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USER'S MANUAL -- COMPUTER-AIDED DESIGN PROGRAMS

FOR INDUCTOR-ENERGY-STORAGE DC-TO-DC

ELECTRONIC POWER CONVERTERS

BY

STEPHEN D. HUFFMAN

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16. Abstract

Detailed instructions on the use of two computer-aided-design programs for designing the energy-storage-inductor for single-winding and two-winding dc-to-dc converters are provided. Step-by-step procedures are given to illustrate the formatting of user input data. The procedures are illustrated by eight sample design problems which include the user input and the computer program output.

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PREFACE

This special report contains detailed instructions on the use of two computer-aided design programs for use in designing the energy-storage reactor for both single-winding and two-winding dc-to-dc converters. Step-by-step procedures are given to illustrate the formatting of user input data. These procedures are illustrated by eight sample design problems and computer runs which include user input and computer program output.

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INTRODUCTION

1.1 DESCRIPTION OF PROGRAMS

DC1DC is a program for the computer-aided design of the reactor element and/or the evaluation of the steady-state operating characteristics of any member of a family of single-winding energy-storage dc-to-dc electronic power converters. Any one of the three converter circuits shown in Figure 1 may be coupled with any one of three types of controllers--constant frequency, constant transistor on-time or constant transistor off-time--for a total of nine possible systems.

DC2DC is a similar program for the design of the reactor element and/or the evaluation of the steady-state operating characteristics of the two-winding voltage step-up/current step-up converter circuit shown in Figure 2. This converter circuit may be coupled with any of the three previously mentioned types of controllers to yield three distinct converter systems.

The design of the reactor and the steady-state evaluation of the converter are based on models of the converter circuits which make certain simplifying assumptions. These assumptions are given in Section 1.2.

User inputs to the programs include the type of converter/controller combination desired and a set of design requirements which the system must meet. In executing a design or evaluation request, the program makes use of a stored data base consisting of a catalog of magnetic core data (usually from manufacturers' catalogs) and a table listing available sizes of magnet wire. The reactor design(s) produced by the program include core catalog information, number of turns, wire sizes and various other design parameters.

In addition to the reactor design routine, an algorithm is included in the programs to assist in the evaluation of certain steady-state operating characteristics of the converter/controller combination. This evaluation algorithm may be used to automatically evaluate the computer generated design(s) or it may be used independently to evaluate a previously generated design or a design computed by hand. Outputs from the evaluation algorithm include: minimum, maximum, average and RMS values for the reactor current(s), the RMS value of the current through the capacitor, pulse widths and frequency of operation, power losses in the various components and the converter efficiency. These output variables are computed over the user specified operating range of the converter in increments of input voltage and output power also specified by the user.

