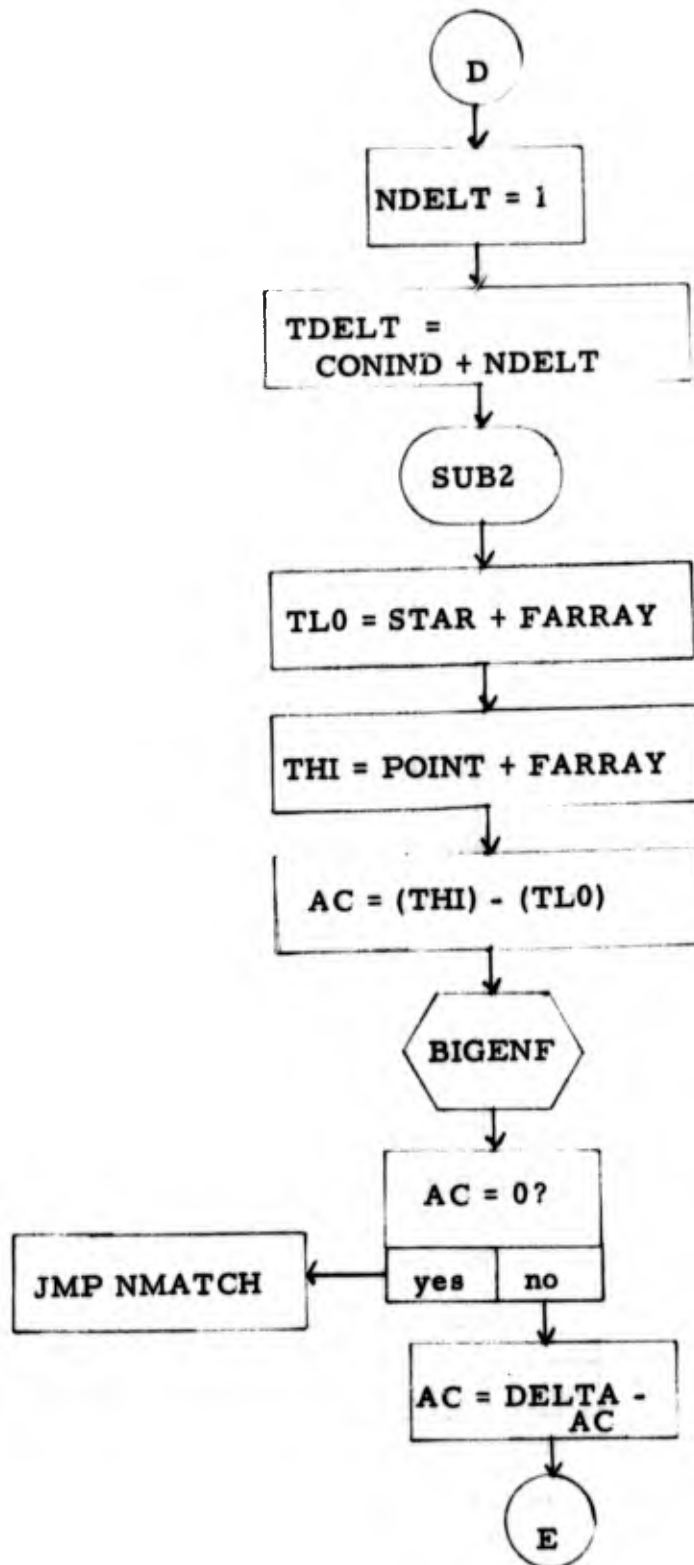


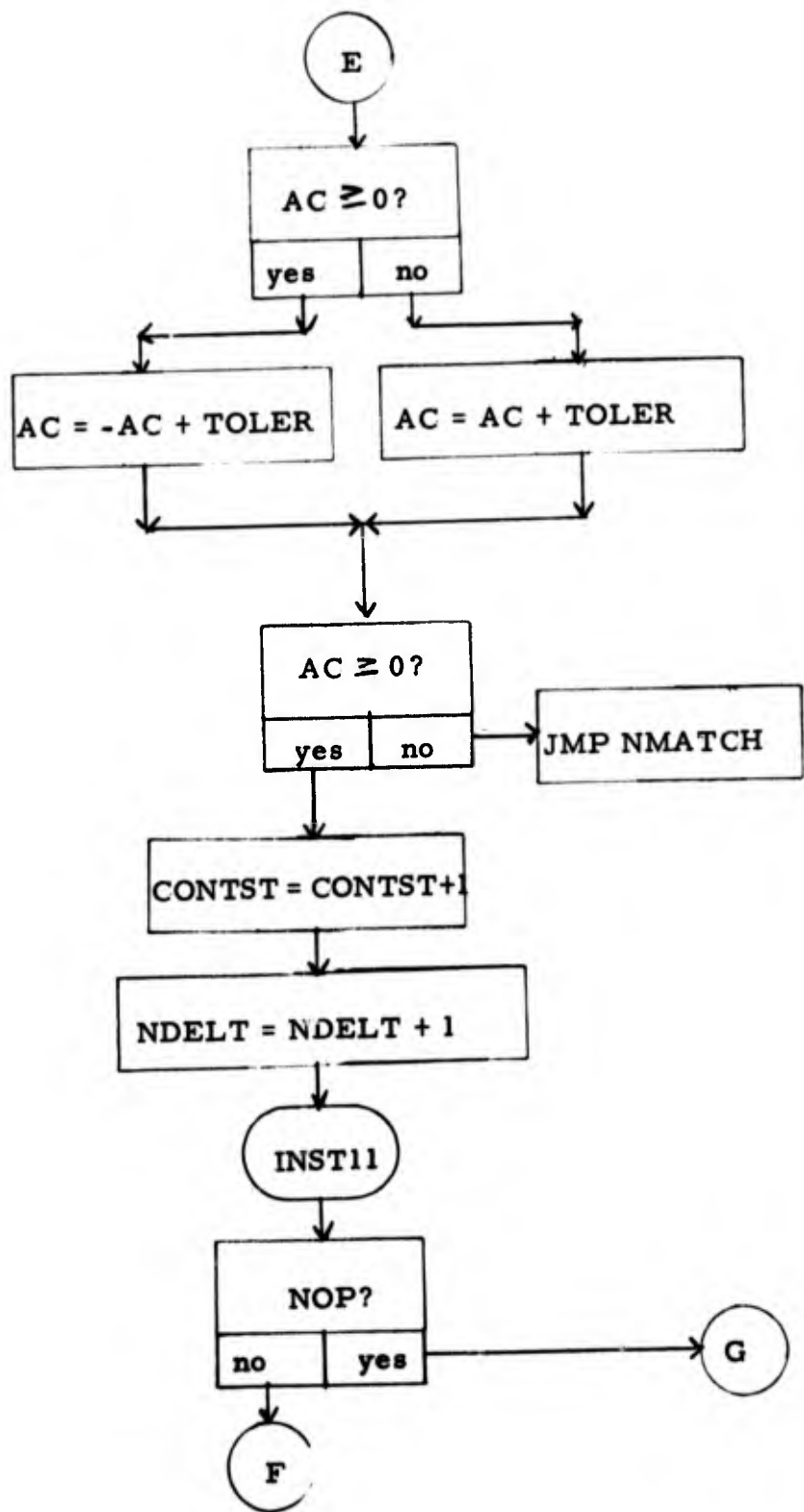


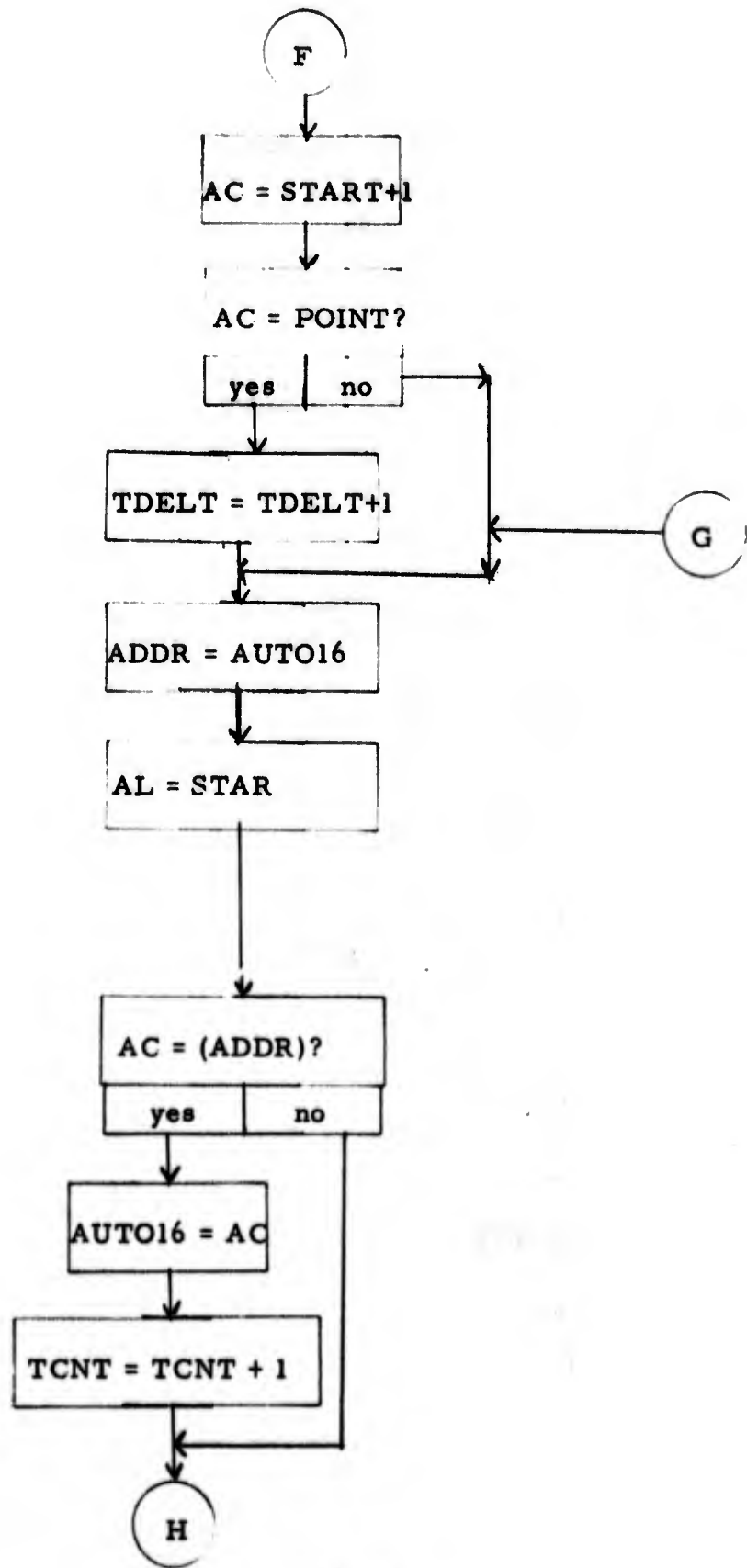


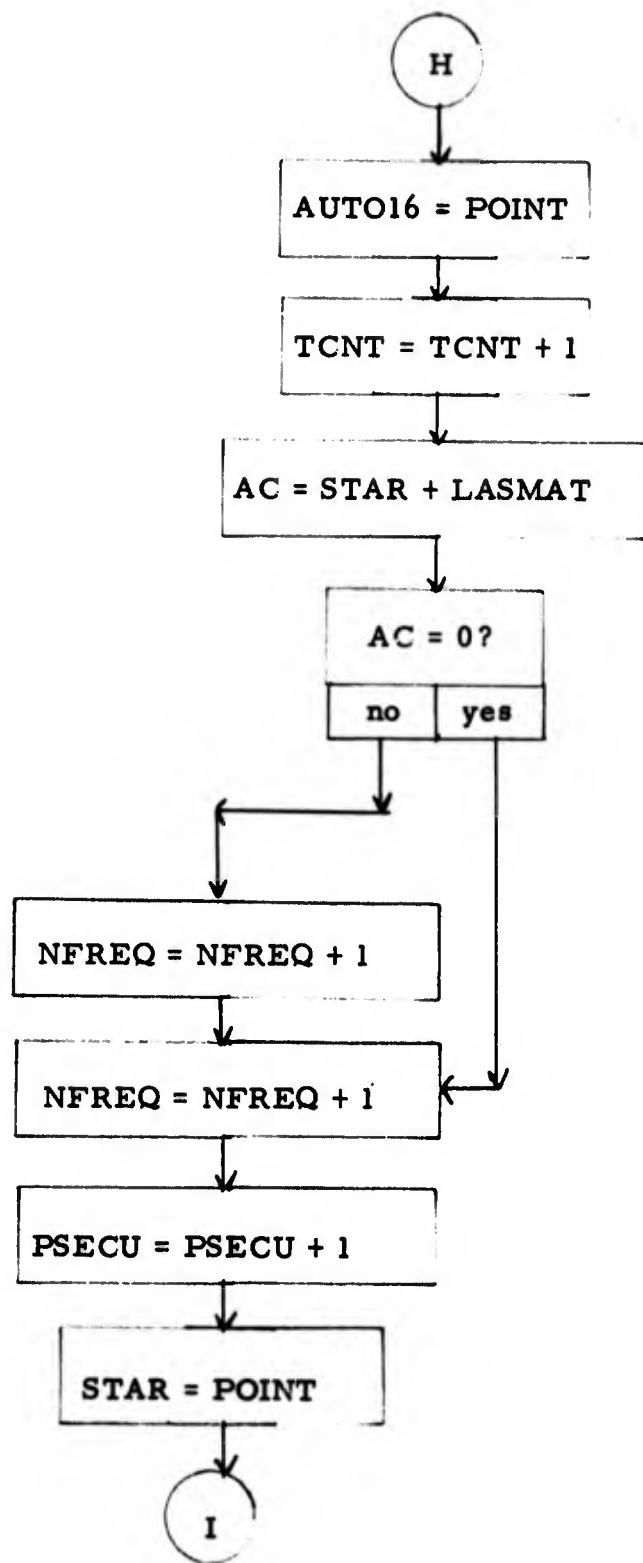


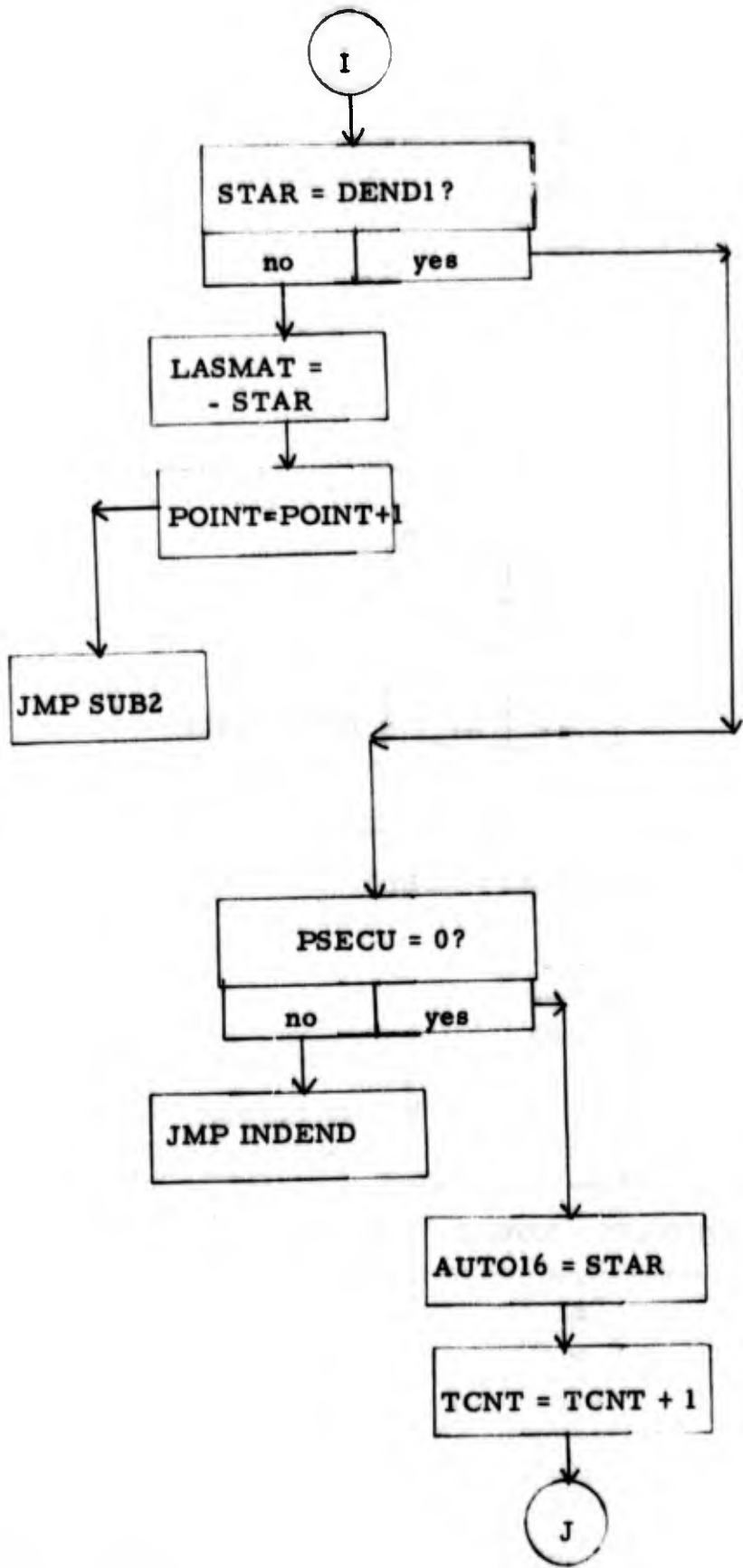


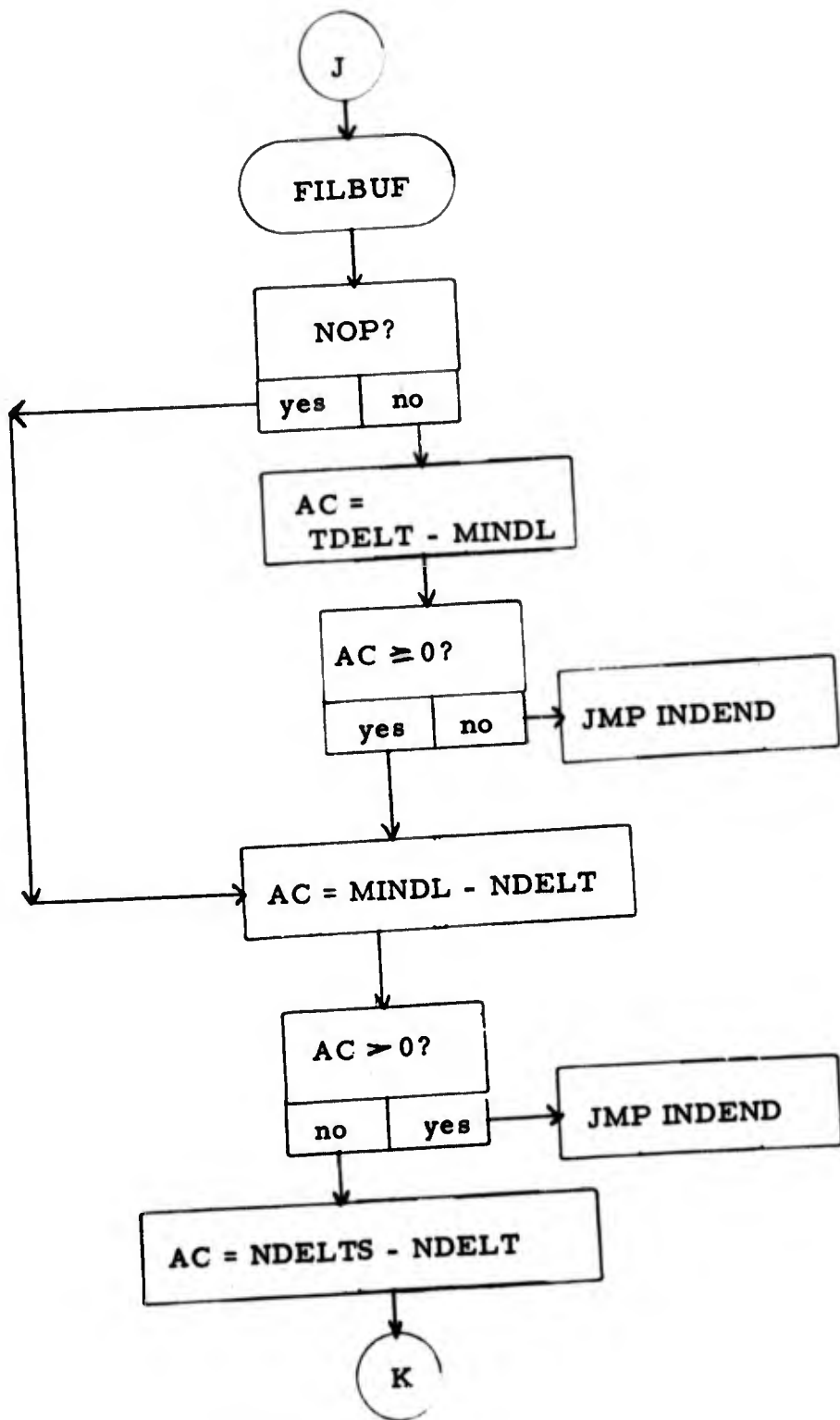


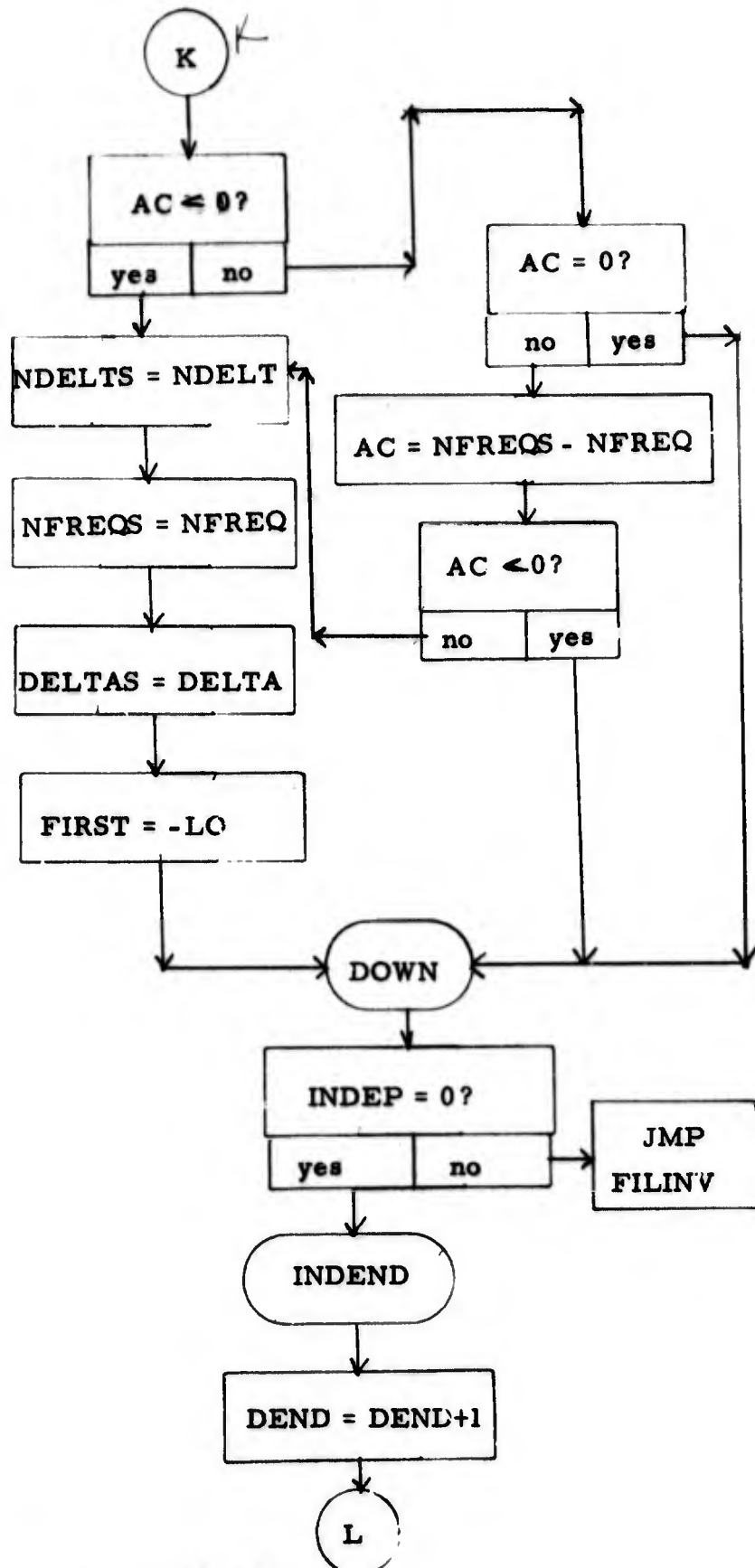


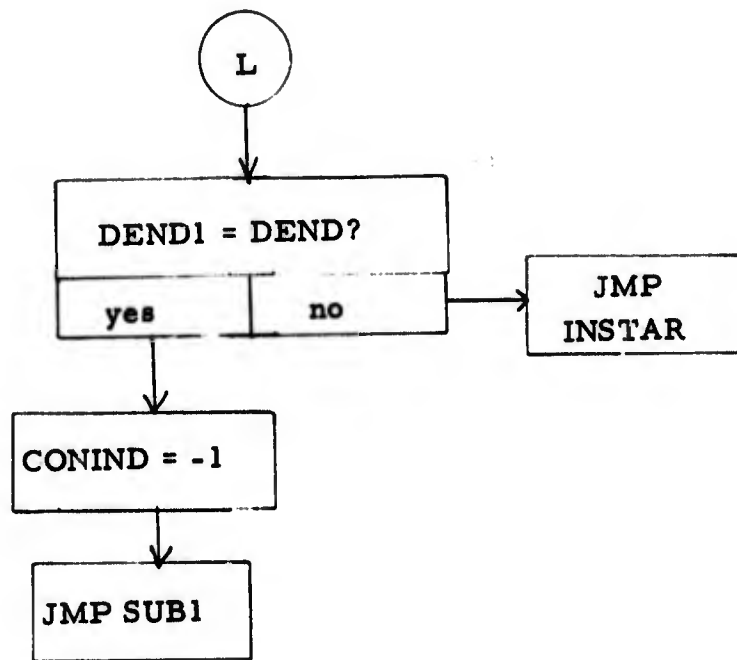




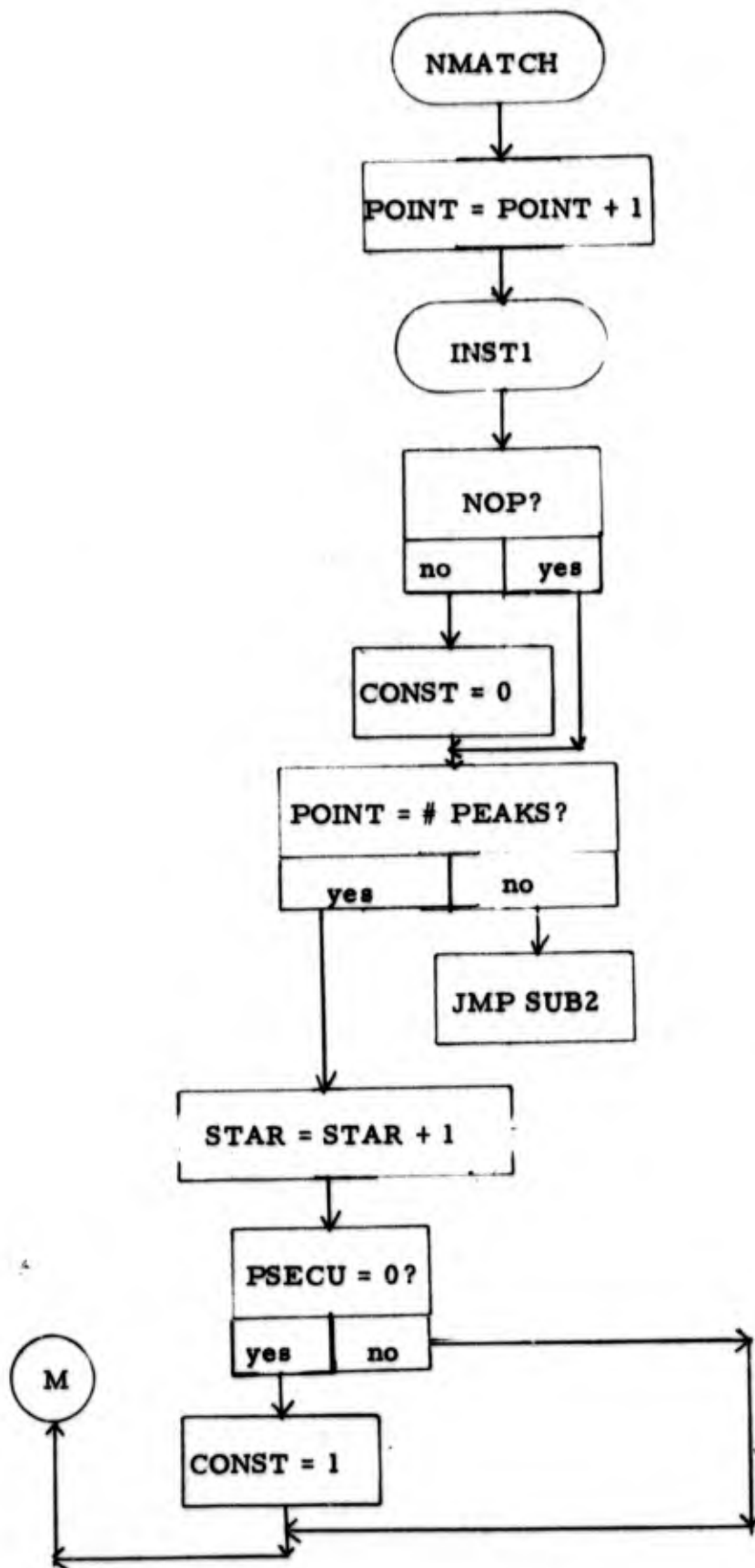


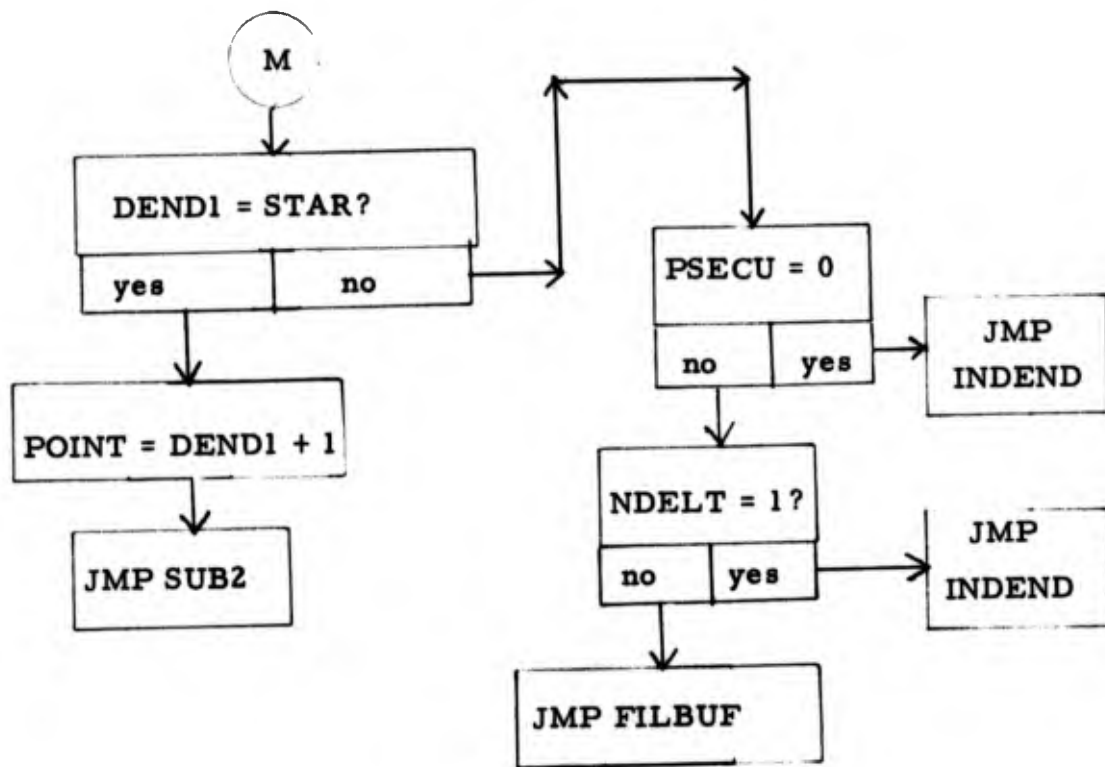


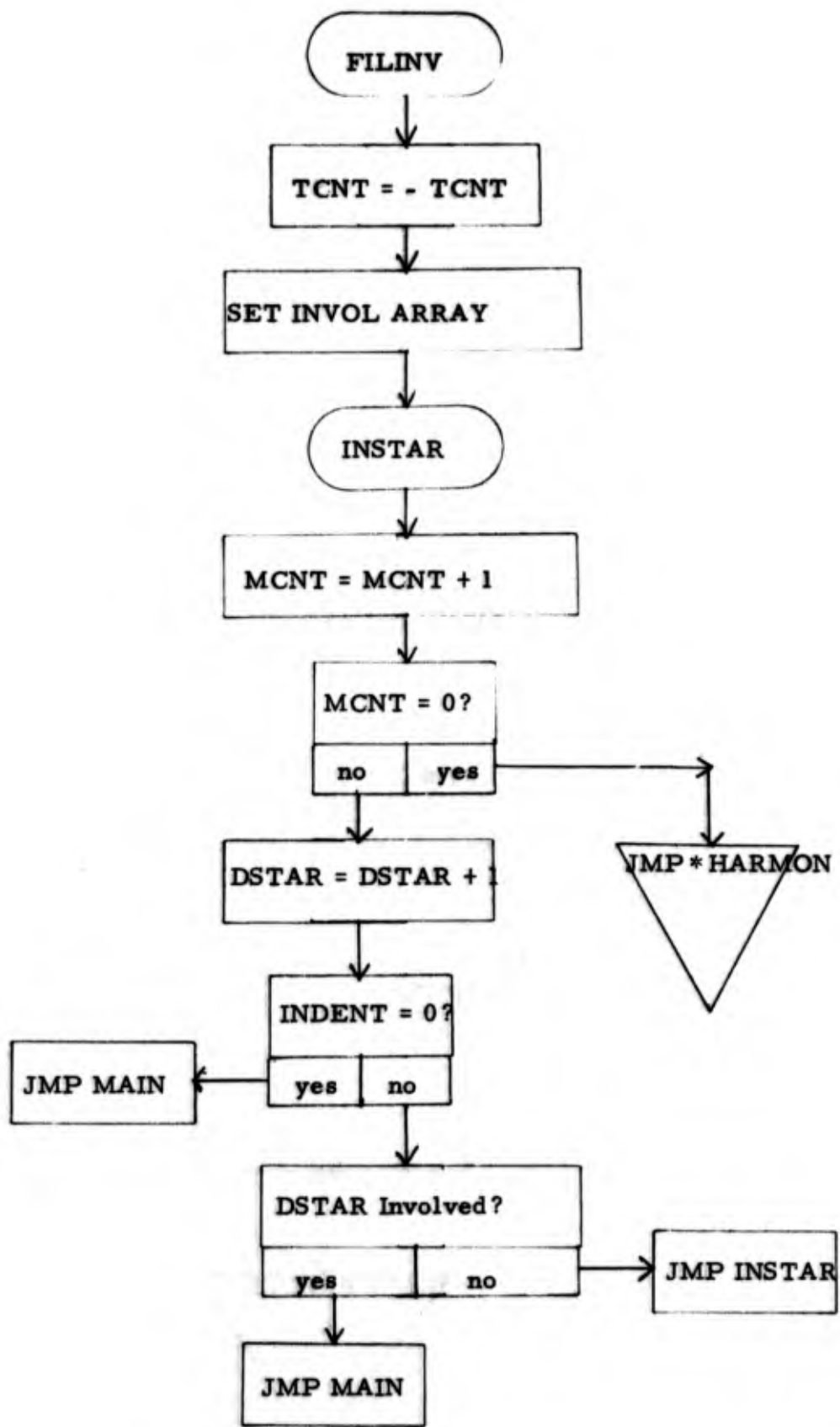


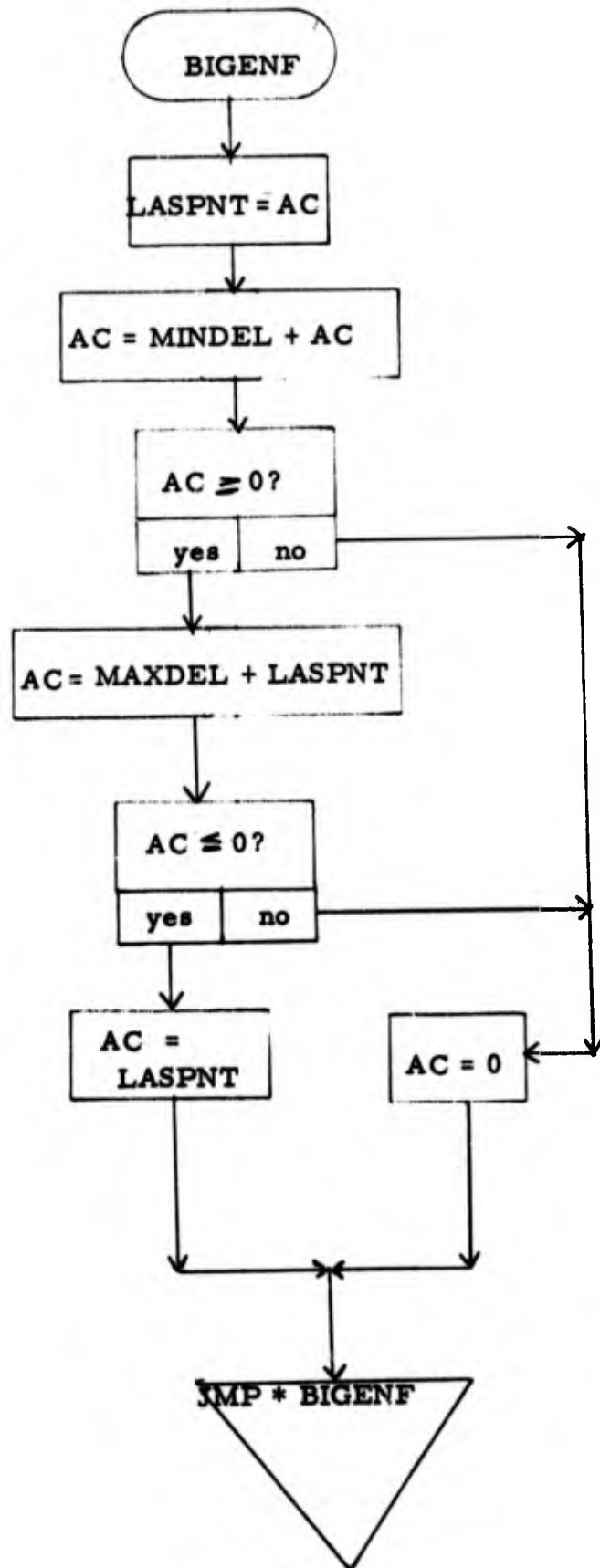






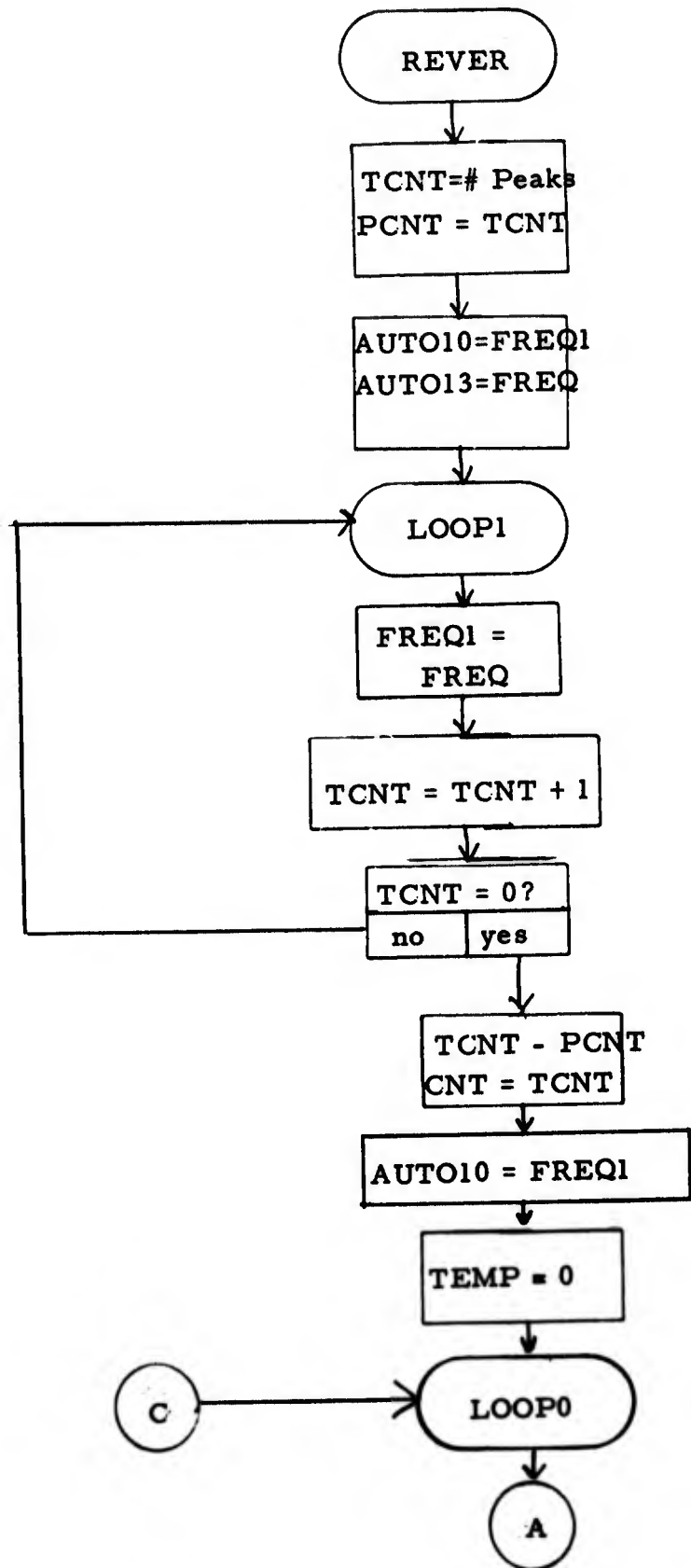


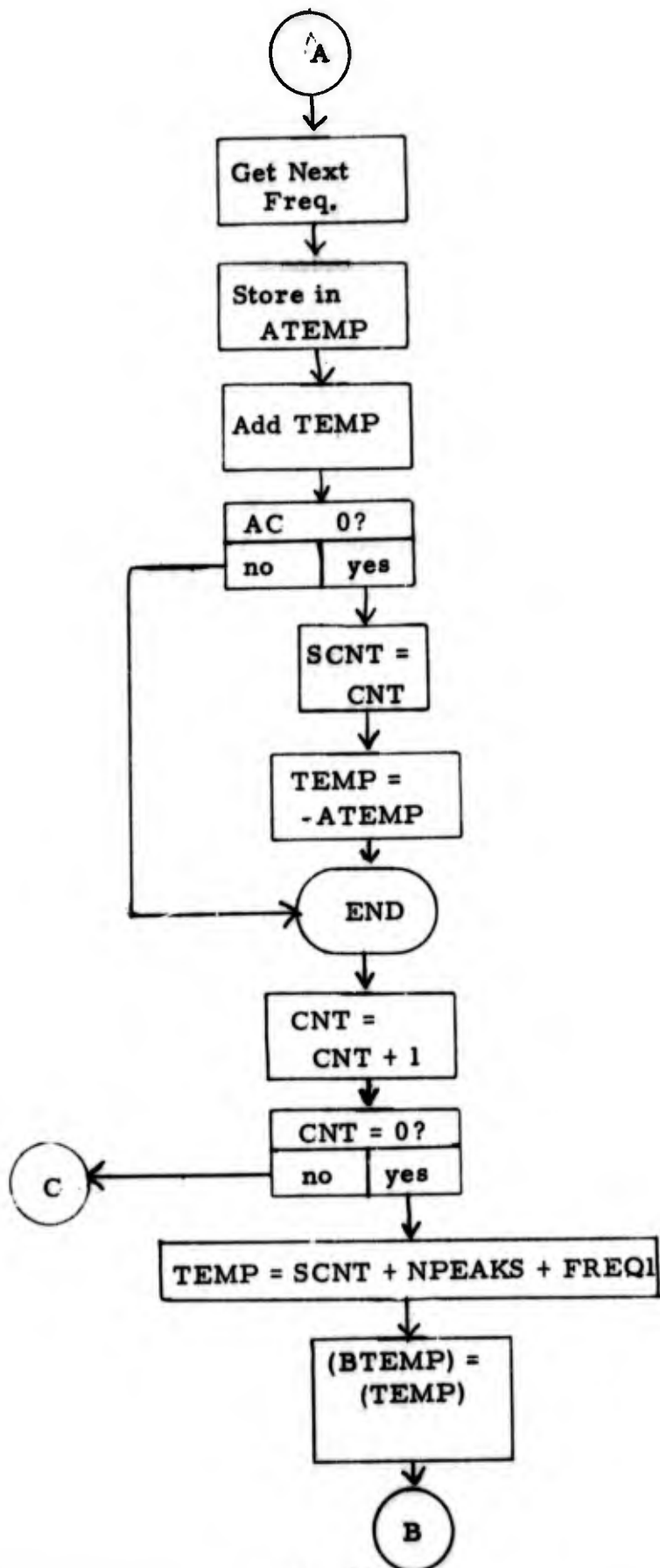


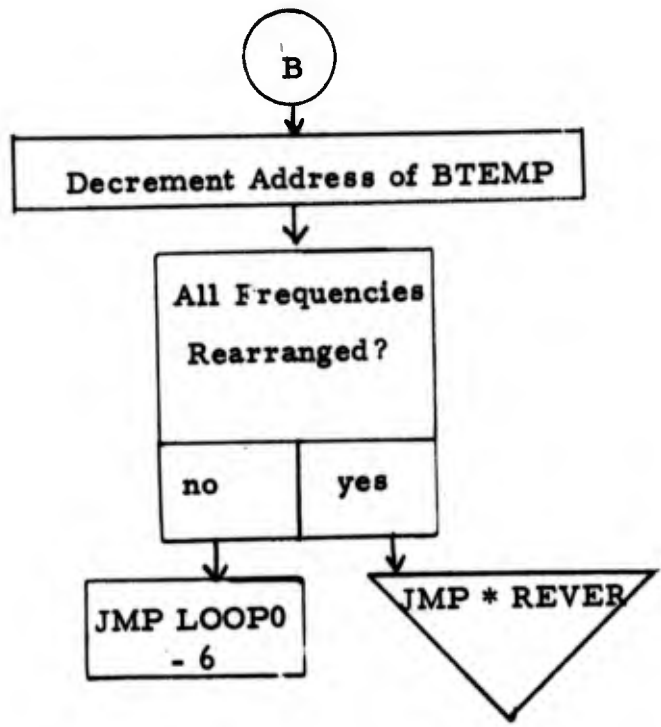


1. Program Name: REVER
2. Language: MACRO
3. Summary: Continue to rearrange frequency arrays of N largest peaks in ascending order according to frequency.
4. Requirements: None
5. Routines Required: None
6. Arrays: FREQ, REVAR, FREQ1
7. GLOBLs: REVER, FREQ, NPEAKS, REVAR
8. Description:

The peak routine returns "N" largest peaks in order of magnitude with the frequency of the largest peak first. The purpose of this routine is to rearrange these peaks in ascending order according to frequency. It searches through the frequency array and finds the largest frequency. It places this frequency in the last position in the new frequency array. This sequence is continued until "N" frequencies are rearranged.









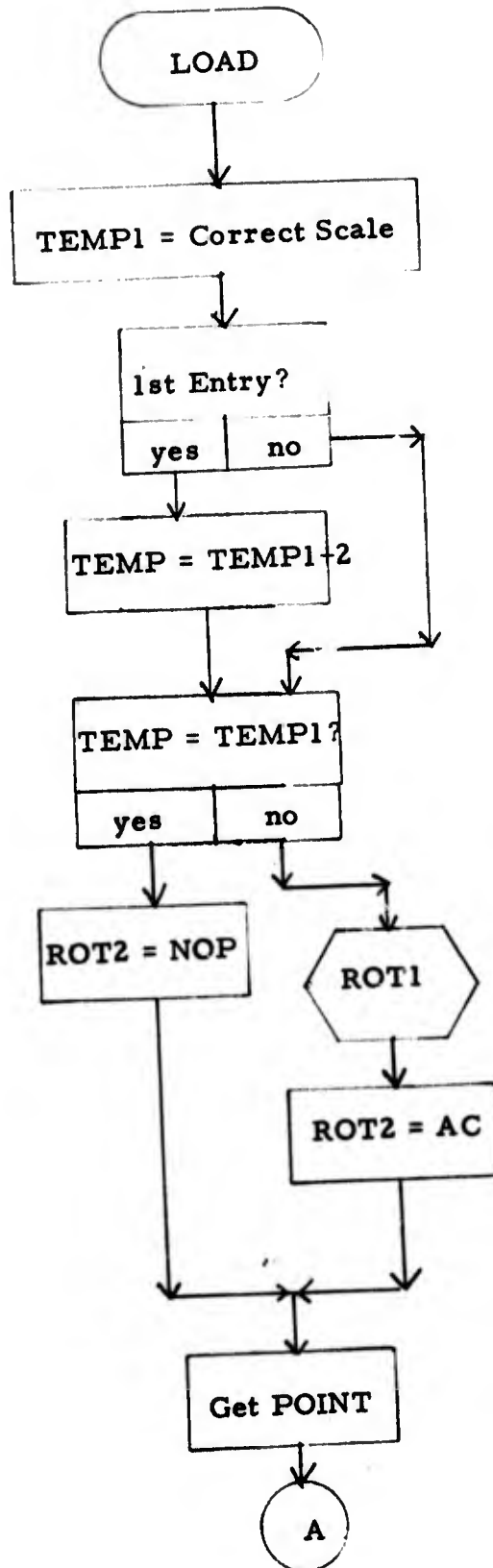
1. Program Name:       LOAD
2. Language:            MACRO
3. Summary:            This routine performs a sliding average of five power spectrums and checks for threshold criteria.
4. Requirements:       None
5. Routines Required:   TSCALE, FEATURE
6. Arrays:             IAR1, IAR2, IAR3, IAR4, IAR5, ISUM, BREAL, IMAG
7. GLOBLs:             IAR1, IAR2, IAR3, IAR4, IAR5, ISUM, BREAL, IMAG, LOAD, SELECT, TSCALE, JSHF, FEAT1, FEAT2, .DA
8. Description:

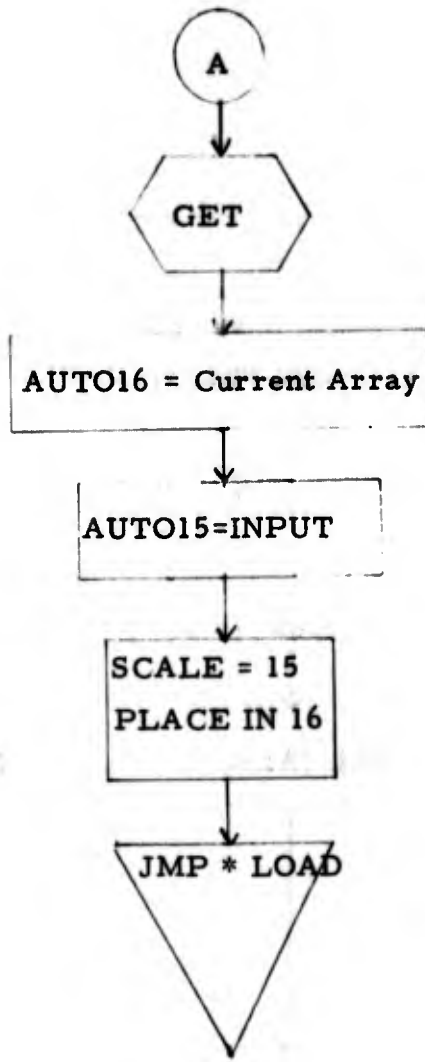