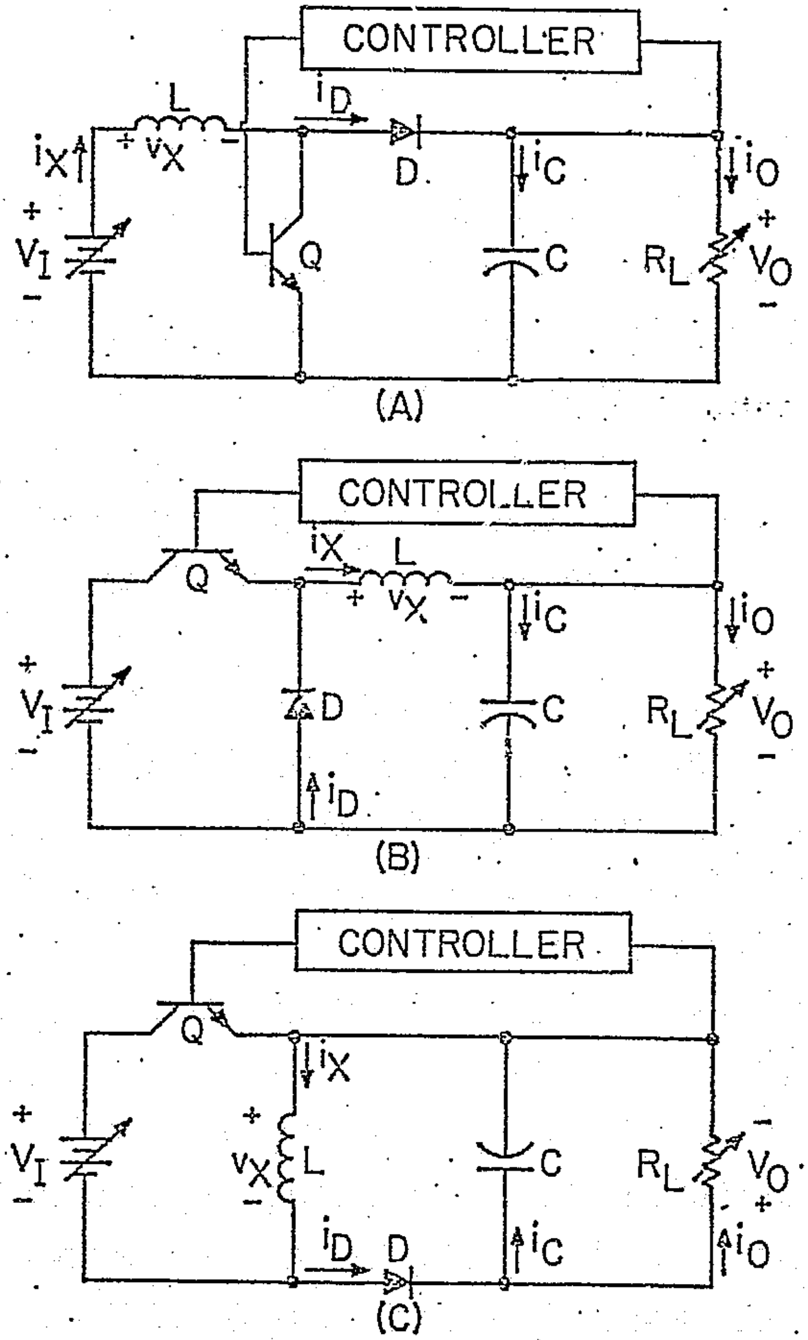


Figure 1. Three Single-Winding Converters

(A) Voltage Step-up

(B) Current Step-up

(C) Voltage Step-up/Current Step-up

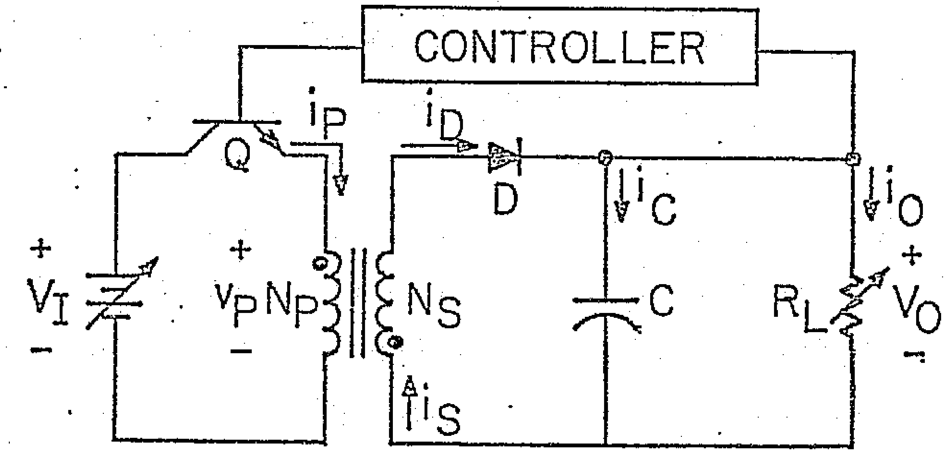


Figure 2. Two-Winding Voltage Step-up/ Current Step-up Converter

1.2 DEVICE MODELS

The design and evaluation algorithms used by the programs are based on circuit models which make certain simplifying assumptions [1]. The following discussion of device models applies to all three converter circuits shown in Figure 1 as well as to the two-winding circuit shown in Figure 2.

1.2.1 Transistor Model

For the design algorithm, the transistor collector-emitter is modeled as a switch with a constant forward voltage drop (switch closed) and infinite reverse resistance (switch open) as indicated by the equivalent circuit and V-I characteristic shown in Figure 3. It is further assumed that the transistor base current is negligible. During the transistor on-time (T ON) the switch is closed. At the end of this interval, the switch opens and remains open during the transistor off-time (T OFF). It is assumed that switching takes place over a negligible time interval.

For design evaluation purposes, the transistor collector-emitter is modeled as a lumped linear saturation resistance as shown in Figure 4. The power loss in the collector is computed by taking the product of the saturation resistance and the square of the RMS value of the collector current.