The routine LOAD has two entry points, LOAD and SELECT. The LOAD entry point is entered for five times and then SELECT is entered for the remainder of the run. Feature extraction is performed on individual spectrums and on the average of five spectrums. The LOAD entry point fills arrays IAR1 - IAR5 and does any shifting required to make their scale factors equal to the first one.

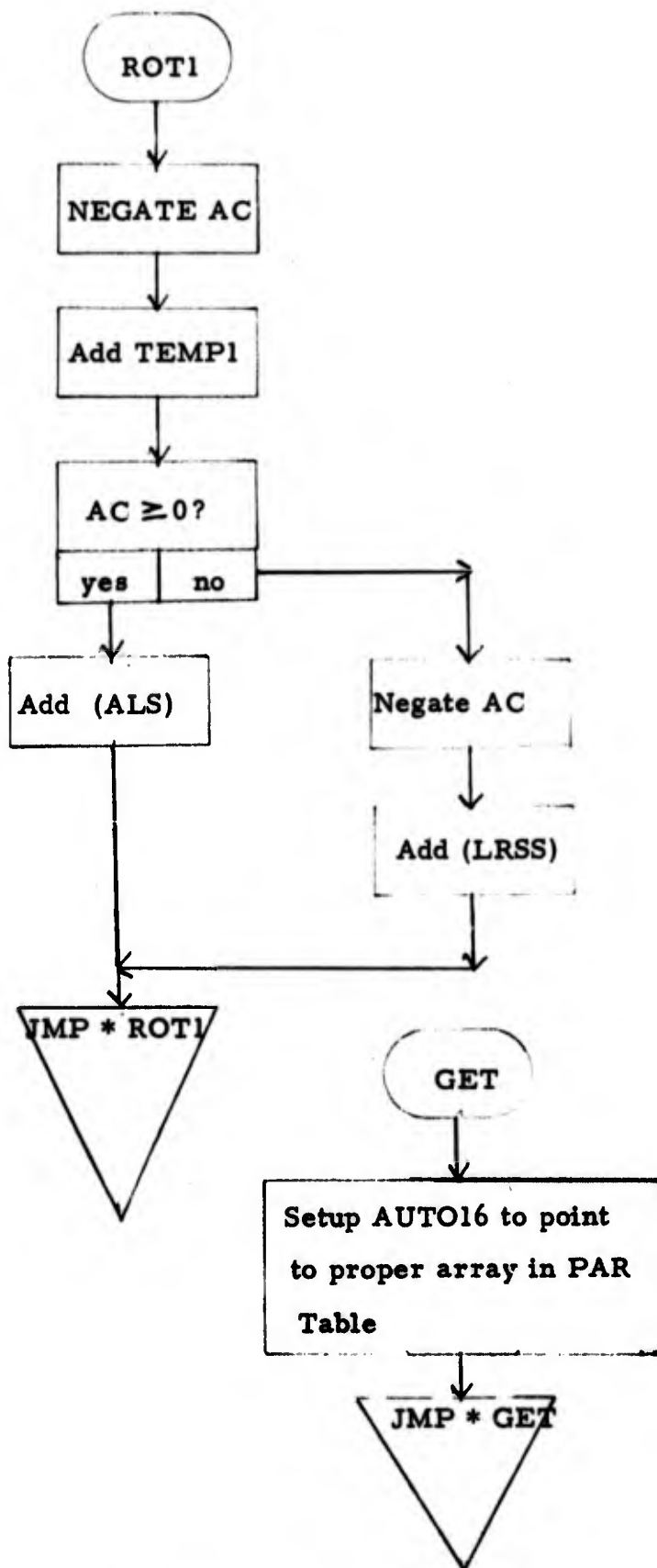
Each time "SELECT" is entered the current and replacement array pointers are updated. The first time "SELECT" is entered the current array is retrieved and feature extraction performed. In each successive entry, the oldest array is replaced by a new .5 sec of spectrum and then the current array is operated on as above.

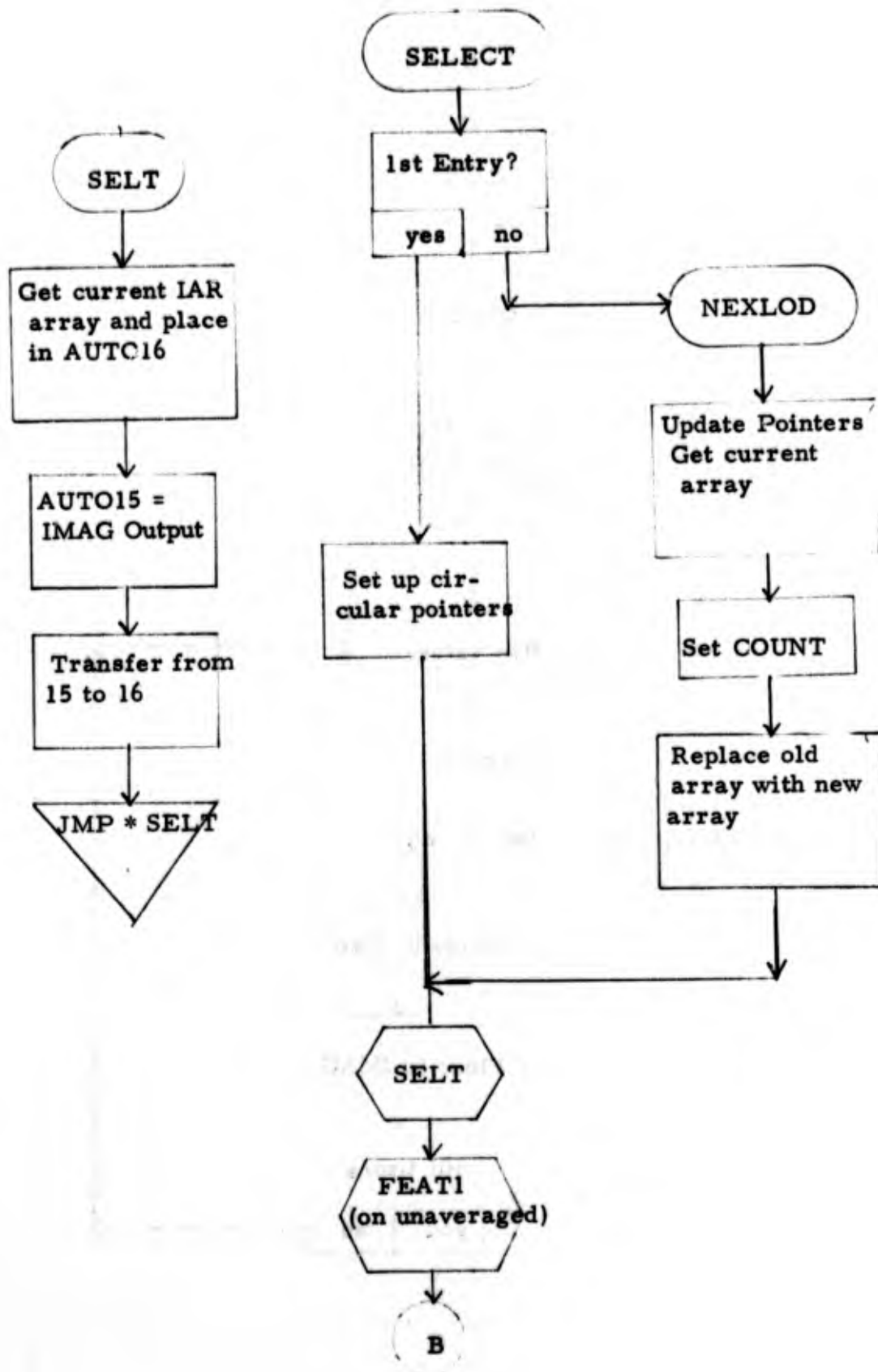
After feature extraction on the unaveraged signal is performed, the five arrays are averaged for feature extraction. After averaging, the routine "TSCALE" is called to check the threshold criterion. If the signal is of sufficient magnitude feature extraction is performed on the averaged spectrum; if no, the routine returns to JTHPNT set to non-zero.