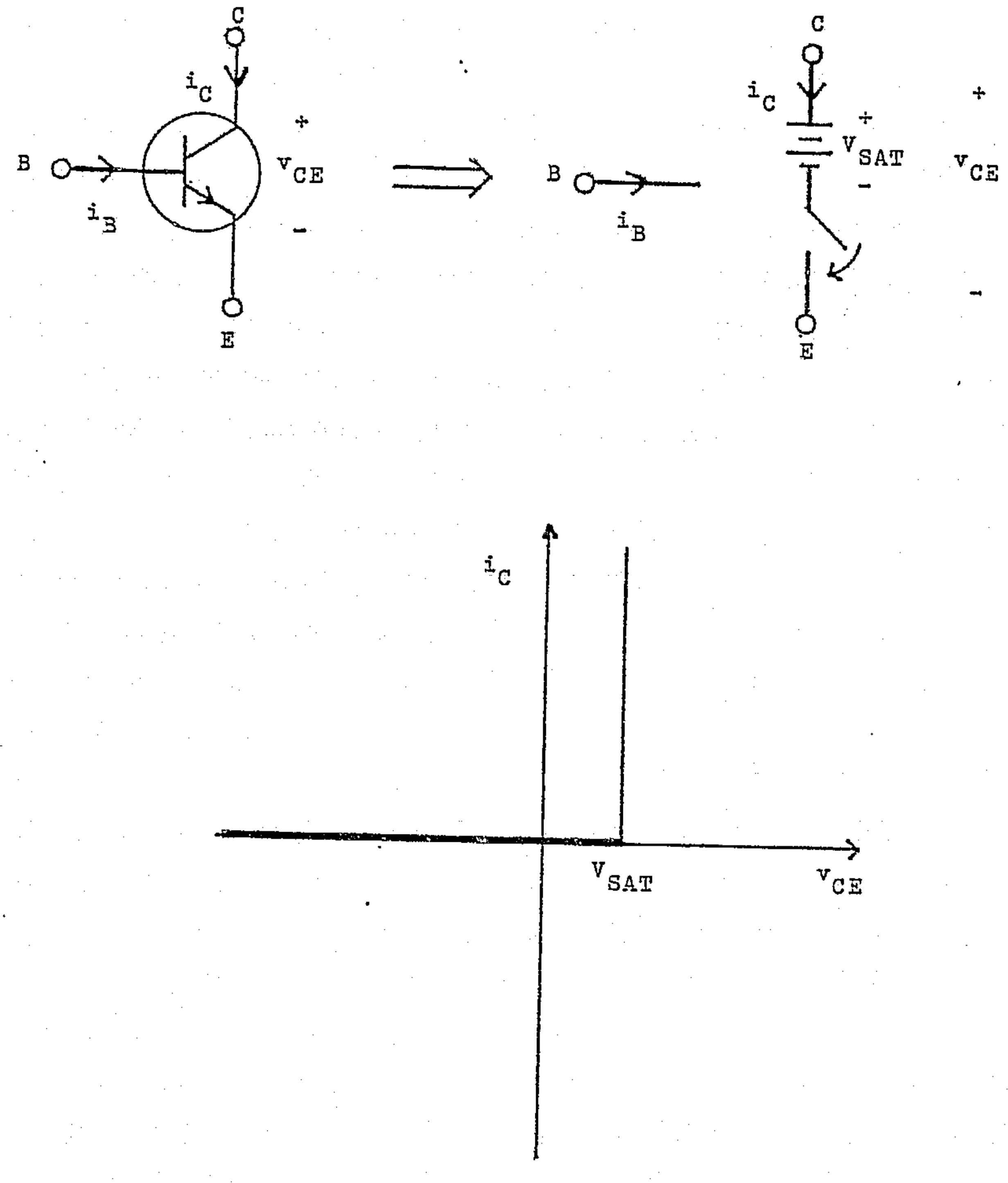


Figure 3. Transistor Model--Design Procedure

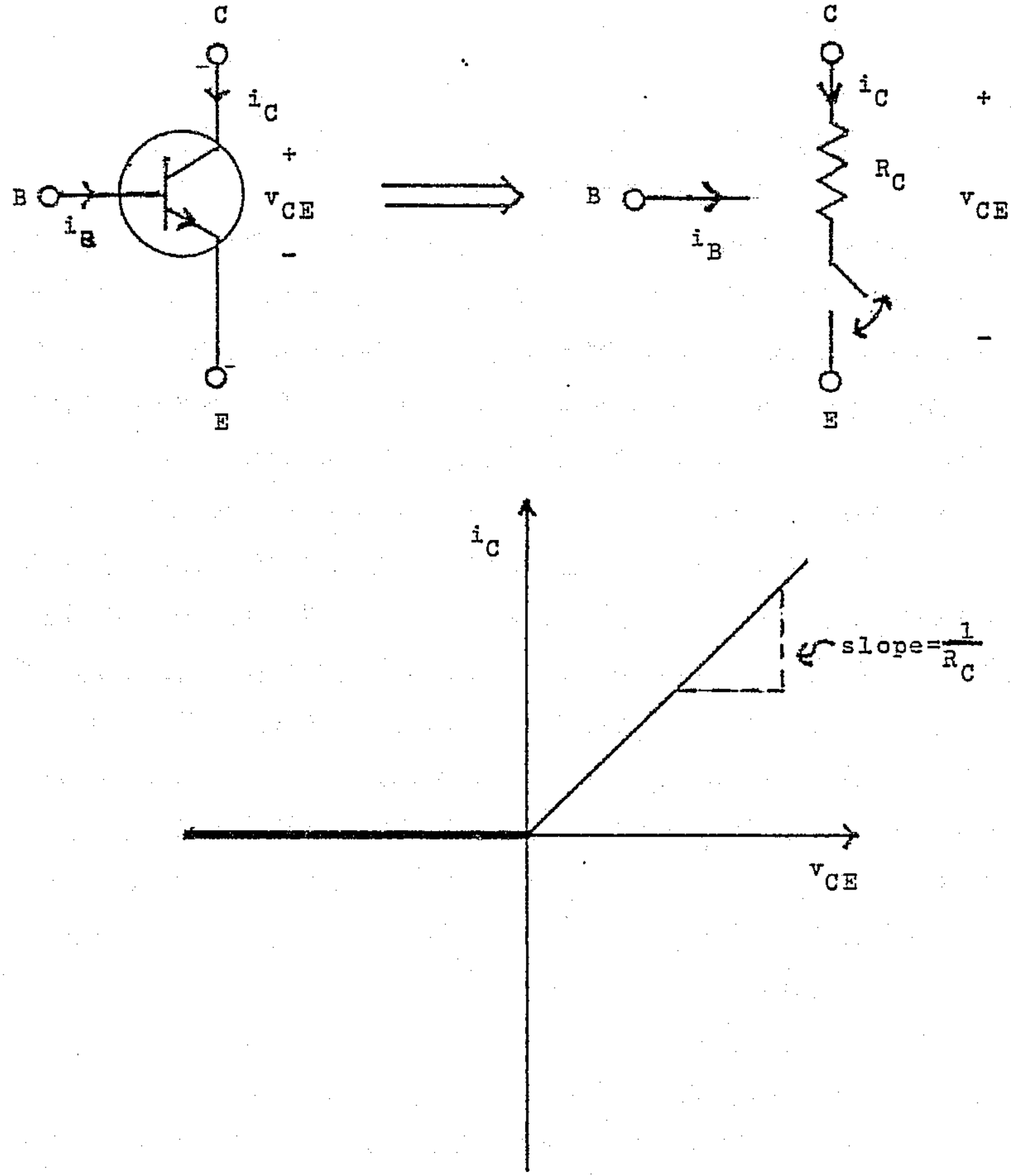


Figure 4. Transistor Model--Evaluation Procedure

1.2.2 Diode Model

Both the design routine and the evaluation algorithm assume the diode acts as a constant voltage source in series with an ideal diode as indicated by the equivalent circuit and V-I characteristic shown in Figure 5. Again, it is assumed that switching takes place over a negligible time interval.

1.2.3 Reactor Element Model

It is assumed that the magnetic core is operated in the linear range of constant permeability as shown in the B-H characteristic in Figure 6. The design routine is carried out assuming that winding resistance is negligible. The evaluation algorithm assumes a lumped linear winding resistance (equal to the product of the computed winding length (meters) and the resistivity (ohms/meter) of the wire size) in calculating the power loss in the winding(s). The winding losses are computed by multiplying the winding resistance by the square of the RMS value of the current in the winding. Power losses in the magnetic core are approximated by use of Legg's equation [2]. Total core loss is computed as the sum of three frequency dependent components, hysteresis loss, eddy current loss and residual loss. These three loss components are related to the <u>core loss resistance</u> by Legg's equation in modified form:

$$R_{ac} = \mu_r L \left(a \Delta B\, 10^4\, f + cf + ef^2\right)$$

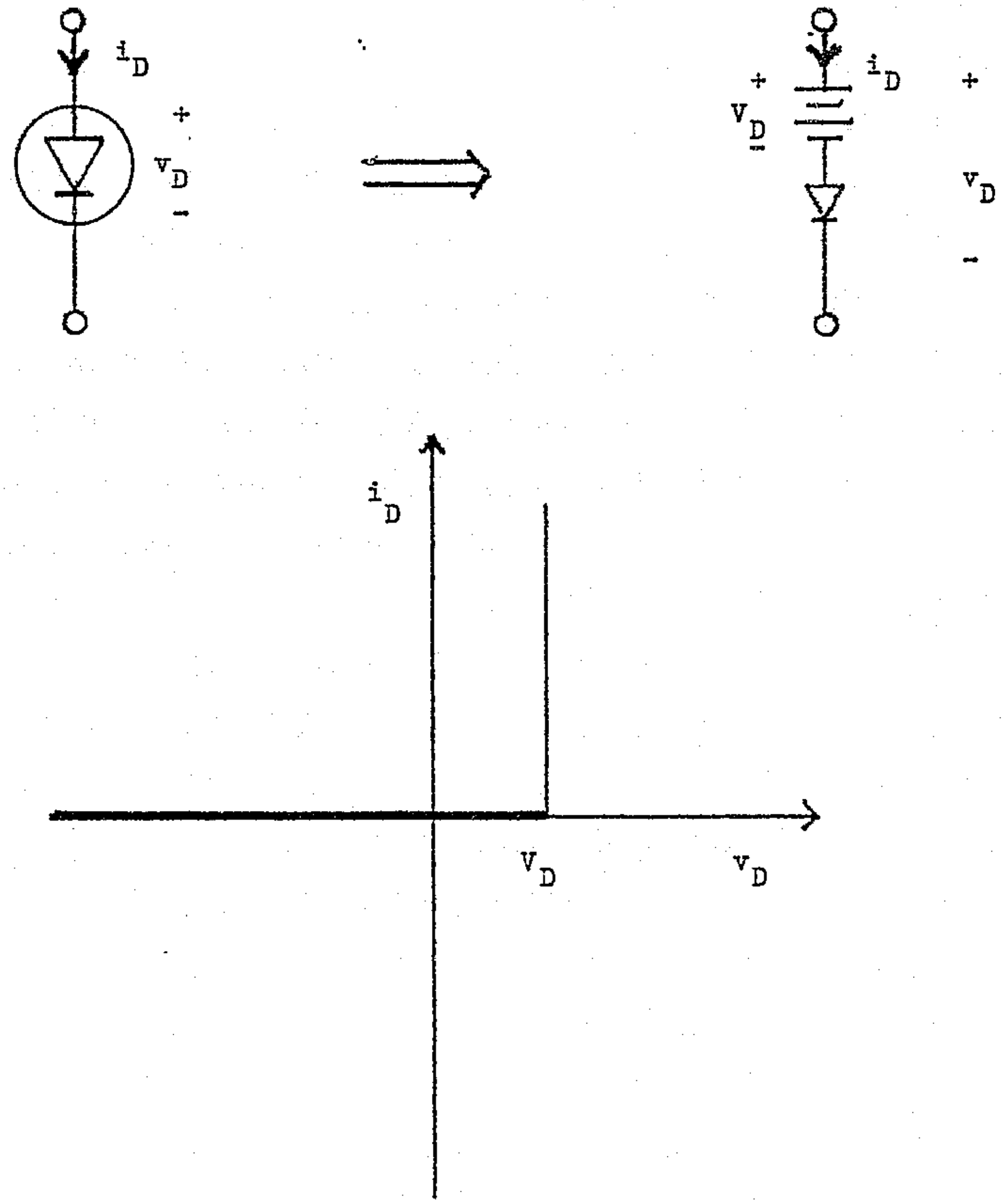


Figure 5. Diode Model

where:

R_{ac} = core loss resistance

μ_r = relative permeability

L = inductance (henries)

a = hysteresis loss coefficient

c = residual loss coefficient

e = eddy current loss coefficient

ΔB = flux density excursion (tesla)

f = frequency (Hz)

The hysteresis, residual and eddy current loss coefficients are available from manufacturers' data sheets. Power loss in the core is approximated by multiplying the core loss resistance by the square of the RMS value of the fundamental component of the winding current. Legg's equation is strictly valid only under the conditions of sinusoidal flux and low flux-density excursions. Although these conditions are seldom met in the converter operation, Legg's equation is the best approximation given the presently available core data.

1.2.4 Capacitor Model

It is assumed that the capacitor is so large that there is negligible ripple voltage at the converter output. To approximate power loss in the capacitor, the evaluation algorithm assumes that the capacitor has a lumped linear effective series resistance (ESR). Power loss in the capacitor is approximated by taking the product of the ESR and the square of the RMS value of current through the capacitor.

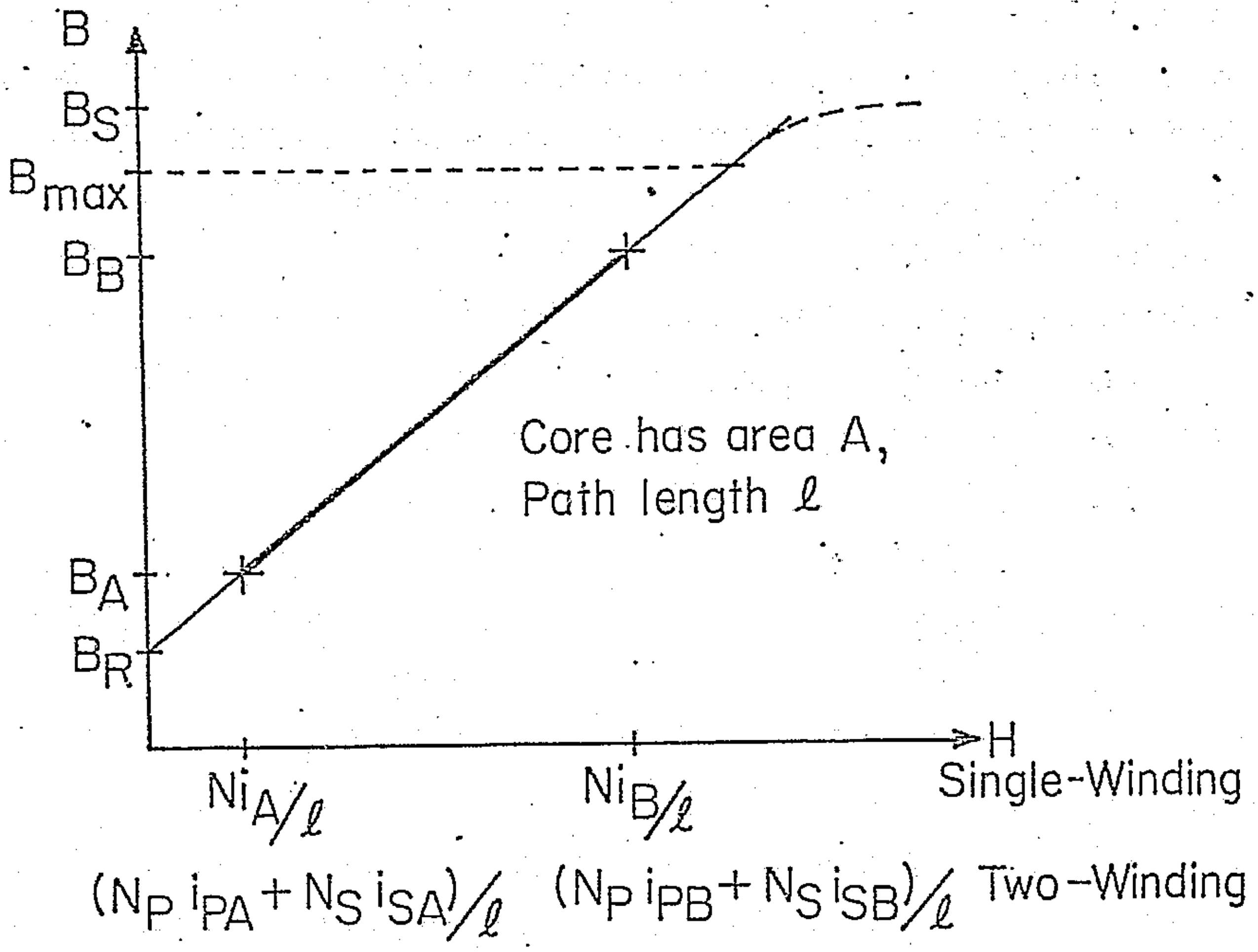


Figure 6. Magnetic Core Characteristics

1.2.5 Controller Model

The controller is assumed to be ideal in that it draws no current from the load and it operates with negligible time delay.