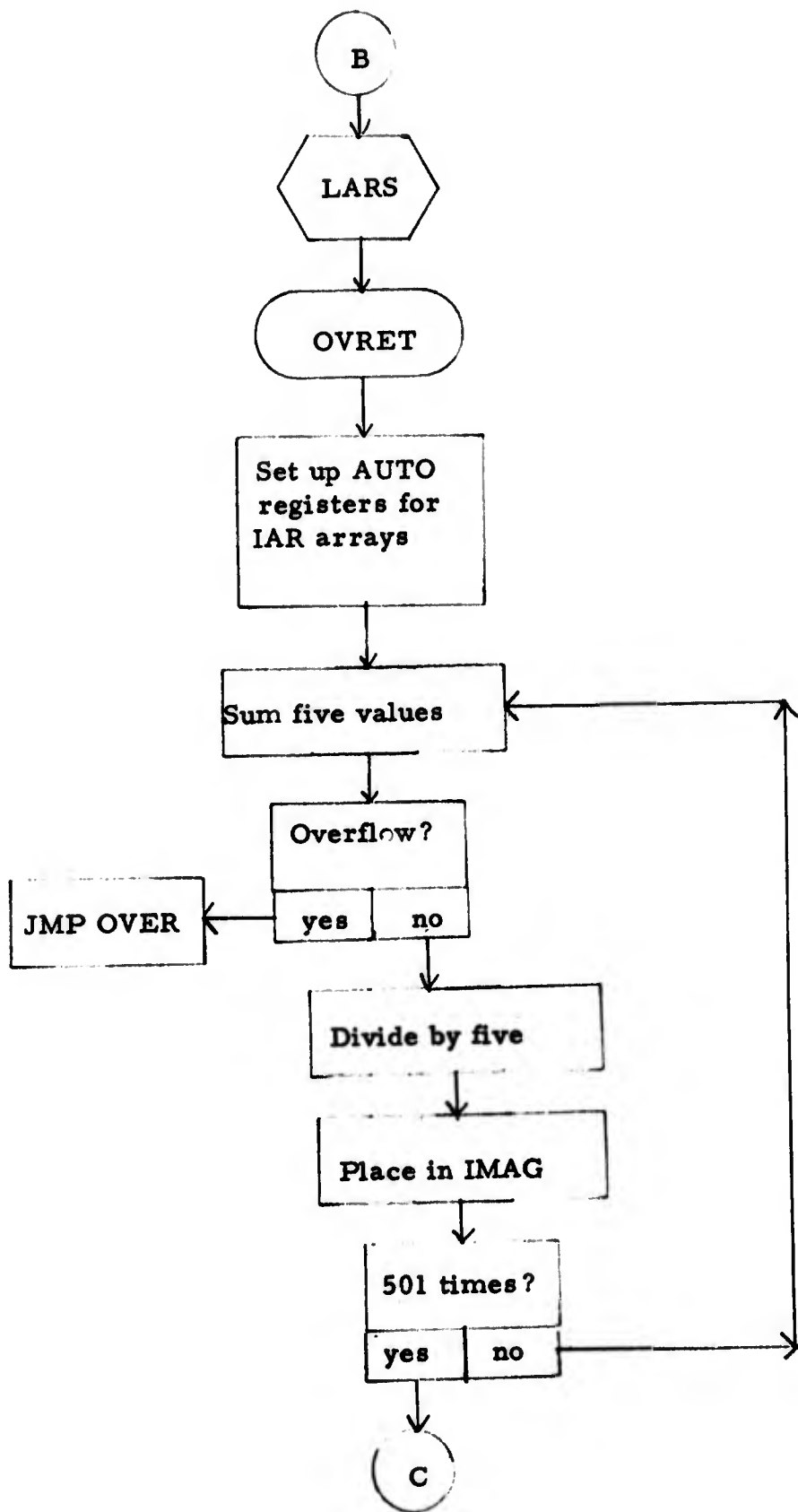
LOAD

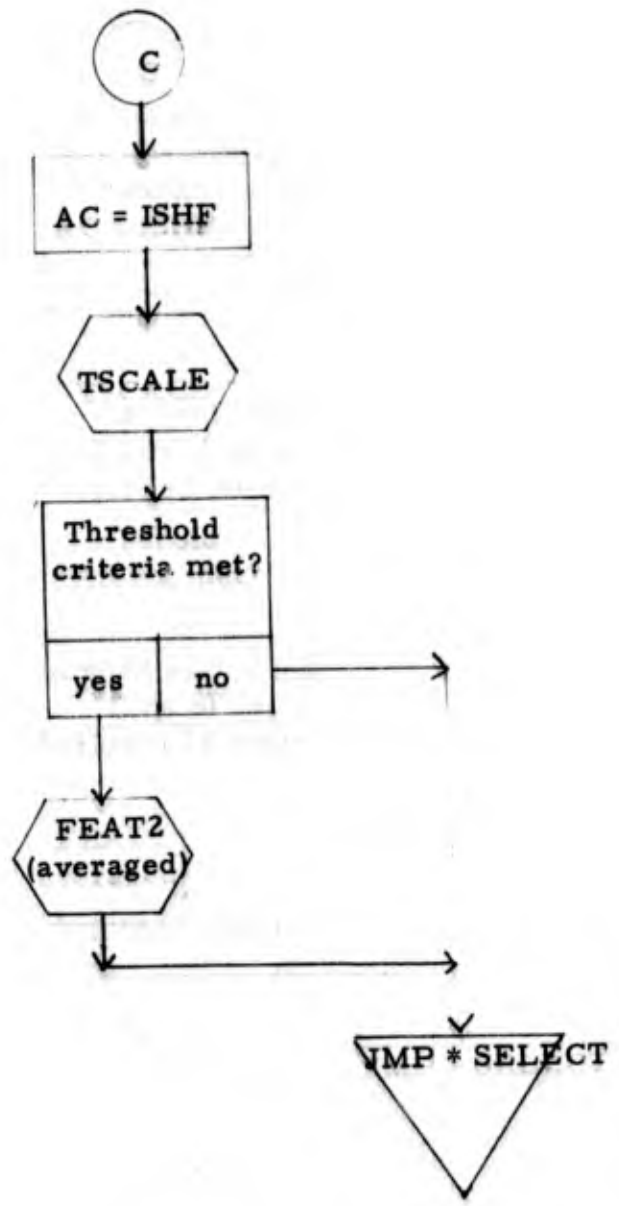


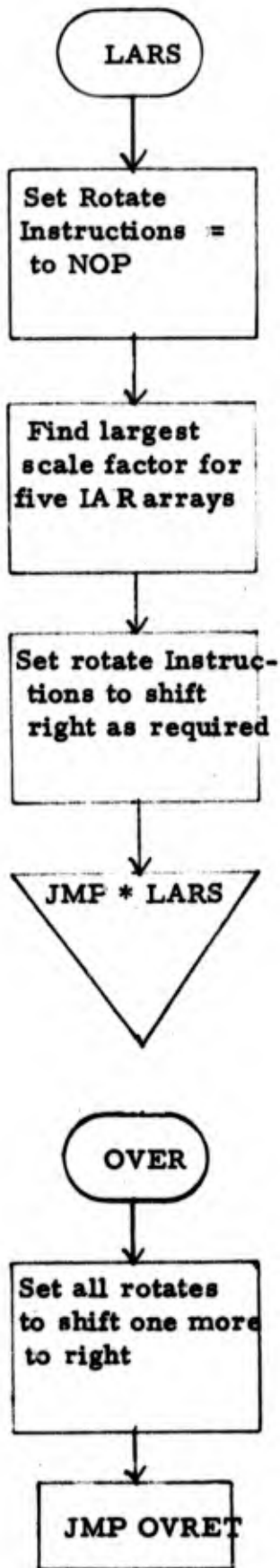








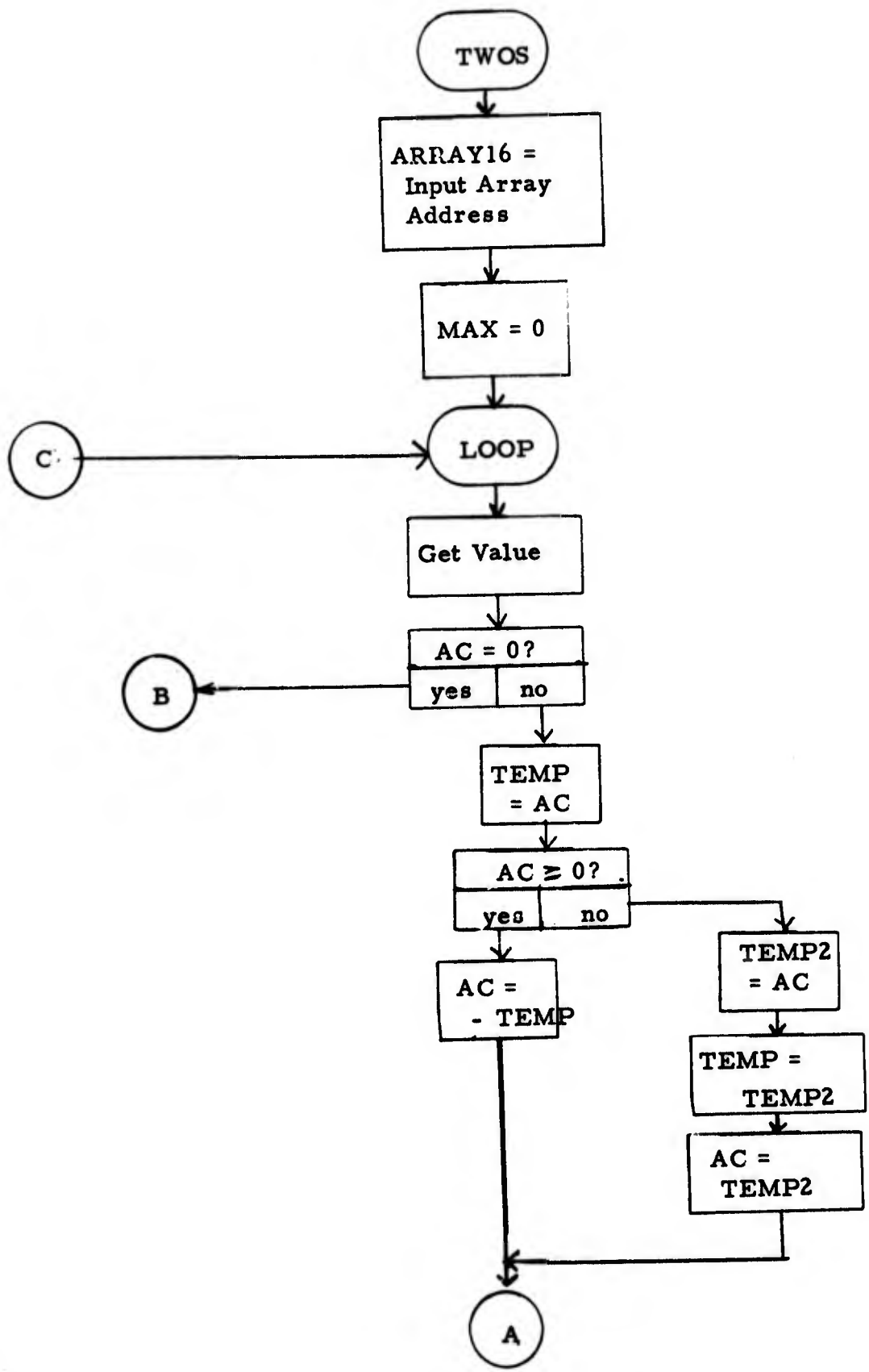


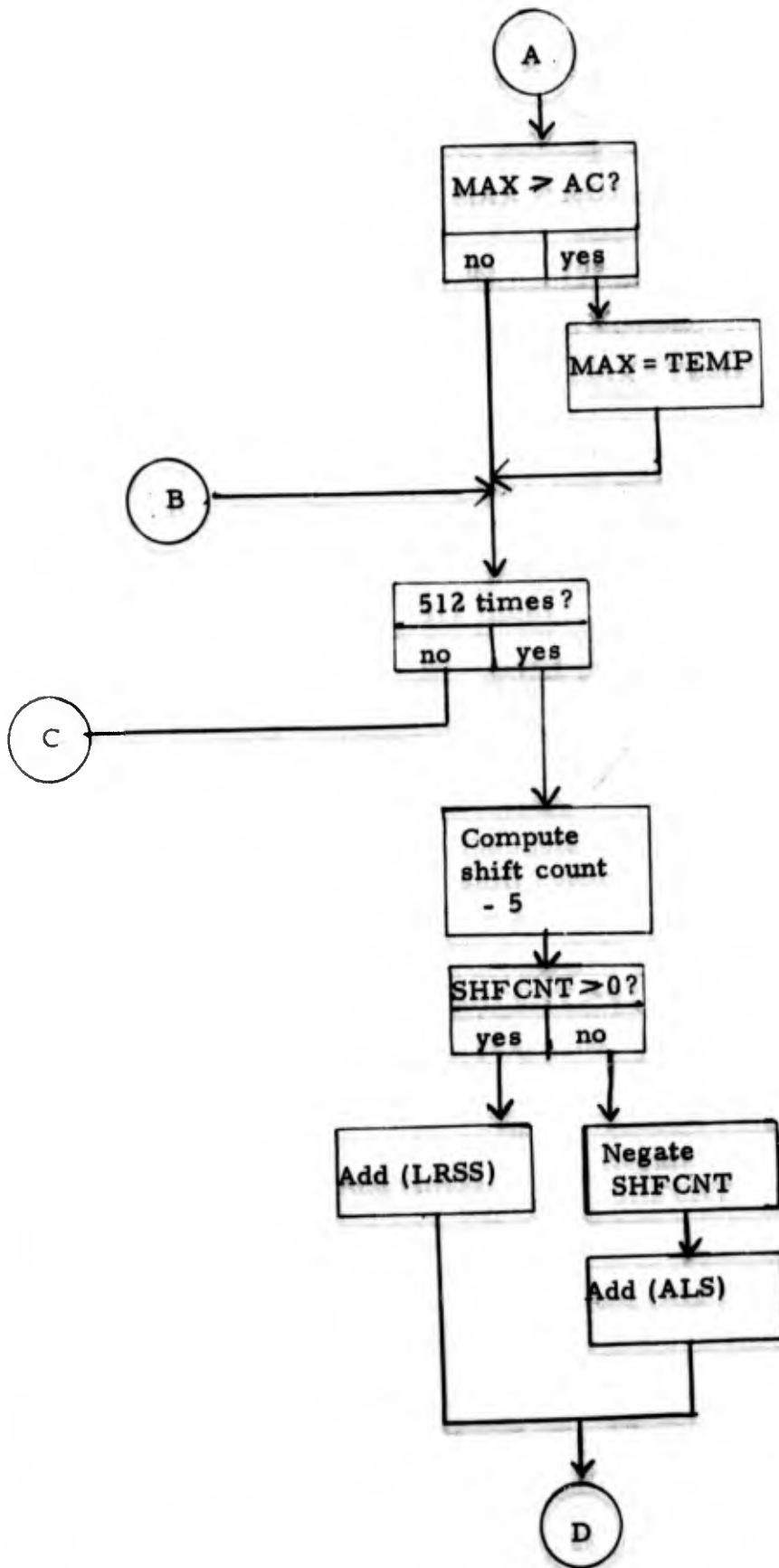


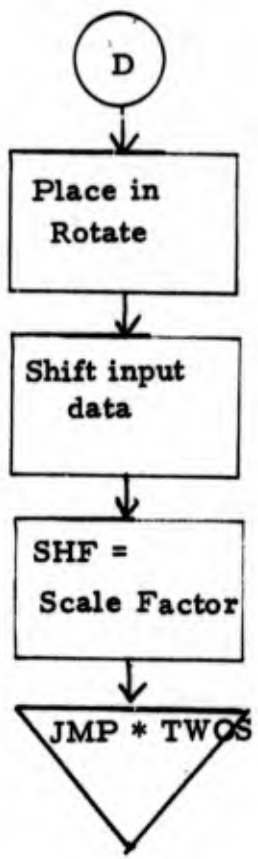


1. Program Name: TWOS
2. Language: MACRO
3. Summary: Routine to scale input data and set up scale factor.
4. Requirements: None
5. Routines Required: None
6. Arrays: INRAY
7. GLOBLs: INRAY, .DA, TWOS
8. Description:

The input data is 12 bits left adjusted from the A/D converter. The FFT expects large numbers, but less than 1/4 maximum. The purpose of this routine is to determine the maximum absolute value and compute a shift count and scale factor. The input data is shifted right or left to meet the above criteria. The shift count, either positive or negative, is multiplied by two and added to the built-in scale factor of the FFT. This scale factor is used in averaging and thresholding in LOAD.

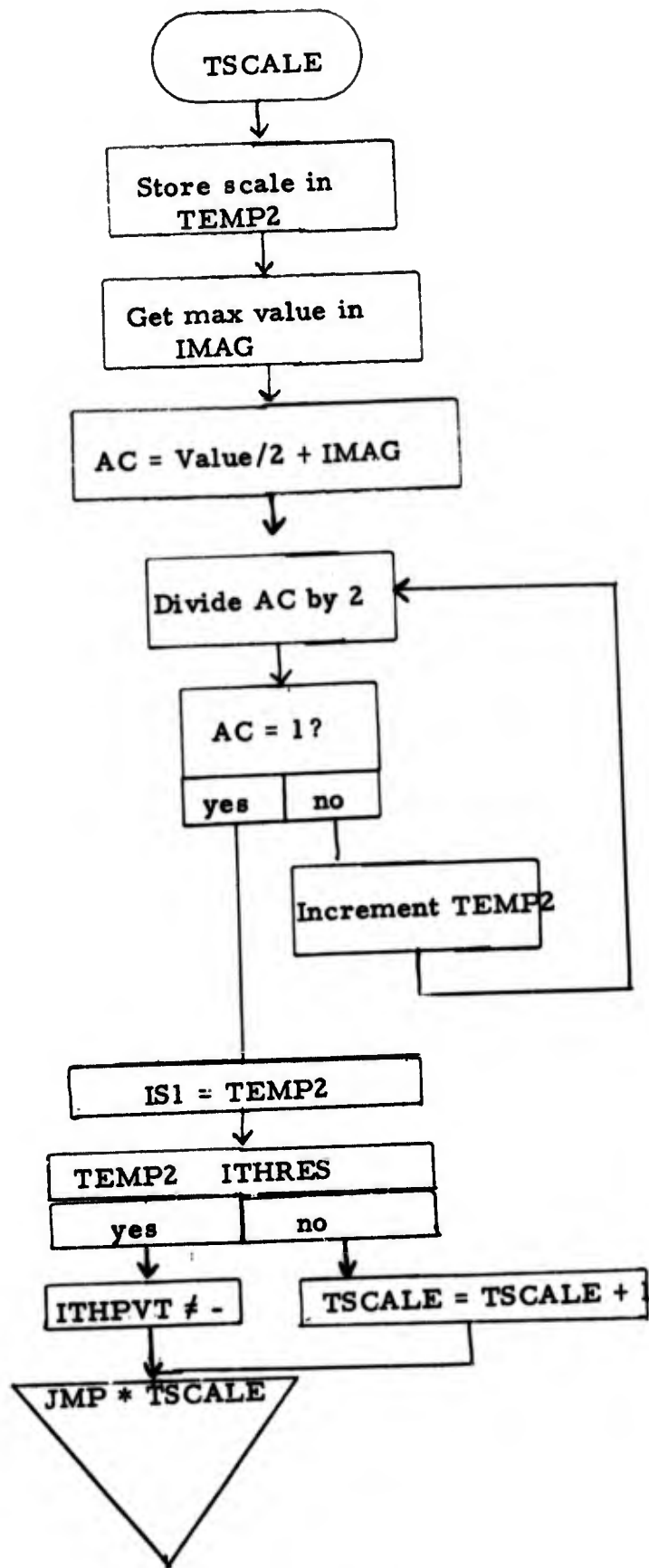






1. Program Name: TSCALE
2. Language: MACRO
3. Summary: Routine for threshold detection to reject background and weak signals.
4. Requirements: None
5. Routines Required: None
6. Arrays: IMAG
7. GLOBLs: IMAG, TSCALE, ITHPNT, ITHRGS, IS1
8. Description:

The routine takes the current scale and the maximum value of the average of five FFT's and converts this to a scale factor. This scale factor is compared to the threshold set by the user. If it is less than this threshold the threshold pointer is set to non-zero and a normal return to LOAD is executed. If not, the return address is incremented by one before returning to LOAD.

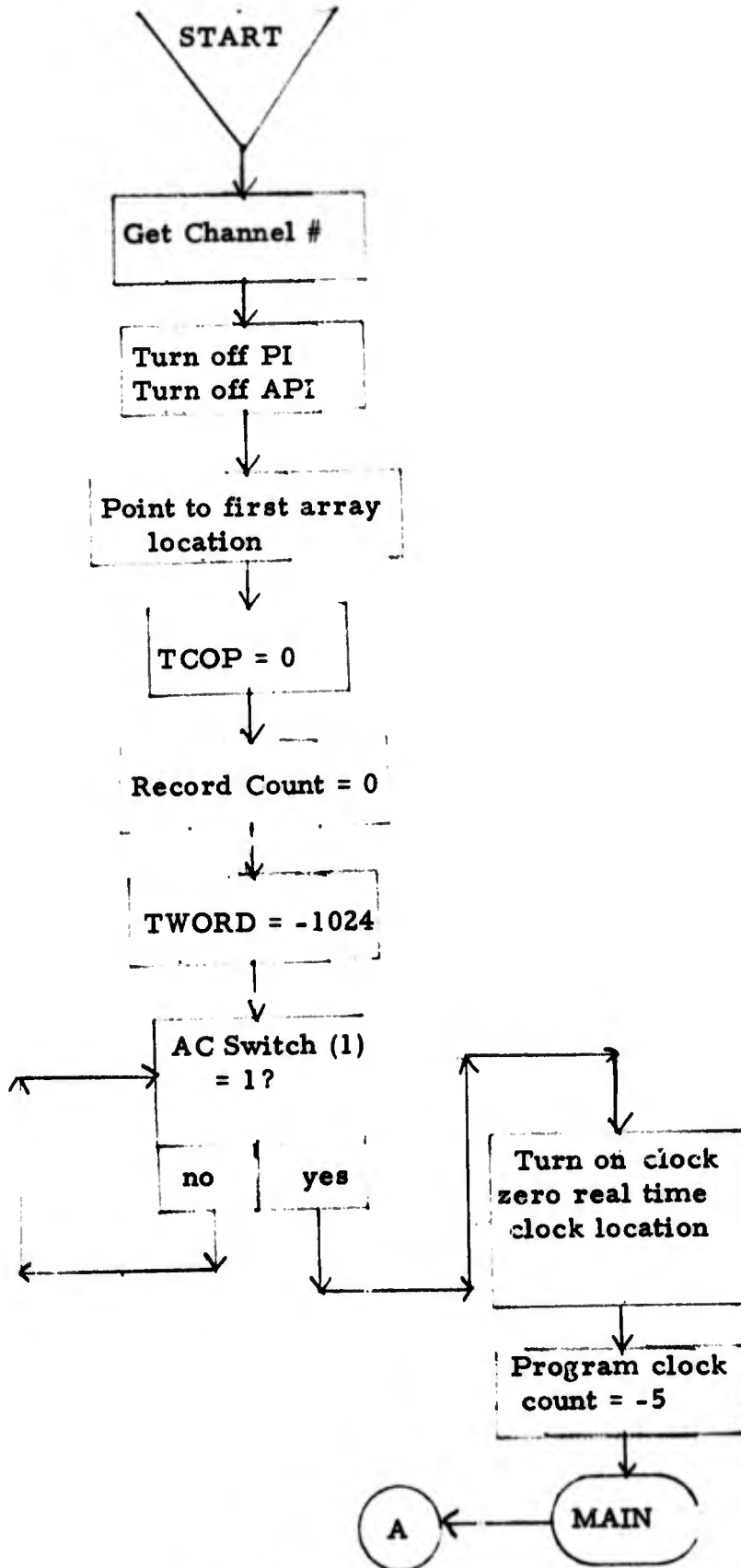


1. Program Name: ANLOG
2. Language: MACRO
3. Summary: Routine to perform digitizing of analog signal at 2 KHz rate. Routine stores signal in .5 sec records on magnetic tape.
4. Requirements: Real clock set to 10 KHz, mag tapes on 0 and 1, A/D set to 12 bits.
5. Routines Required: None
6. Arrays: INRAY, IMAG
7. GLOBS: ANLOG, .DA. INRAY, IMAG
8. Description:

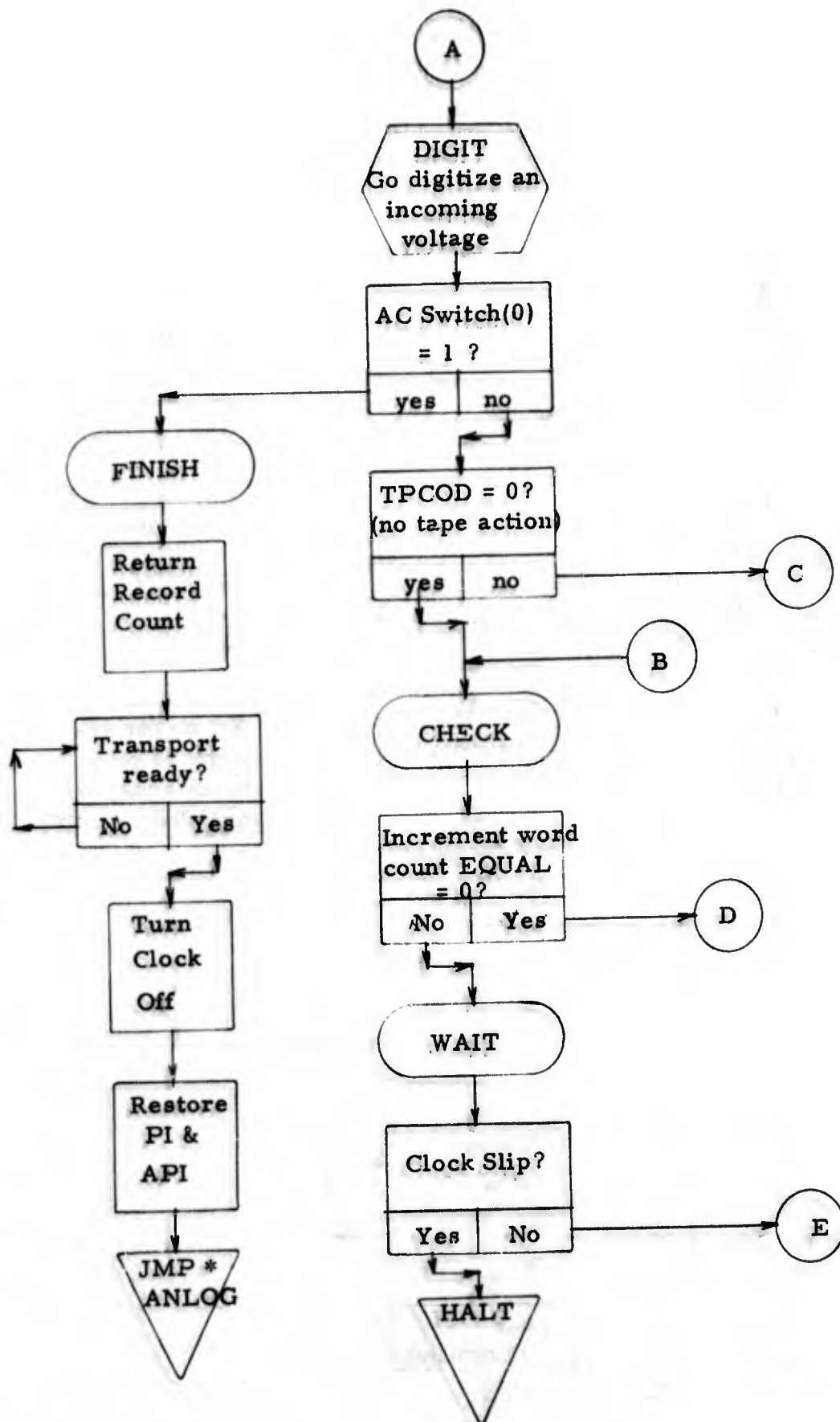
The routine ANLOG performs the digitizing function for the simulation system. The analog signal from either tape recorder or microphone are input to the A/D buss. The digitizing routine initiates a conversion and reads the buffer every .5 msec which corresponds to a 2 KHz sampling rate. The dynamic range of the A/D is 12 bits. The values are placed left-adjusted in one of two buffers. Two buffers are used so that in the case of a magnetic tape error, one rewrite with an extended record gap can be made. Each buffer size is 1025 words with the last word being a record count.

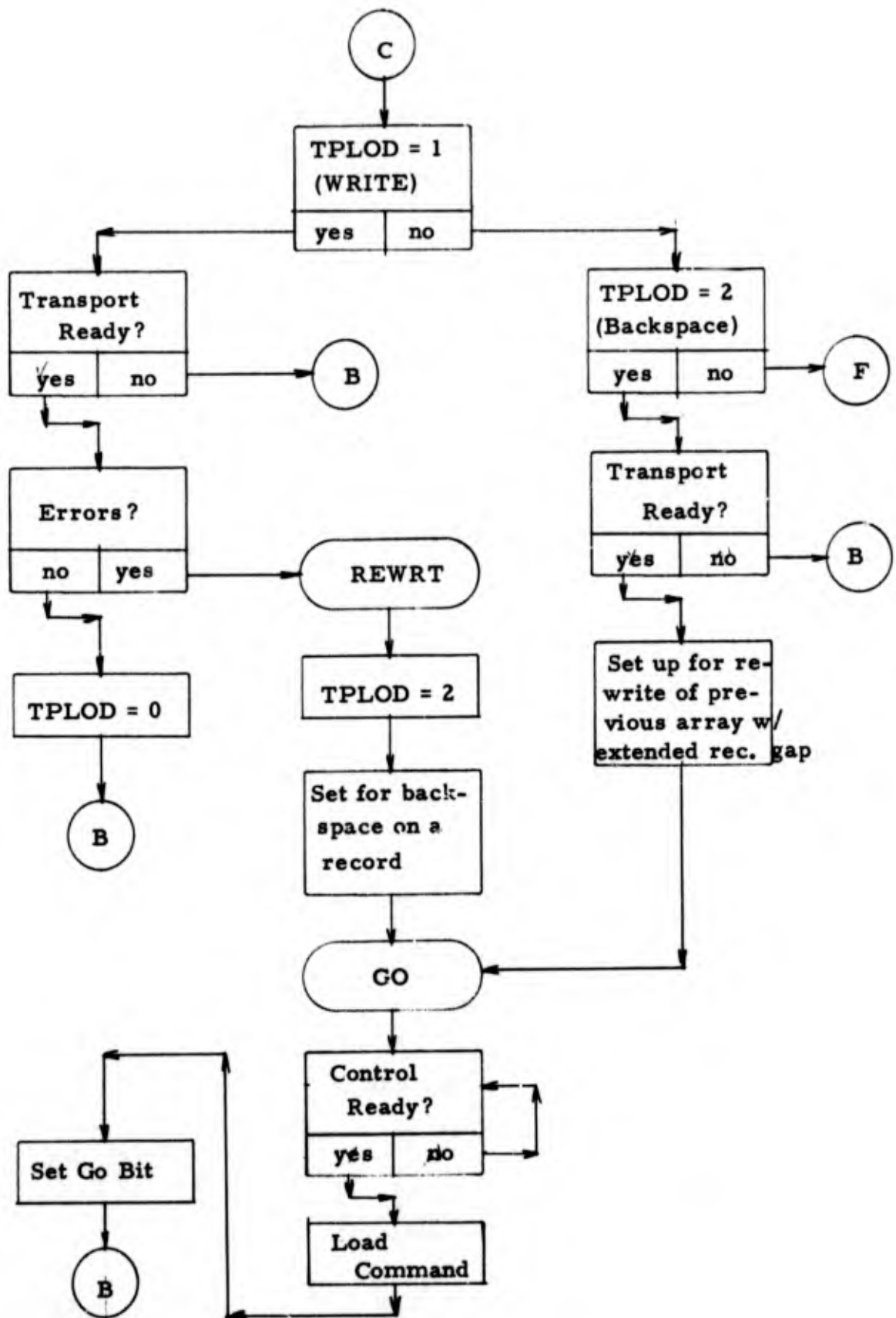
The real-time clock must be set to 10 KHz, the word size of the A/D to 12 bits, and the mag tape unit must be set to zero.

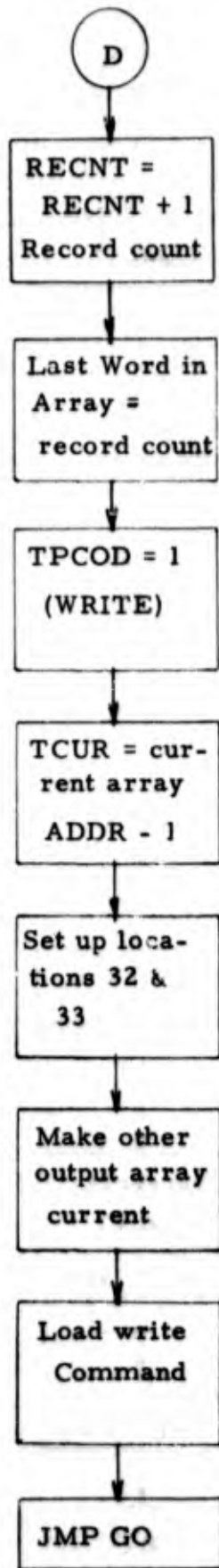
ANLOG

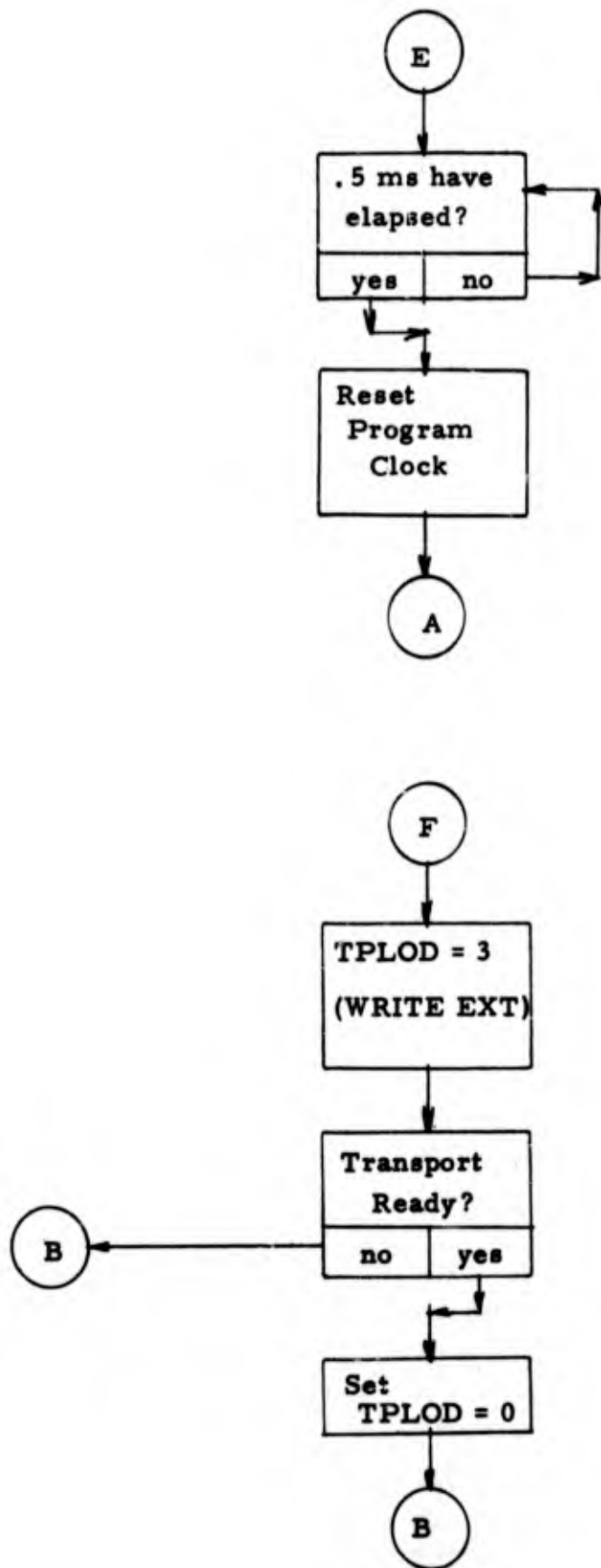


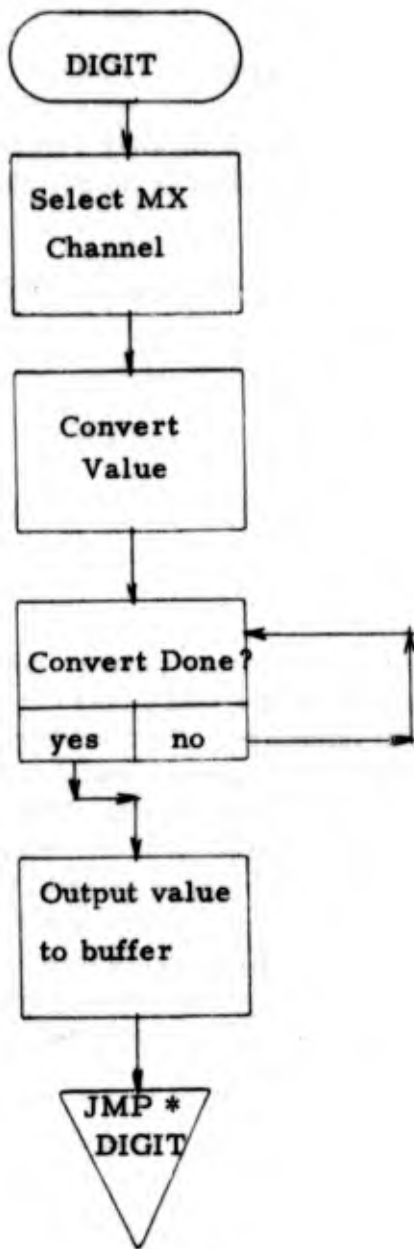






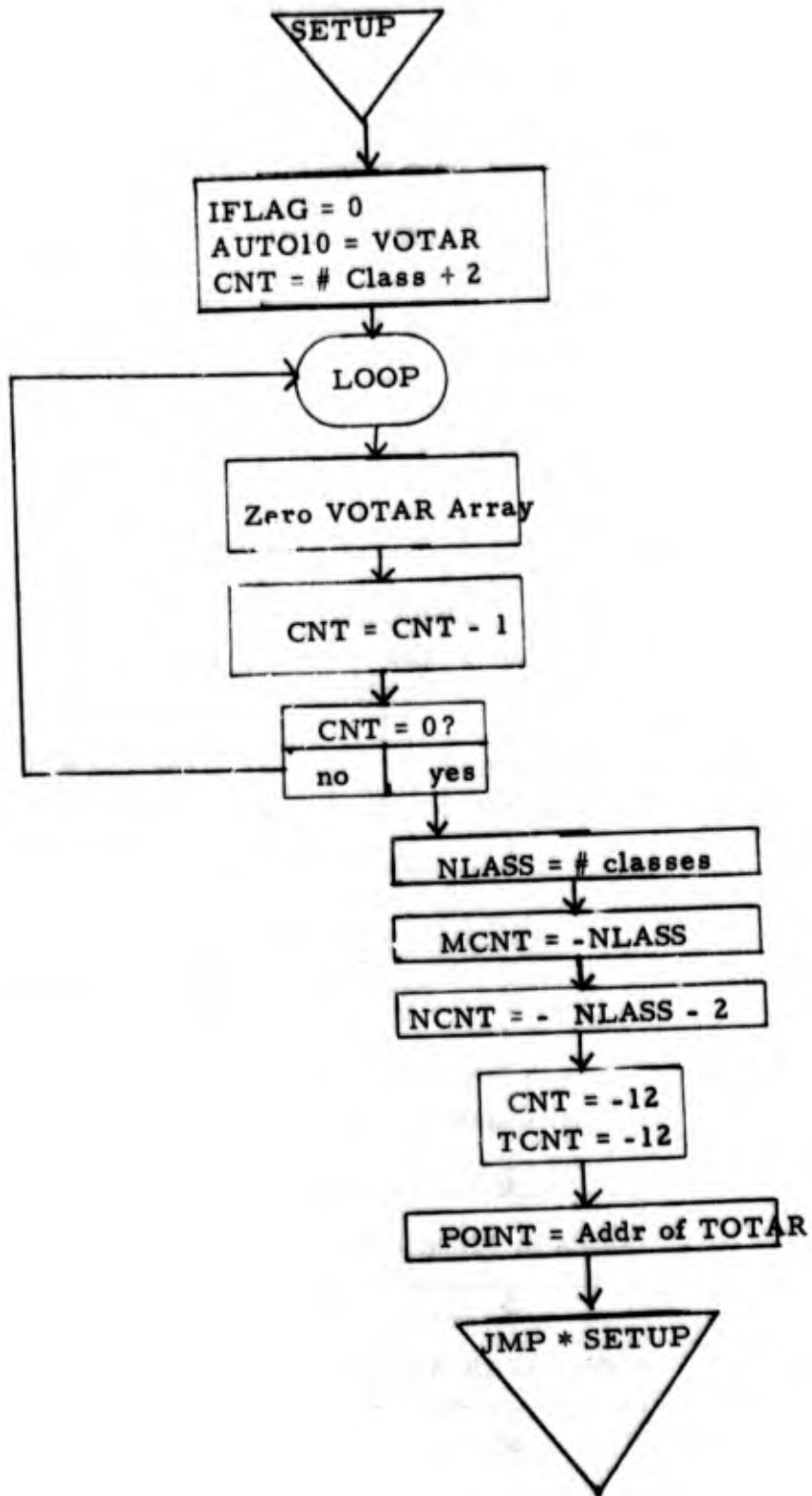


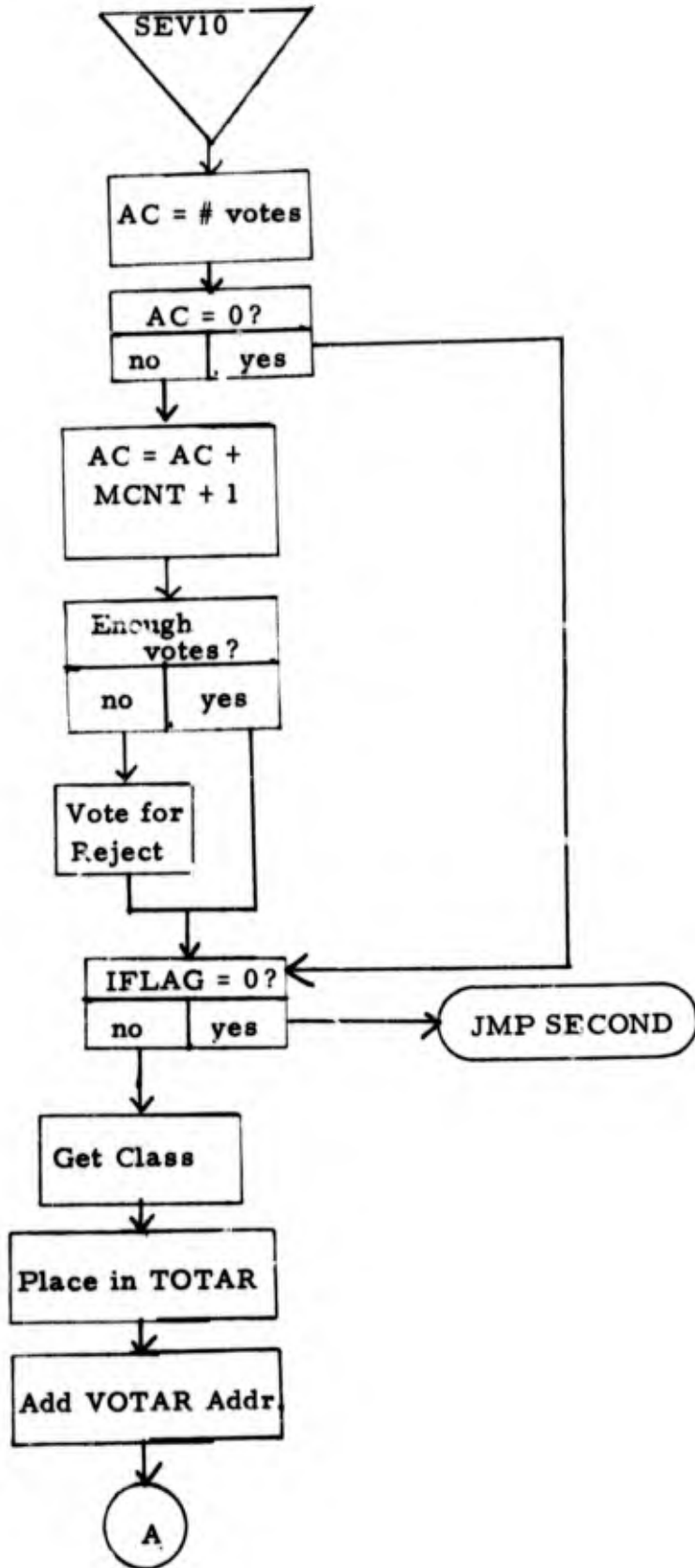




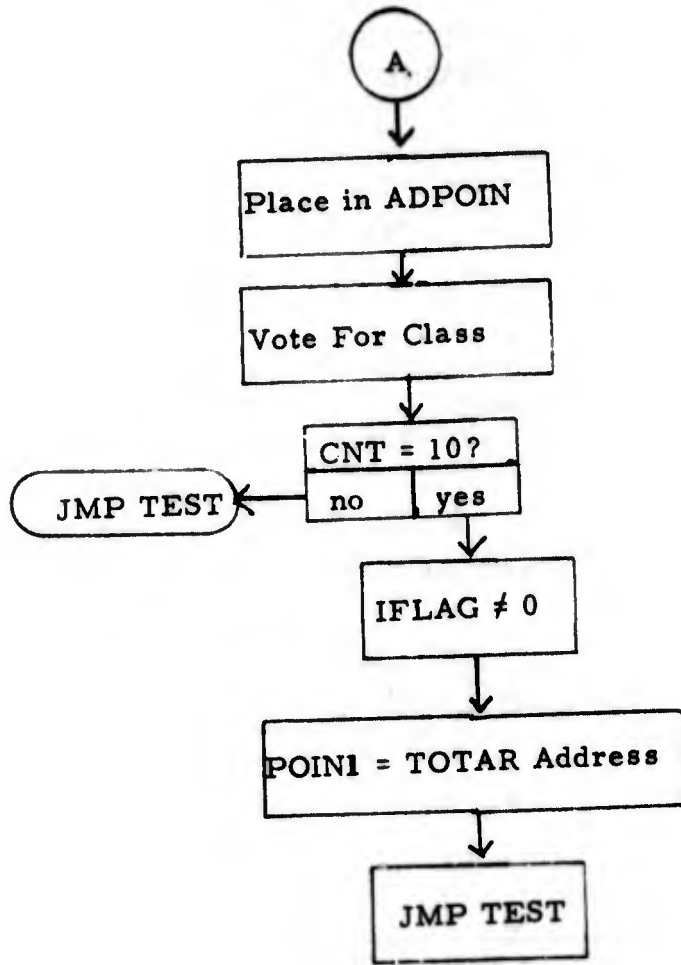
1. Program Name: SEV10
2. Language: MACRO
3. Summary: Routine to keep running talley of classes receiving votes and to output the class receiving 7 out of 10 votes.
4. Requirements: Prior execution of DOTP
5. Routines Required: None
6. Arrays: VOTAR, TOTAR
7. GLOBLS: SEV10, MOST, ICLASS, NCLASS, SETUP, JSHF
8. Description:

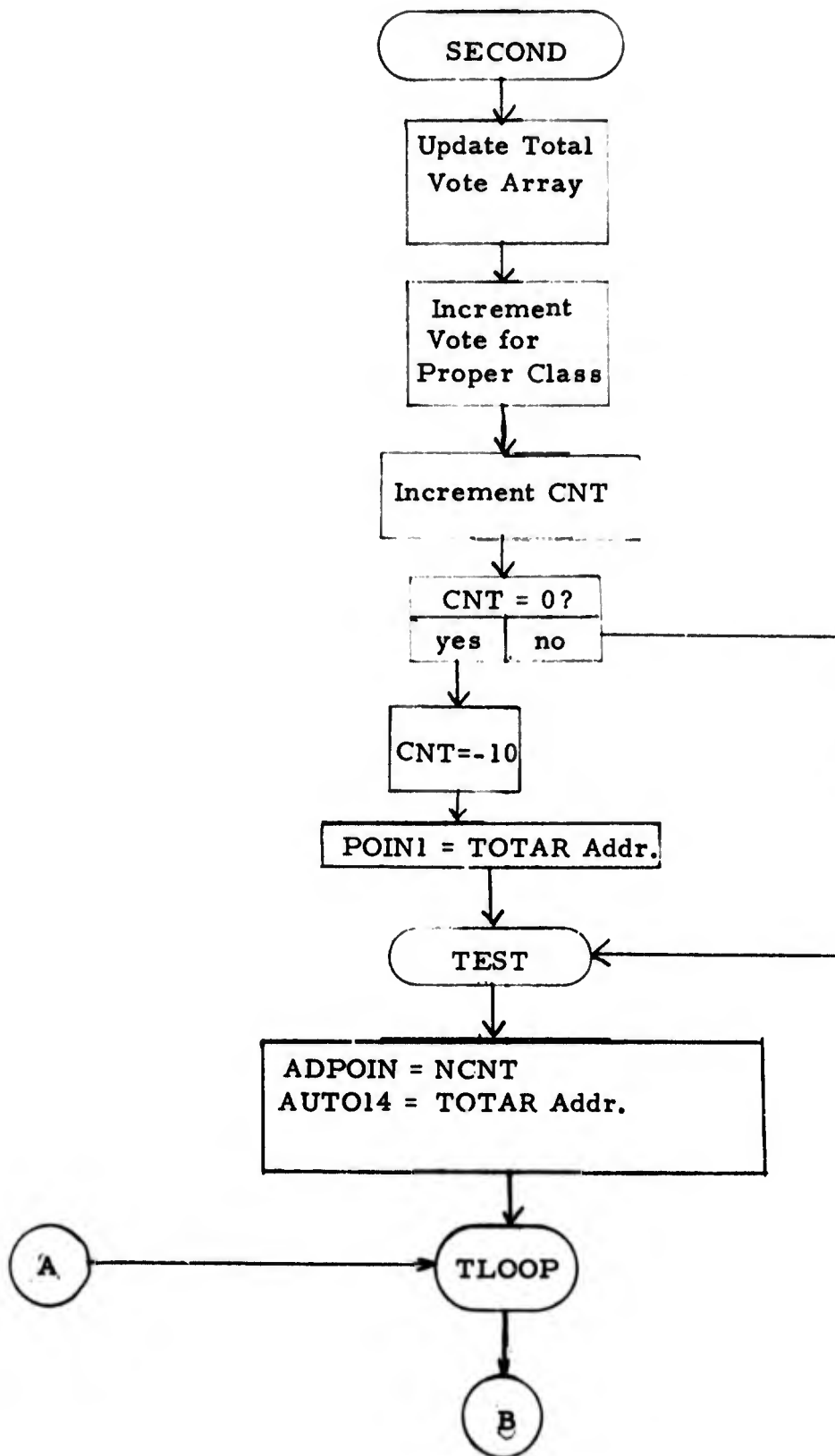
This routine has two entry points: SETUP and SEV10. SETUP must be entered first before the main classification loop in SIMUL. It initializes pointers and counters. Two arrays are used in SEV10 to record votes. One array, "TOTAR" keeps a running talley of 10 votes for 10 segments or 5 seconds of classification. The array "VOTAR" represents each of the six classes plus reject and no vote. Array position 1 corresponds to class 1, etc. As a new segment is passed through the classification logic and receives a vote the arrays TOTAR and VOTAR are updated accordingly. When any class receives seven votes, that class is returned in the GLOBL NCLASS which is then processed by SIMUL. In the event no class has received 7 votes, a NOVOTE is returned.

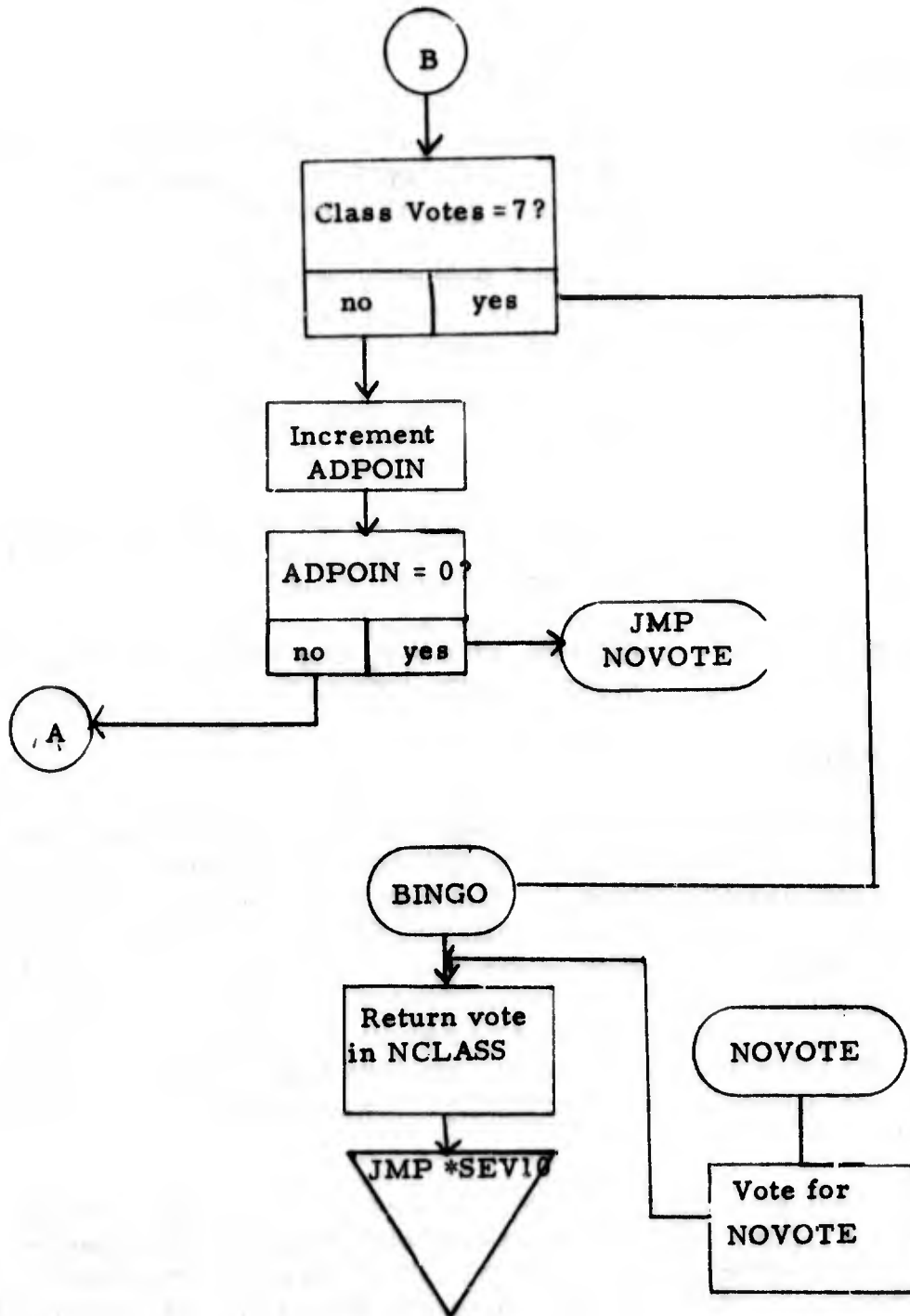












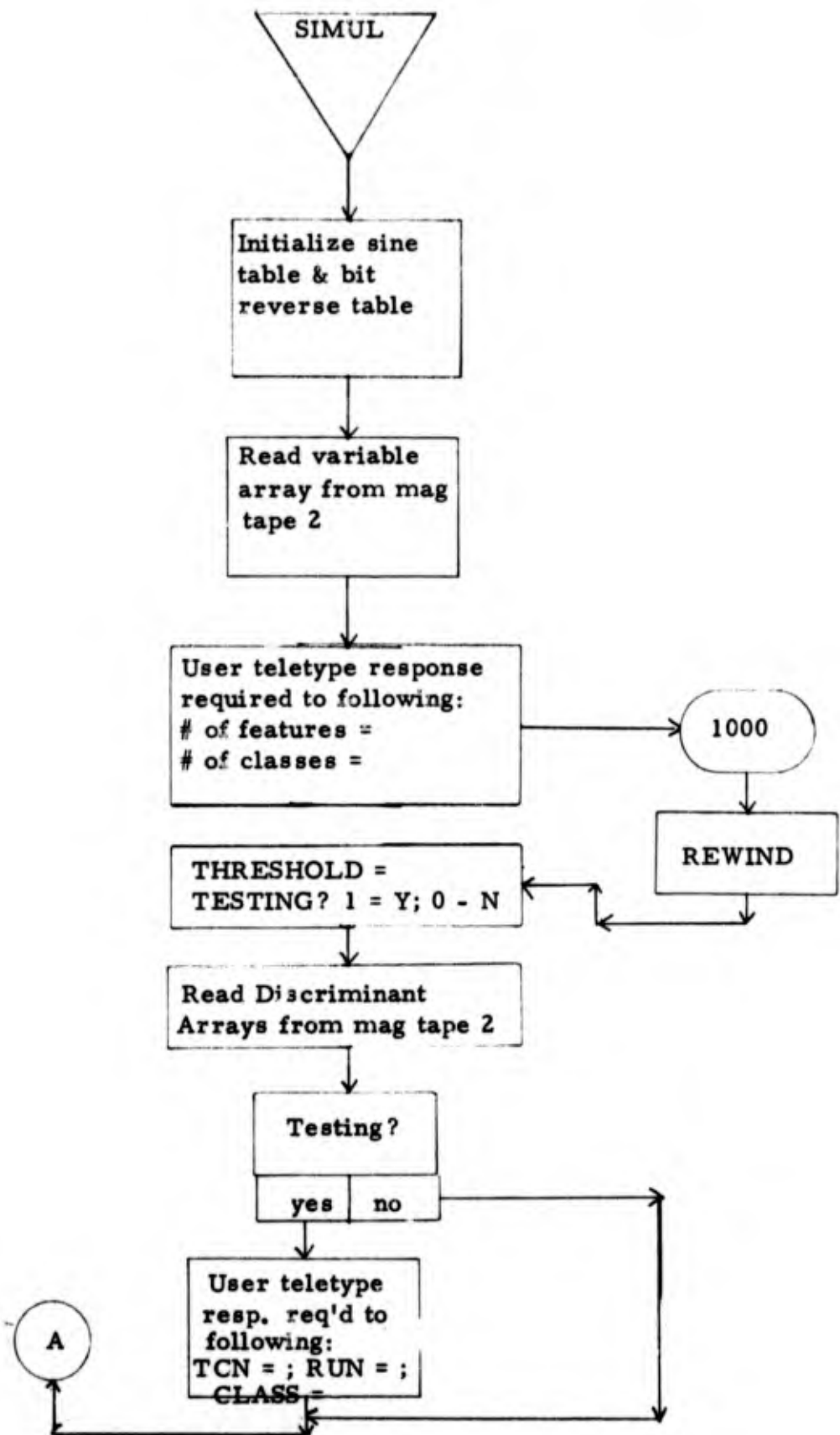
1. Program Name: SIMUL
2. Language: FORTRAN
3. Summary: This routine is the executive routine controlling the flow of the system and determining action to take after classifier decisions.
4. Requirements: Magnetic tape must be loaded on unit 2. It is a previously created tape consisting of variables and logic weights and thresholds.
5. Routines Required: FLOAT2, BINB, IFIXL, BUFIN, ANLOG, TWOS, FFT, LOAD, DOTP, SEV10.
6. Arrays: AB, TRIG, IFEAT, ISUM, IAR1, IAR2, IAR3, IAR4, IAR5, JVAR, INRAY, BREAL, IMAG, BINBUF, ILOGIC, IOUT
7. GLOBS: ITHRES, ITHPNT, IS1, NCLASS, JSHF, ICLASS, MUST, NENT, NKFEAT
8. Description:

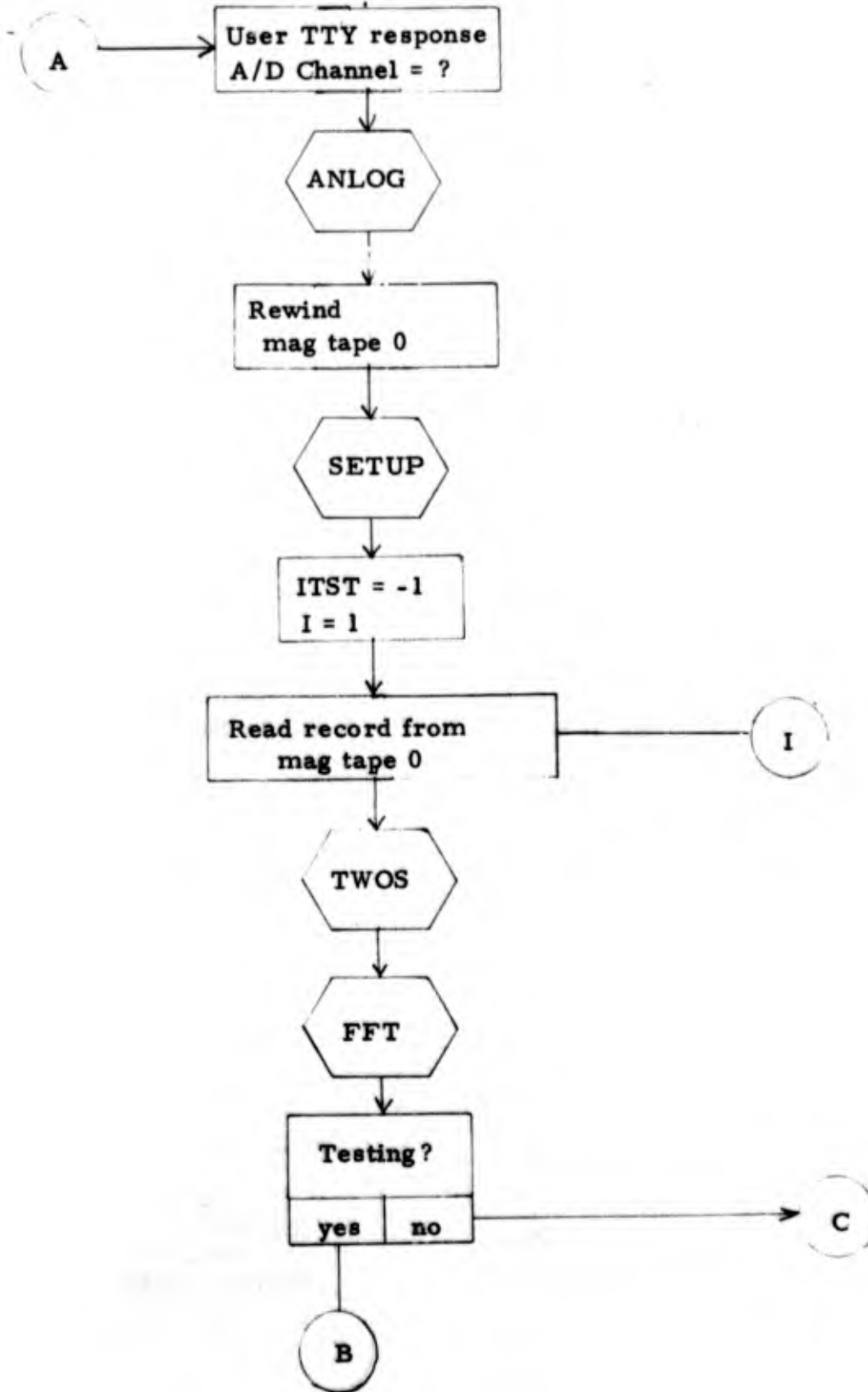
The routine controls the program flow. It initializes a sine table and a bit reversal table which are used by the FFT routine. Next, one record is read from mag tape 2. This record is an array of variables previously created by a program called "FEASET". The user is then asked a series of questions as to the number of features, number of classes, and the threshold. More records are read from the mag tape and placed in the logic array. These records represent the pairwise discriminant values scaled to a maximum integer value and their decision thresholds. These records were created previously using routines called "LOGIC" and "MODLOG".

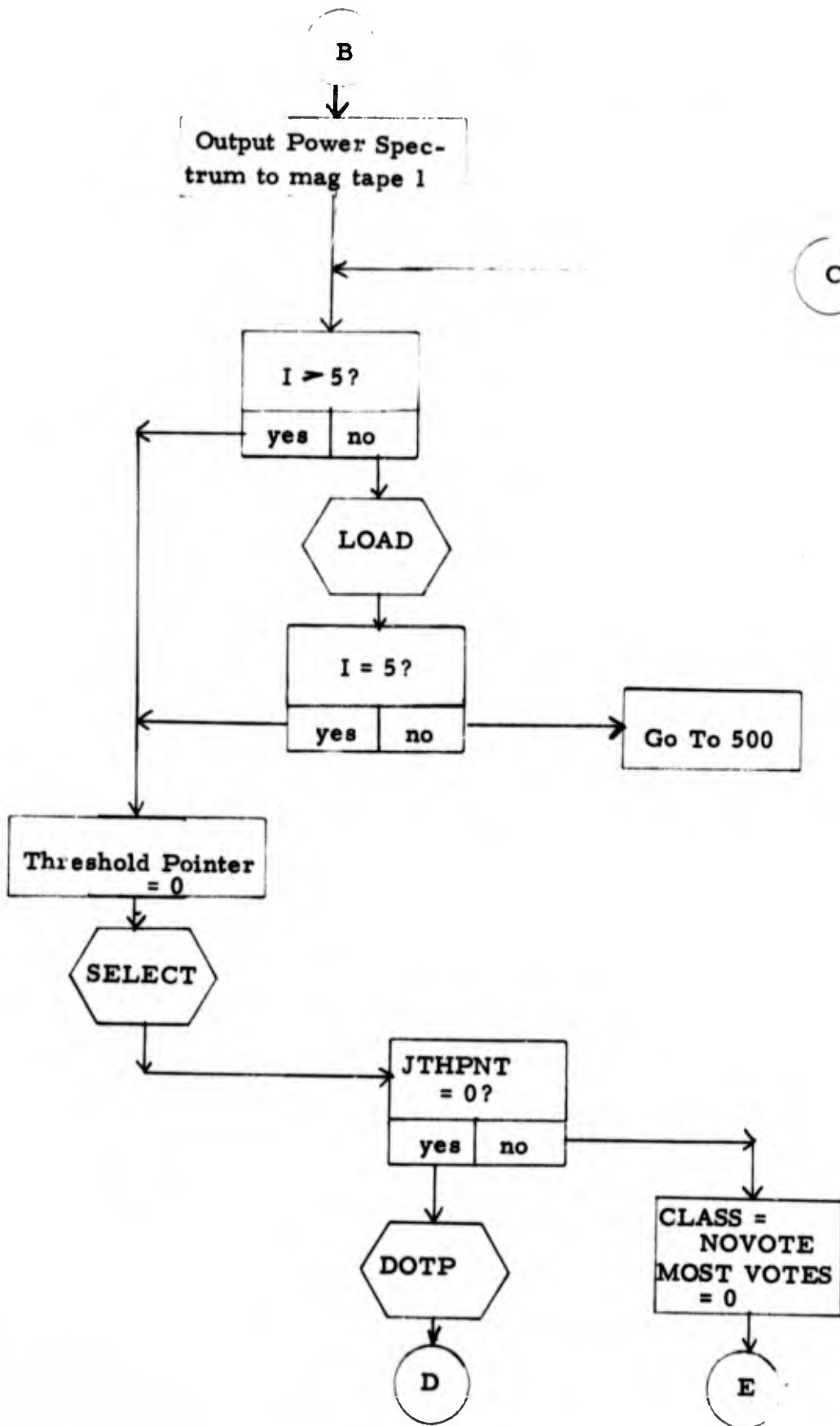
The user is next required to reply to the message "Testing? 1-Y, 0-N". If he replies yes, then he will receive maximum information concerning the classification and the FFT will be stored on mag tape 1. The labels "TCN" and "RUN" will be output with the FFT. This tape can be analyzed later using the plot system. If he is testing he must specify the correct class. He then responds to the question "A/D Channel ". The subroutine ANLOG is called and waits until he lowers AC switch 0 and raises switch 1. The digitizing begins and continues until he lowers 1 and raises 0. The mag tape is rewound and SETUP is called.