1.2.6 Input Voltage Magnitude

The minimum input voltage is assumed to be always larger than the transistor saturation voltage drop.

1.3 THE DATA BASE

The data base consists of two sections, a core catalog and a wire-size table. The programs use the data base along with the design-requirement data in executing an assigned task. Unlike the design-requirement data, the data base will be modified infrequently. Thus, once the data base is constructed and stored in some fashion which allows the computer to access the information (i.e. cards, magnetic disk, etc.), the user need not concern himself with the data base until such time as he desires to make revisions or additions to this data. Part II of this manual deals with construction and revision of the data base.

1.3.1 The Core Catalog

The Core Catalog consists of data concerning the available magnetic cores. It contains core dimensional data, manufacturers' catalog numbers and loss coefficients (see Section 1.2.3) for the values of relative permeability available. The data in the core catalog is usually obtained from manufacturers' core catalogs.

1.3.2 The Wire Table

The Wire Table gives the cross-sectional area and resistivity of the available sizes of magnet wire. The area of each wire size is listed for bare wire as well as for single, heavy, triple and quad synthetic insulated wire. The wire-table data is usually obtained from wire manufacturers' data sheets.

PART I -- USE OF THE PROGRAMS

PRELIMINARY INFORMATION

The designer, in using either Program DC1DC or DC2DC, must input a set of design requirements which the program will use along with a stored data base in executing the assigned task. Part I of this manual deals with the use of the program for carrying out design and evaluation problems and centers on the input of design-requirement data. It is assumed in Part I that the stored data base is already available for use. Part II deals with the construction of the data base.

2.1 PROGRAM PROCEDURES

DC1DC and DC2DC offer three design/evaluation procedures to the user. Procedure DSN1 produces a list of up to fifty usable reactor designs for a given set of design requirements, and evaluates as many of these designs as the user desires. Procedure DSN2 allows the designer to have a single design computed and evaluated using a specified magnetic core. The third procedure, EVAL, may be used to evaluate any previously completed design.

2.1.1 Procedure DSN1

In Procedure DSN1, the user inputs to the program the type of converter/controller combination desired and a set of specifications for the system. All cores in the core catalog are checked by the program for windability under the constraints imposed by the design specifications. A list of up to fifty usable designs is printed out, including manufacturers' core numbers, value of relative permeability, value(s) of inductance, number of turns, wire size(s), winding factor, and various operating parameters. Beginning with the smallest volume core, each of these designs, up to a user specified maximum, is evaluated under steady-state conditions over a user specified range of input voltage and output power. Outputs include: minimum, maximum and RMS values for the winding current(s), RMS value of the capacitor current, pulse widths and frequency of operation, power losses in the core, wire, transistor, diode and capacitor, and the estimated converter efficiency.

2.1.2 Procedure DSN2

Under Procedure DSN2, the user may specify that a design be computed and evaluated for a specific core. The designer simply enters the integer core number from the core catalog along with the relative permeability and the design requirements. By entering dimensional information, the user is also allowed to request that a design be generated for a core which is not in the core catalog. Also, if a value of relative permeability other than a catalog value is required, the user may enter loss coefficient information and request a design for a particular core having the entered value of relative permeability. If loss coefficients are not supplied, default values will be assumed (see Section 3.4.3). The outputs under Procedure DSN2 are the same as those under Procedure DSN1, except that only the specified core can appear in the windable core list. If the core entered should fail to meet the design specifications, a message to this effect will be printed by the programs.