SIMUL (Continued)

The main classification loop now begins. A record is read from mag tape 0 and it is scaled and a power spectrum is computed. If the user is testing the FFT is output to mag tape 1. For the first five records the routine LOAD is called. From that point on a second entry point in LOAD called SELECT is called. These two determine the unaveraged FFT or average of five FFT's and call for feature extraction. If, during the average of five calculations the threshold criteria is not met, the class is called NOVOTE and the logic testing is omitted. If the criterion is met and a feature vector calculated, the routine DOTP is called. The class chosen and number of votes received are returned. A check is again made for testing. If the user is testing, information for each segment is displayed. If the user is not testing, then a class must receive seven out of ten votes to be designated as a class. Classes meeting this criterion are printed out. After completing the run, the routine returns to rewind mag tape 0 and asks for the user input again. On completion of all work, the user types control C.

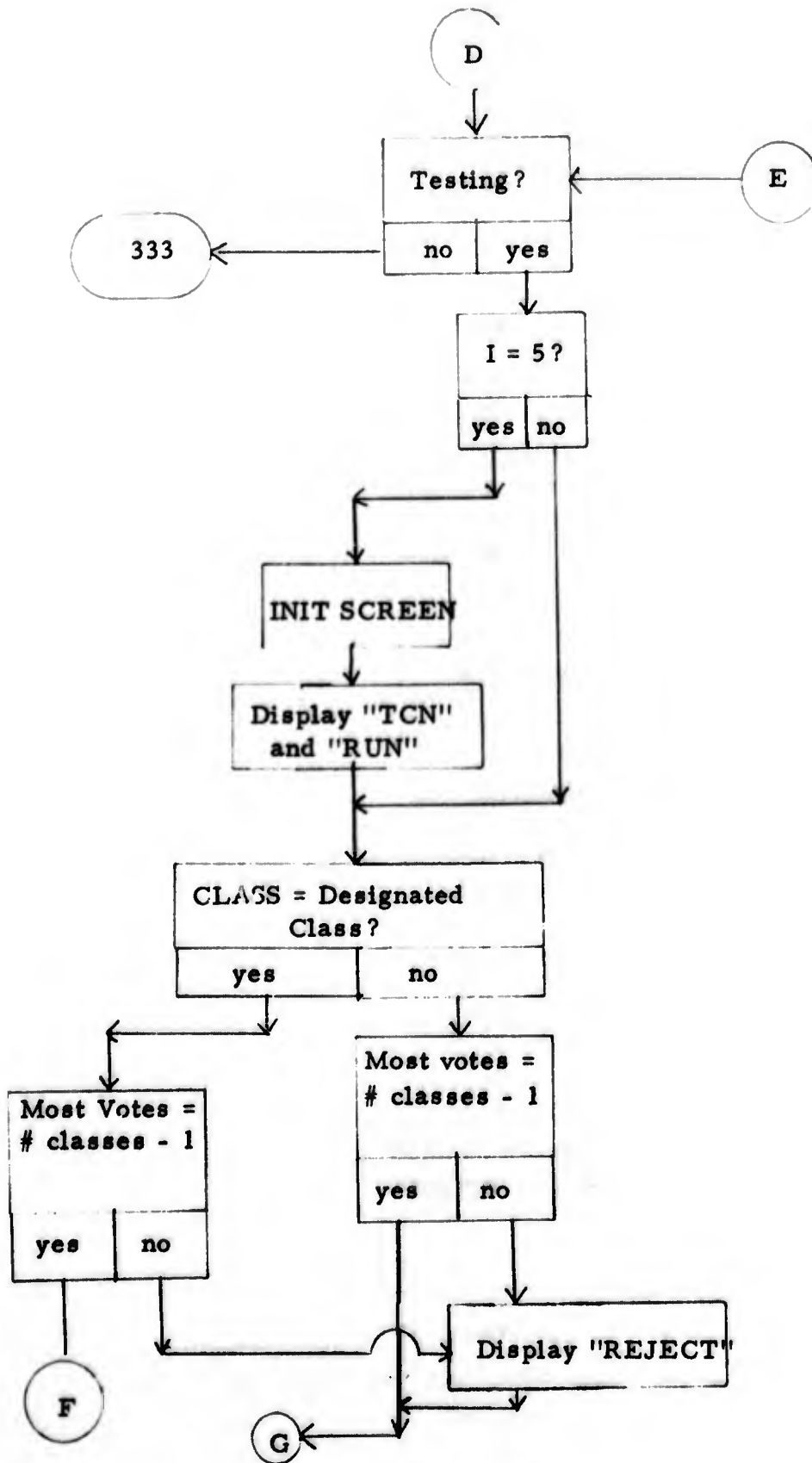


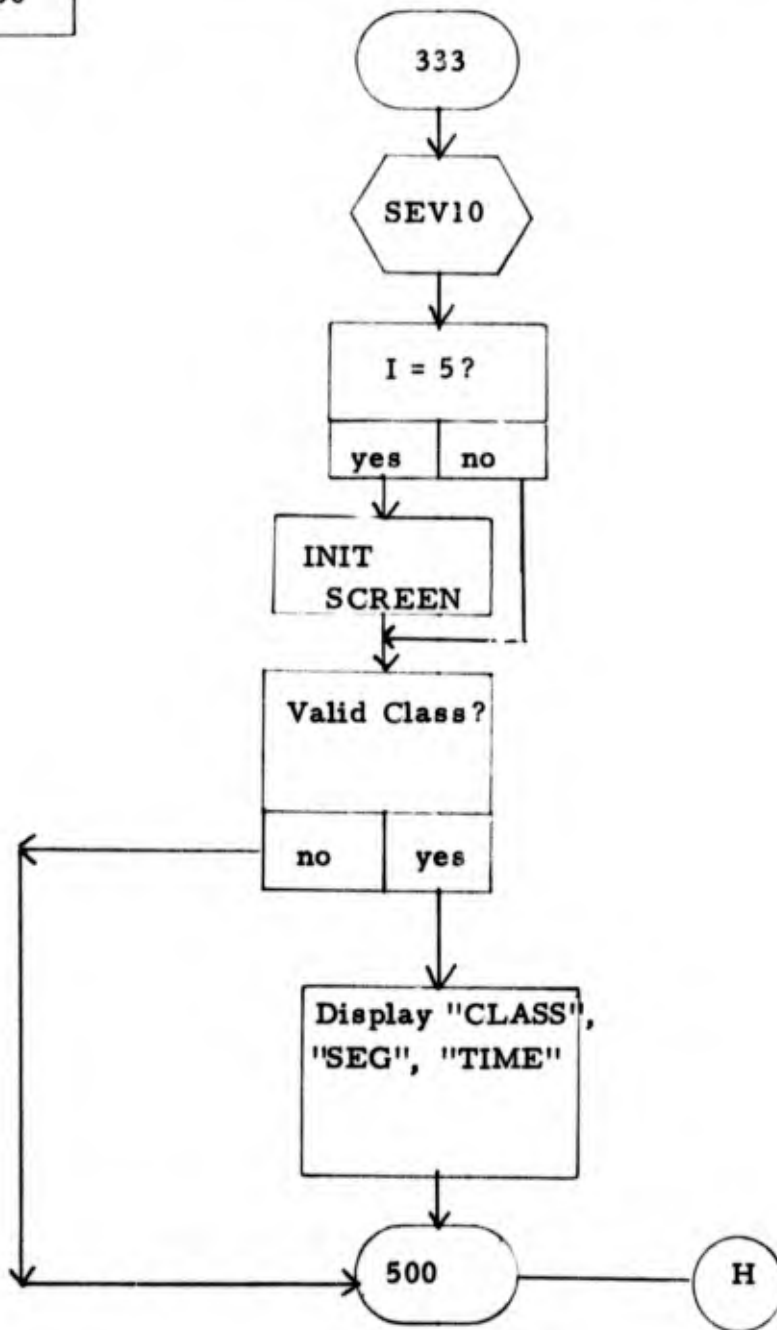
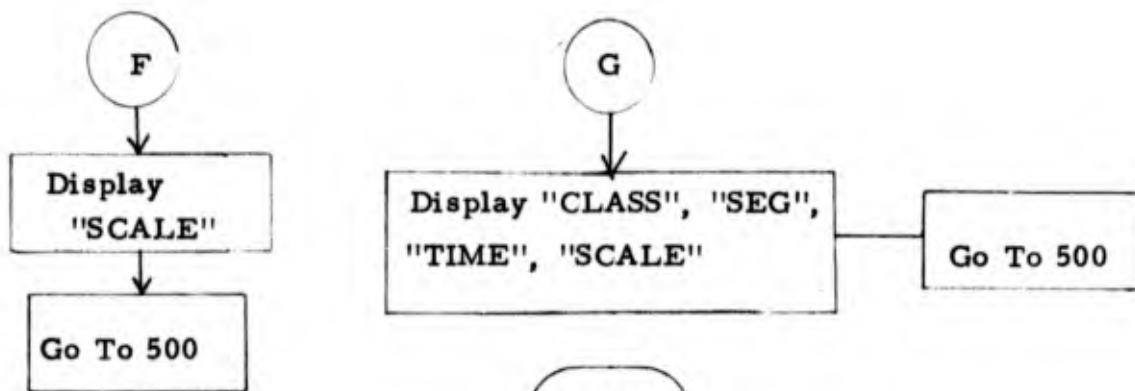