2.1.3 Procedure EVAL

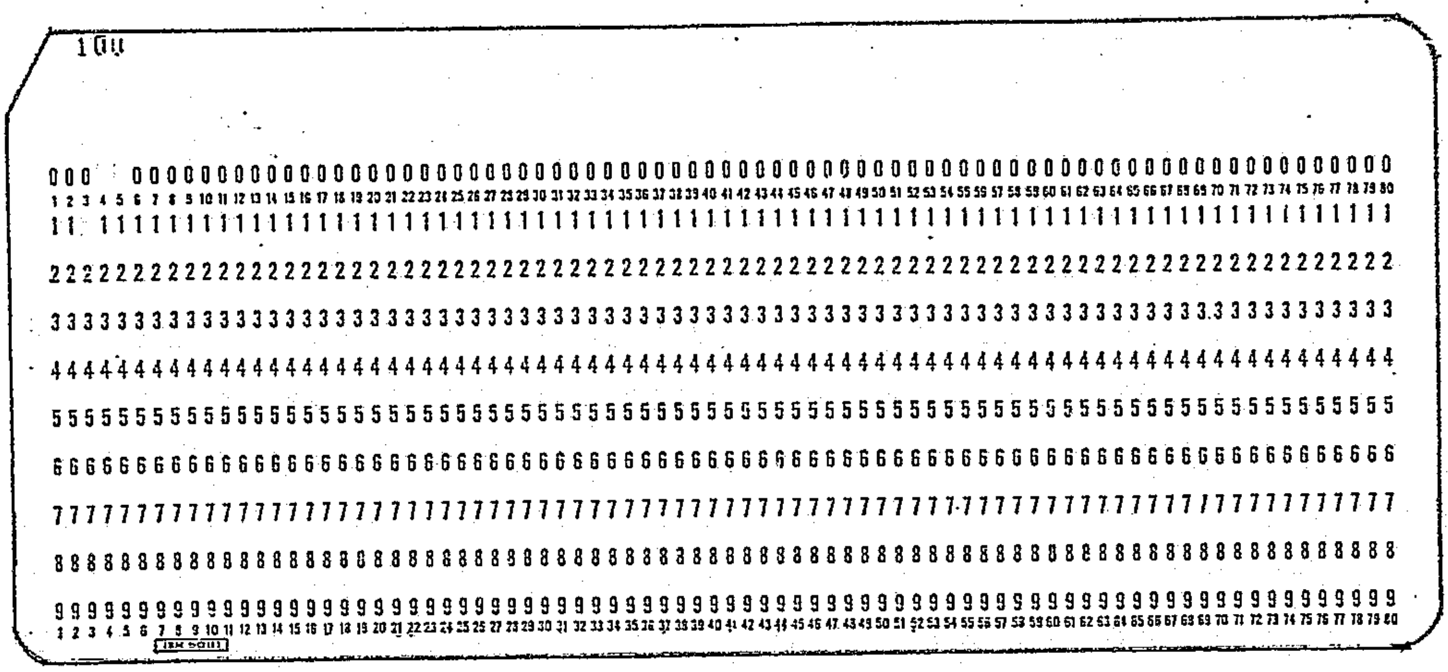
Under Procedure EVAL, the user may enter a completed design of a reactor element and request that an evaluation be performed. The evaluation is performed under steady-state conditions over a specified range of input voltage and output power. As in Procedure DSN2, the core size and relative permeability need not be in the core catalog in order for a design to be evaluated. However, the wire size used must be in the wire table. To use Procedure EVAL, the designer must input the core number (integer) of the core used, the relative permeability of the core, the number(s) of turns, the AWG wire size(s) and the number of cores in the stack. If a core which is not in the catalog is used, dimensional information must be supplied. Similarly, if a value of relative permeability which is not in the catalog is used, information of the loss coefficients may be given. If loss coefficients are not supplied, default values will be assumed (see Section 3.4.3). The outputs from Procedure EVAL include: minimum, maximum and RMS values for the winding current(s), RMS value of the capacitor current, pulse widths and frequency fo operation, power losses in the various components and the converter efficiency.

2.2 INPUT FORMAT

The input data for the programs is entered in the form of eighty-character records. In the instructions for preparing the data, each such record will be refered to as a "card" although the input data may not necessarily be in the form of computer cards. For example, it may be convenient to store the data base on magnetic disk or tape to reduce the number of punched cards which must be handled. Each record, or "card", is divided into a varying number of data fields with each data field containing the value of a particular variable. The field descriptor, or format, indicates what type of data is contained in a particular field. The field descriptors for each of the variables on a card are given in the instructions and are one of the standard FORTRAN IV field descriptors discussed in the following sections [3].

2.2.1 I Format

The form of the I format is: Im where m is an integer greater than zero. The integer m indicates the number of spaces allocated to the field. Variables which take on integer values in the program are read in under the I format. Any column within the field which is left blank will be read as a zero. Thus, it is important that all variables read in under the I format be right justified. Characters other than digits, plus and minus are invalid in I fields. For an example of the use of the I format, see Figure 7.