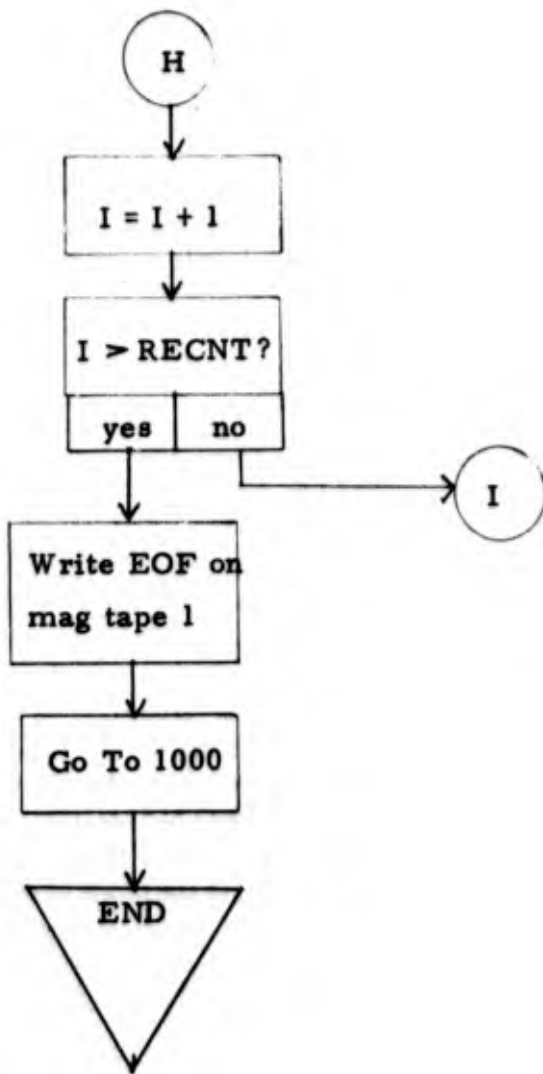


C



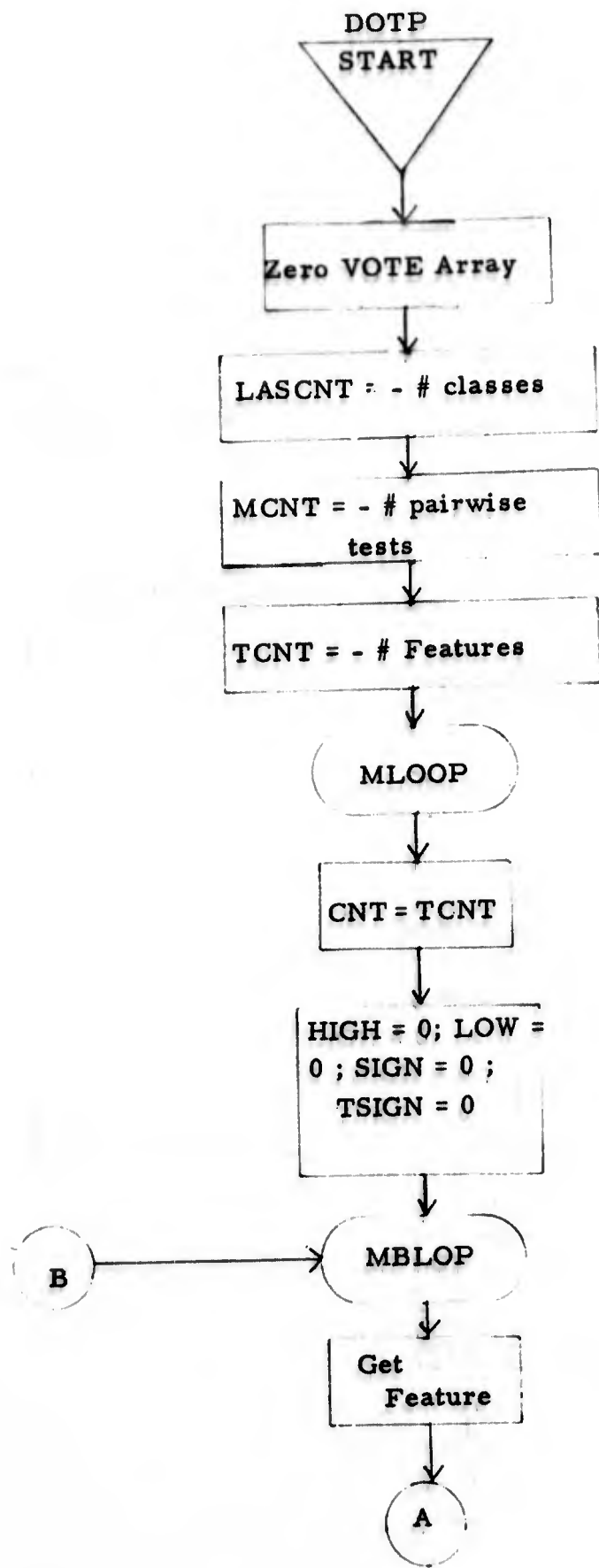


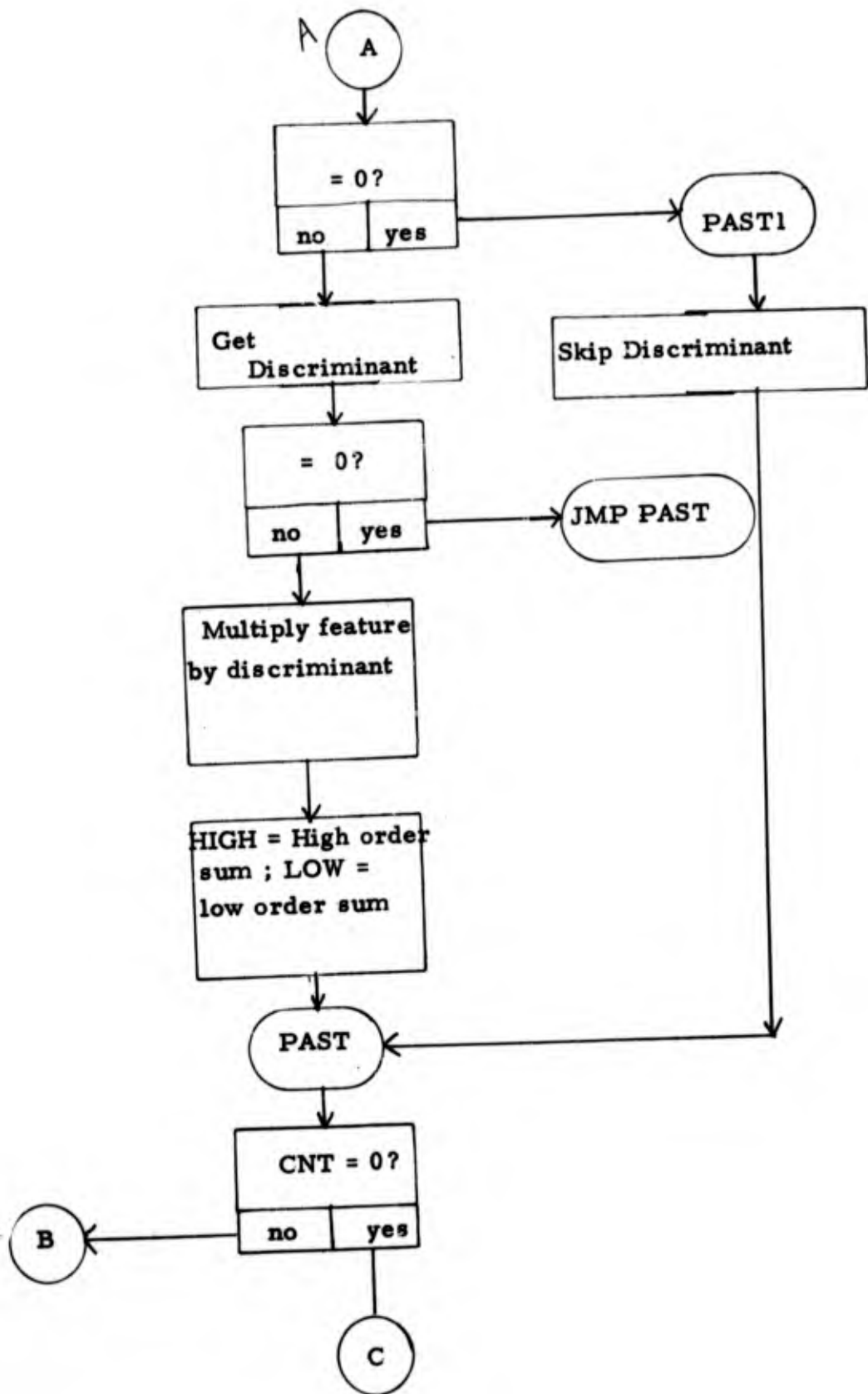


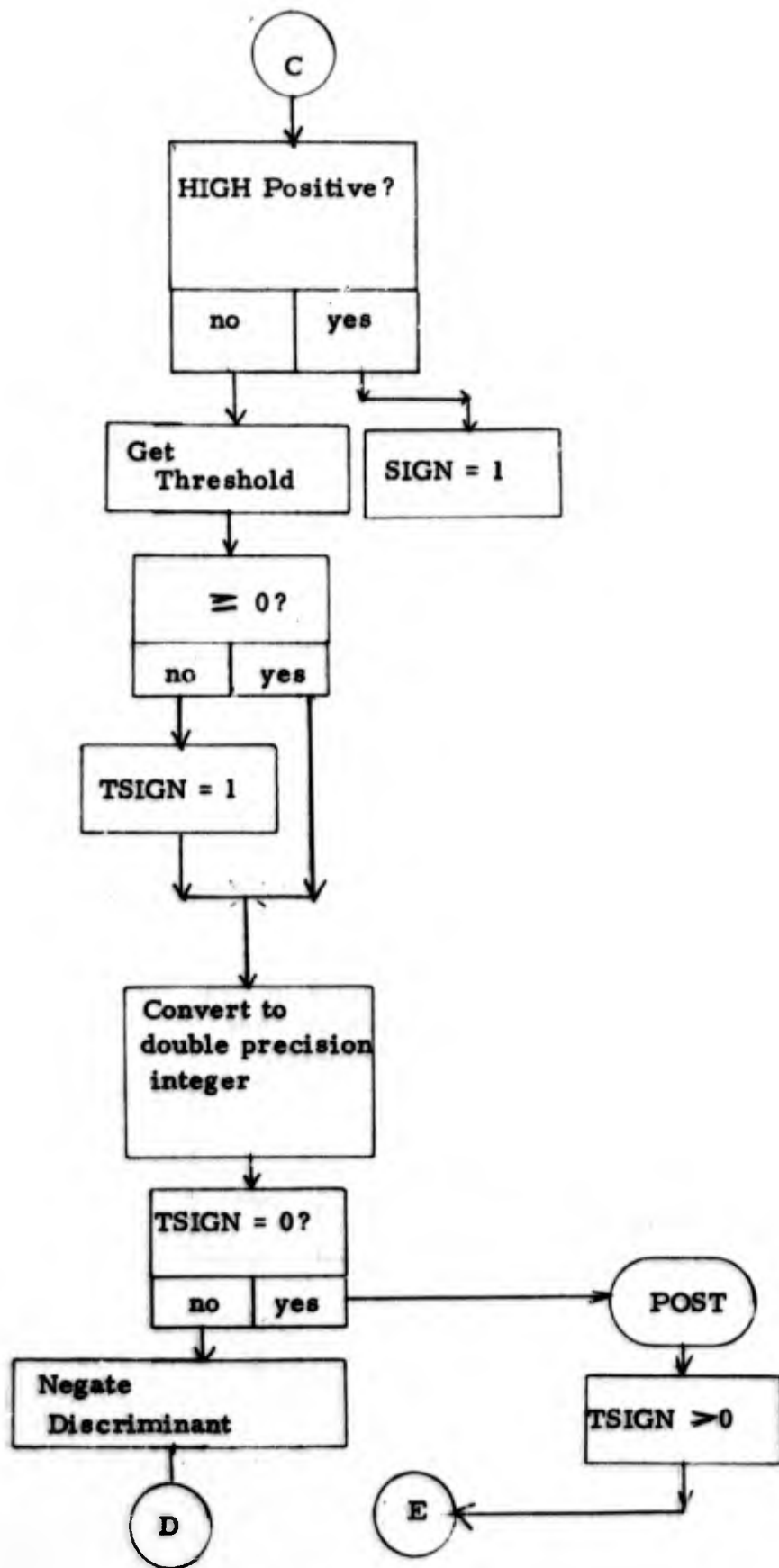


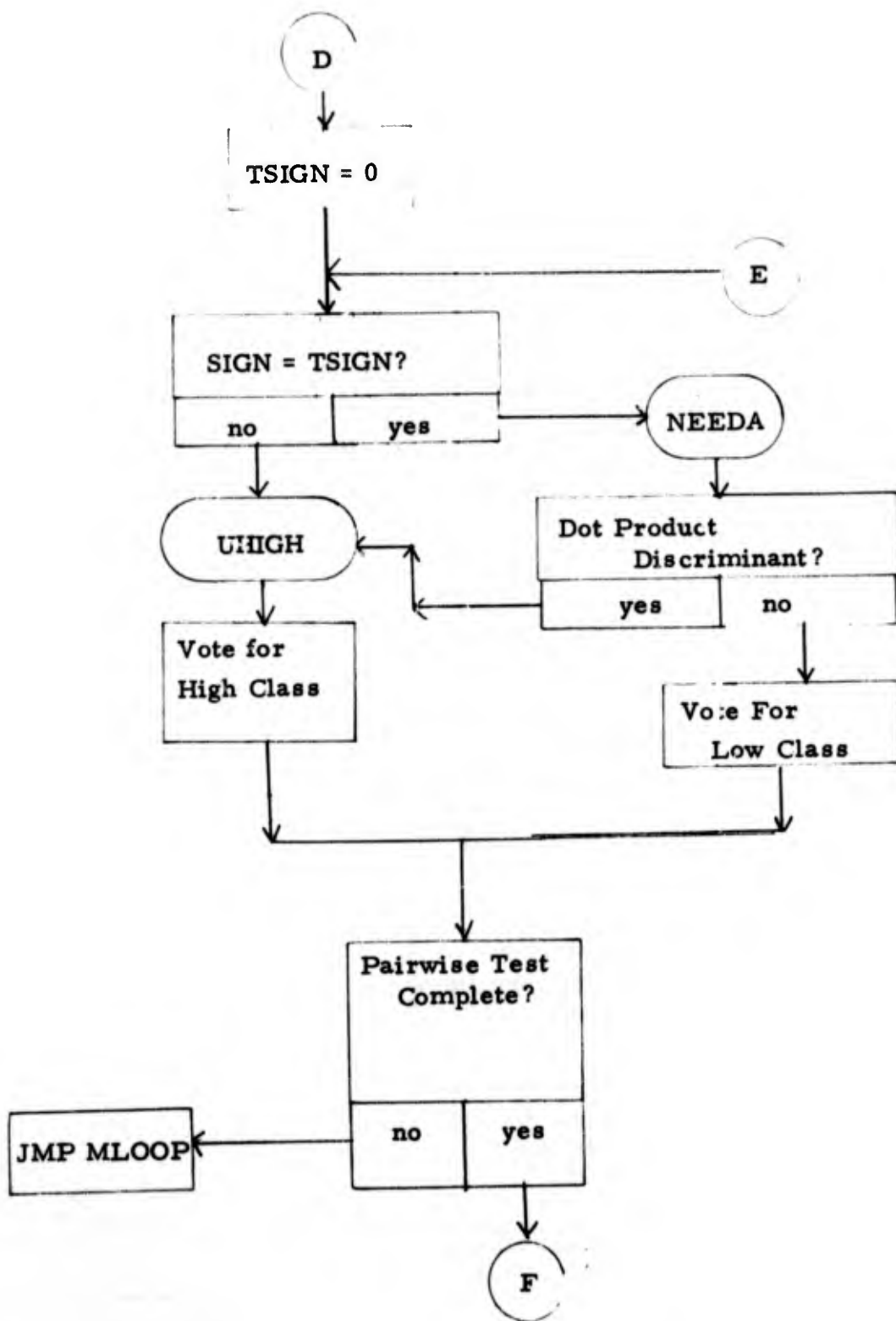
1. Program Name: DOTP
2. Language: MACRO
3. Summary: Perform pairwise Dot Product of feature vector and discriminant vectors and determine class with maximum possible votes.
4. Requirements: None
5. Routines Required: None
6. Arrays: VOTE
7. GLOBLs: DOTP, NENT, NCLASS, ILOGIC, IFEAT, NKFEAT, MUST, ICLASS
8. Description:

Given "N" classes, there are  $(N-1) * N/2$  pairwise tests required. The dot product of the feature vector and the discriminant vector is performed and then compared to a threshold value. If the dot product is below the threshold, one class receives a vote; if above, the other class receives the vote. This is done in a pairwise manner until all required tests are performed. If a class receives N-1 votes, it is designated as the selected class. If not, the class is called a reject. The maximum number of votes received by any class is returned in either case.

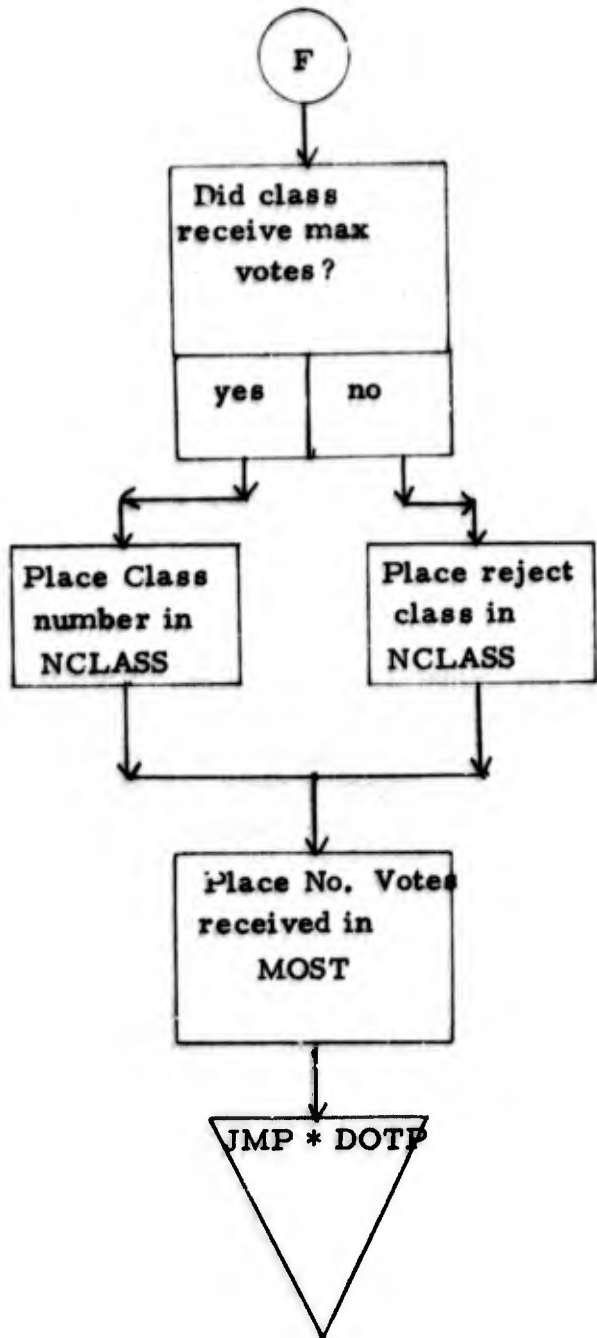








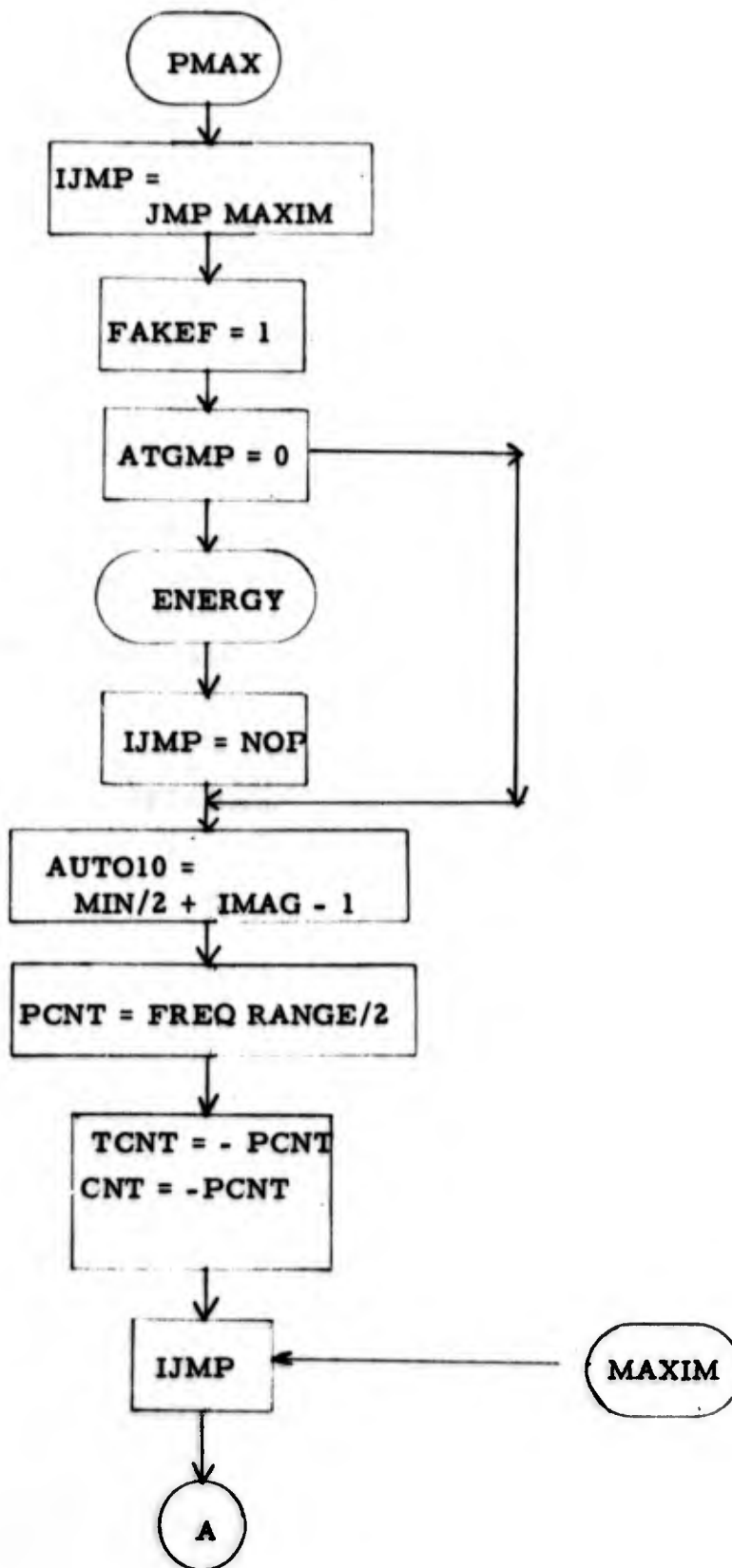


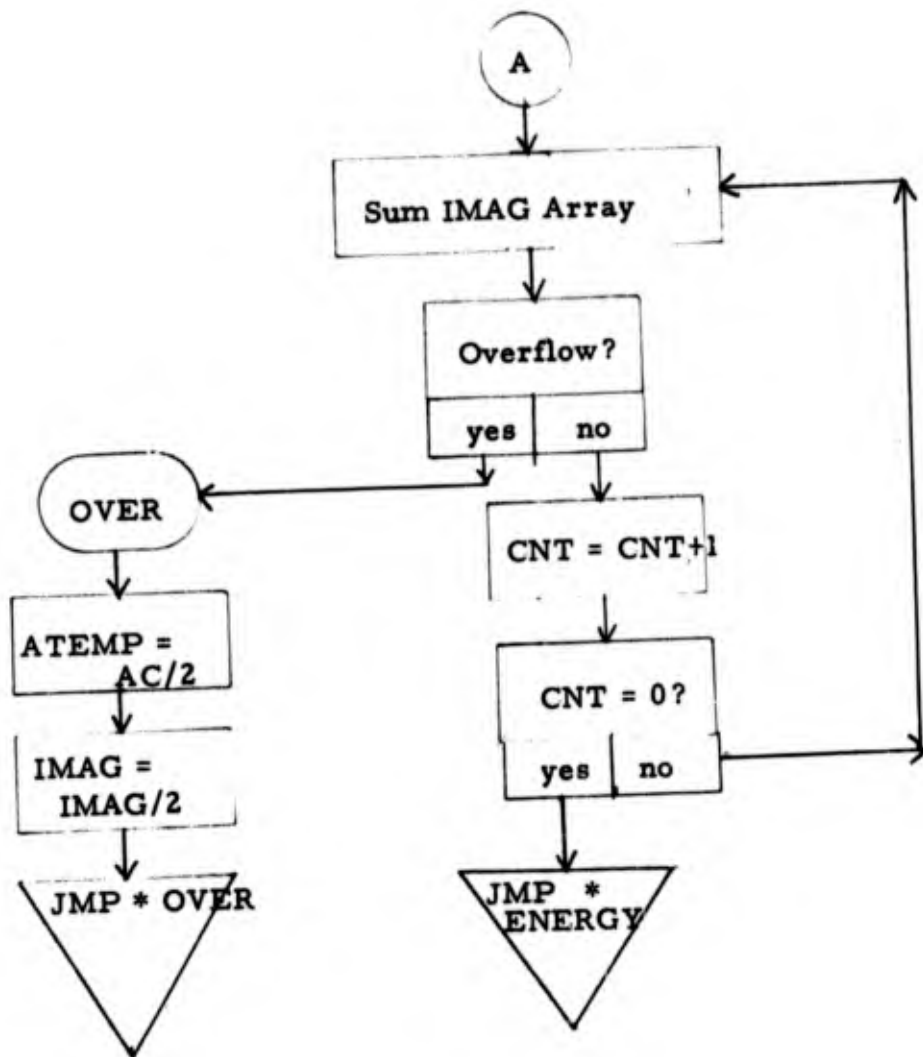


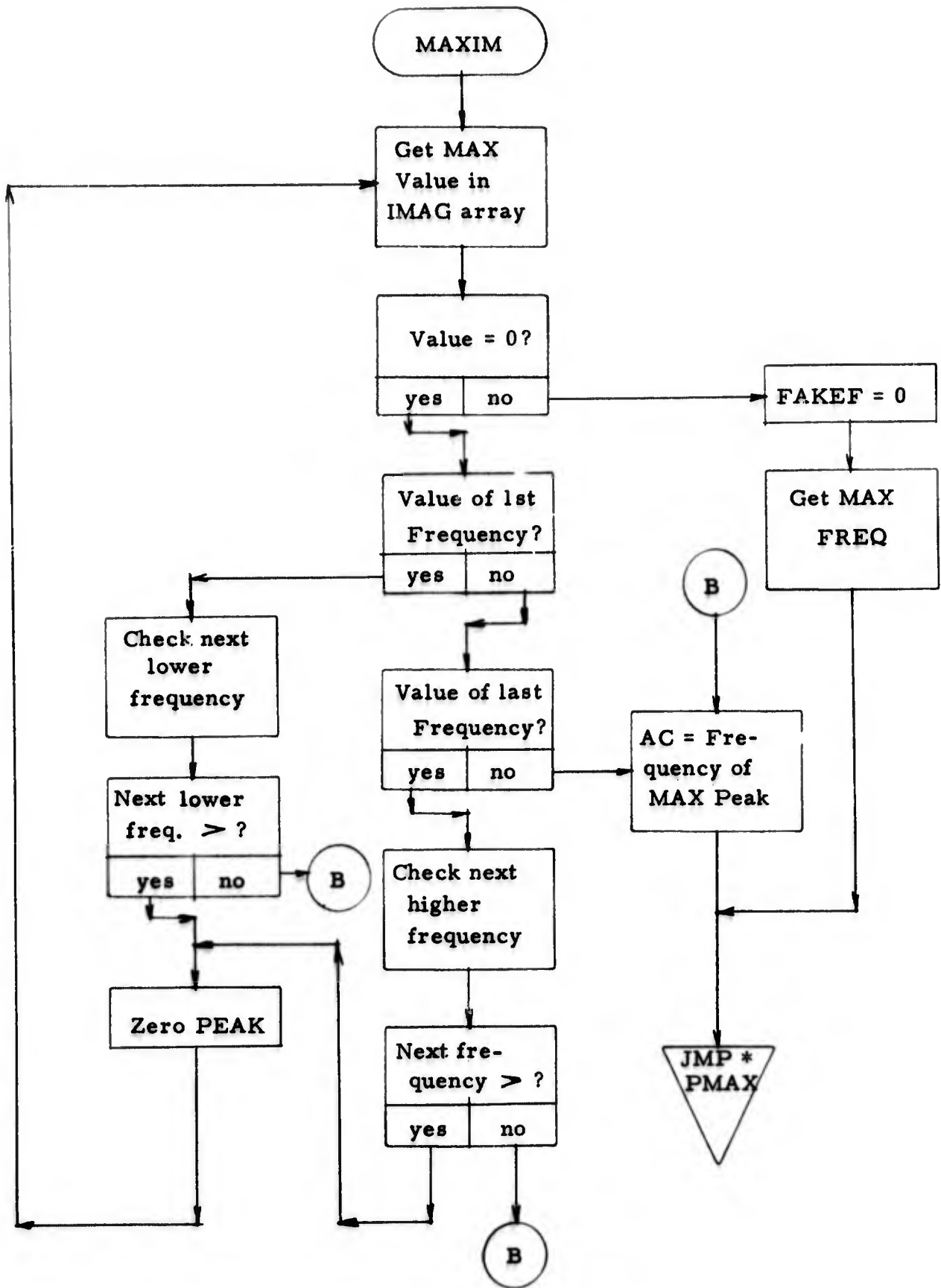
1. Program Name: ENERGY
2. Language: MACRO
3. Summary: Routine to find total energy or max peak of power spectrum.
4. Requirements: None
5. Routines Required: CPEAKS
6. Arrays: IMAG, FREQ
7. GLOBS: MIN, MAX, IMAG, PMAX, ENERGY, SLIDE, TEMP, FREQ, FAKEF
8. Description:

This routine has multiple entry points "ENERGY" and "PMAX". If ENERGY is entered then the IMAG array which contains either the un-averaged or averaged spectrum is summed to find the total energy. The upper and lower limits are in GLOBS MIN and MAX. If PMAX is entered, then the frequency of the peak with the maximum magnitude is returned.

ENERGY







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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-73-247, Volume I	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TIME DOMAIN ANALYSIS	5. TYPE OF REPORT & PERIOD COVERED Final Report Sep 1972 - Jun 1973	
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9. PERFORMING ORGANIZATION NAME AND ADDRESS Pattern Analysis & Recognition Corporation 128 East Dominick Street Rome, New York 13440	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Job Order No. 692B02B1	
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  Approved for public release; distribution unlimited.		
18. SUPPLEMENTARY NOTES  None		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Classifier Acoustic Features Classification Logic Simulation Programs Acoustic Signatures		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Under Contracts F30602-72-C-0027 and F30602-73-C-0070, Pattern Analysis and Recognition (PAR) Corporation has designed and simulated a six-class classifier for identifying targets of tactical interest based on their acoustic signatures. The classes are: wheeled vehicles, tracked vehicles, propeller aircraft, rotary aircraft and jet-powered aircraft. Background is rejected to prevent false alarms. Design or training set recognition rates on data collected by RADC/OCDE under a wide variety of environmental conditions		

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20. was 100%. Limited preliminary testing of the simulated classifier has also yielded 100% results.

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