OR

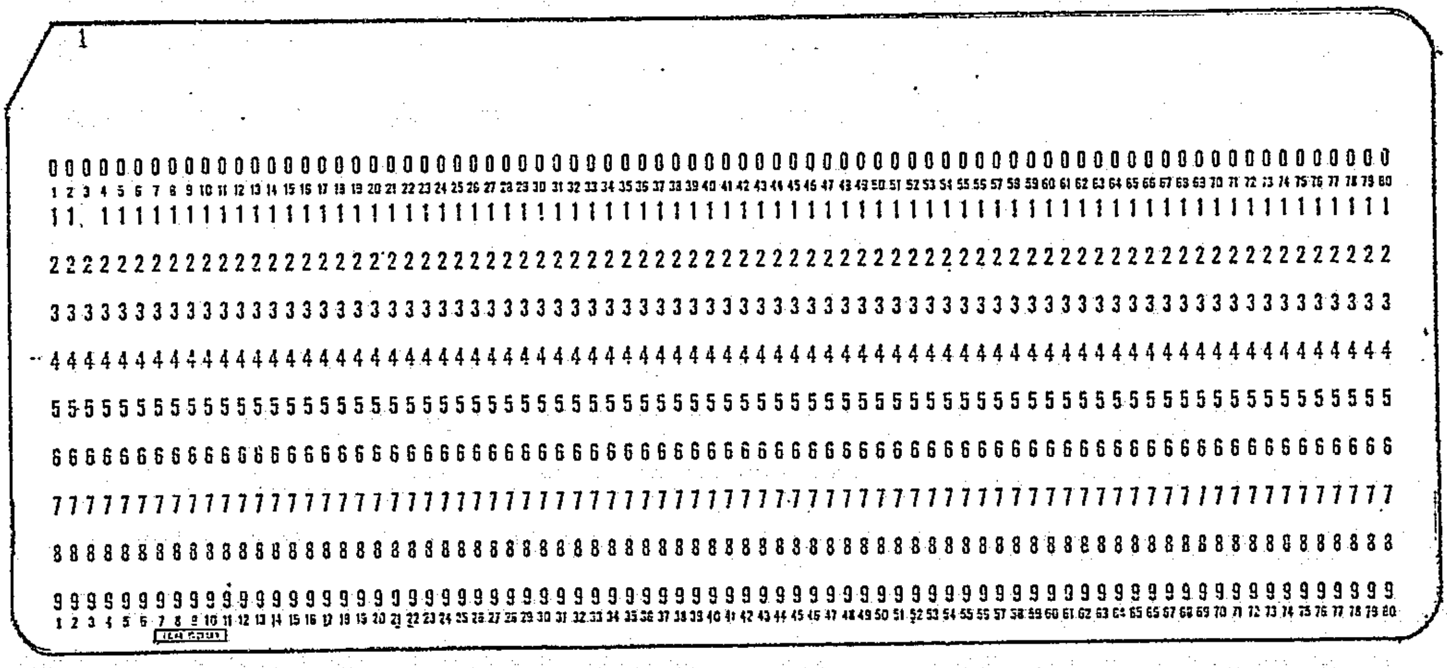


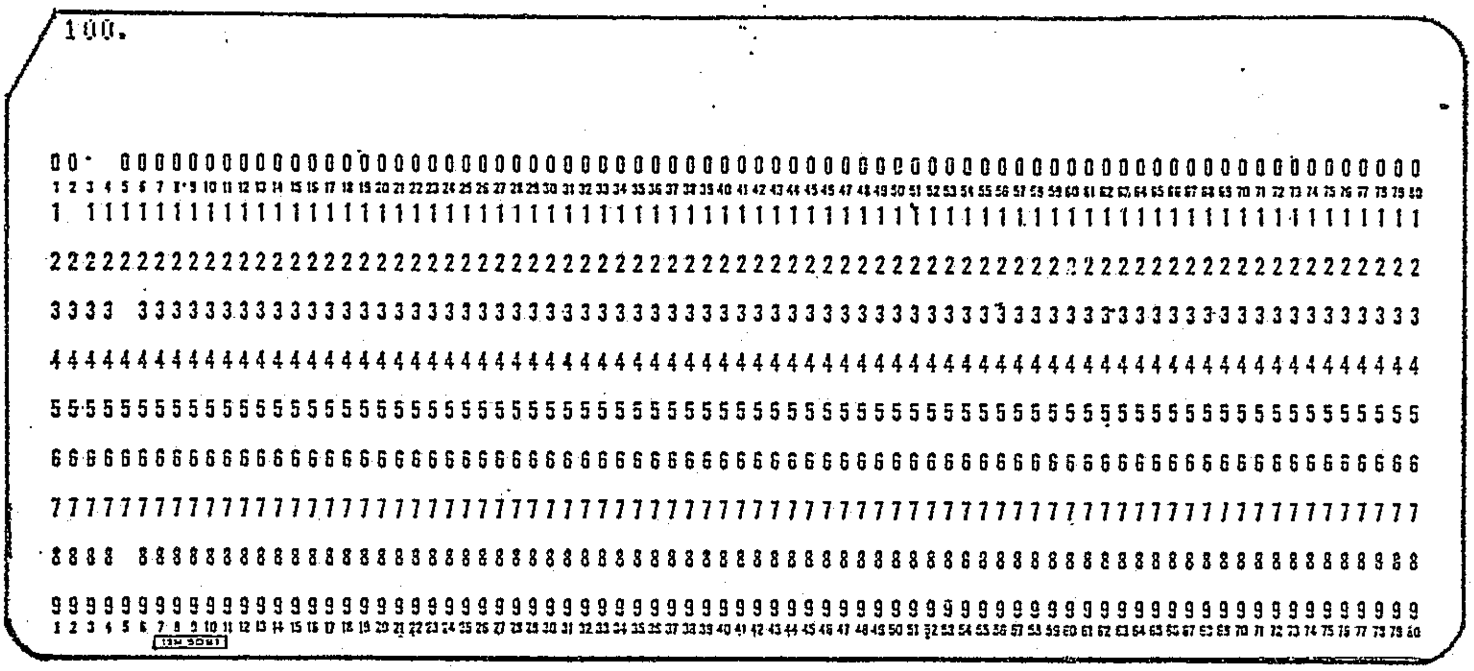
Figure 7. The Integer 100 Read Under
An I5 Format

2.2.2 F Format

The form of the F format is: Fm.n where m is an integer greater than zero and n is a integer greater than or equal to zero. The letter F indicates that this variable is a fixed point decimal number. The integer m indicates the number of spaces allocated to the field and the integer n indicates the number of decimal places present in the number. Placing a decimal point within the field overrides the value on n and is suggested. Use of a decimal point allows the placement of the number anywhere within the m spaces. Characters other than digits, plus, minus, and decimal point are invalid under the F format. For an example of the use of the F format, see Figure 8.

2.2.3 E Format

The form of the E format is: Em.n where m is an integer greater than zero and n is an integer greater than or equal to zero. The E format is used to read floating point decimal numbers with integer exponents. The integer m gives the number of spaces allocated to the field and the integer n indicates the number of decimal places present in the number. Use of a decimal point within the field overrides the value of n and is suggested. Exponents are entered by placing either an "E" or a space between the mantissa and the exponent. Blank columns are read as zeros, so the exponent should be right justified in order for its value to be read properly. For an example of the use of the E format, see Figure 9.



<u>OR</u>

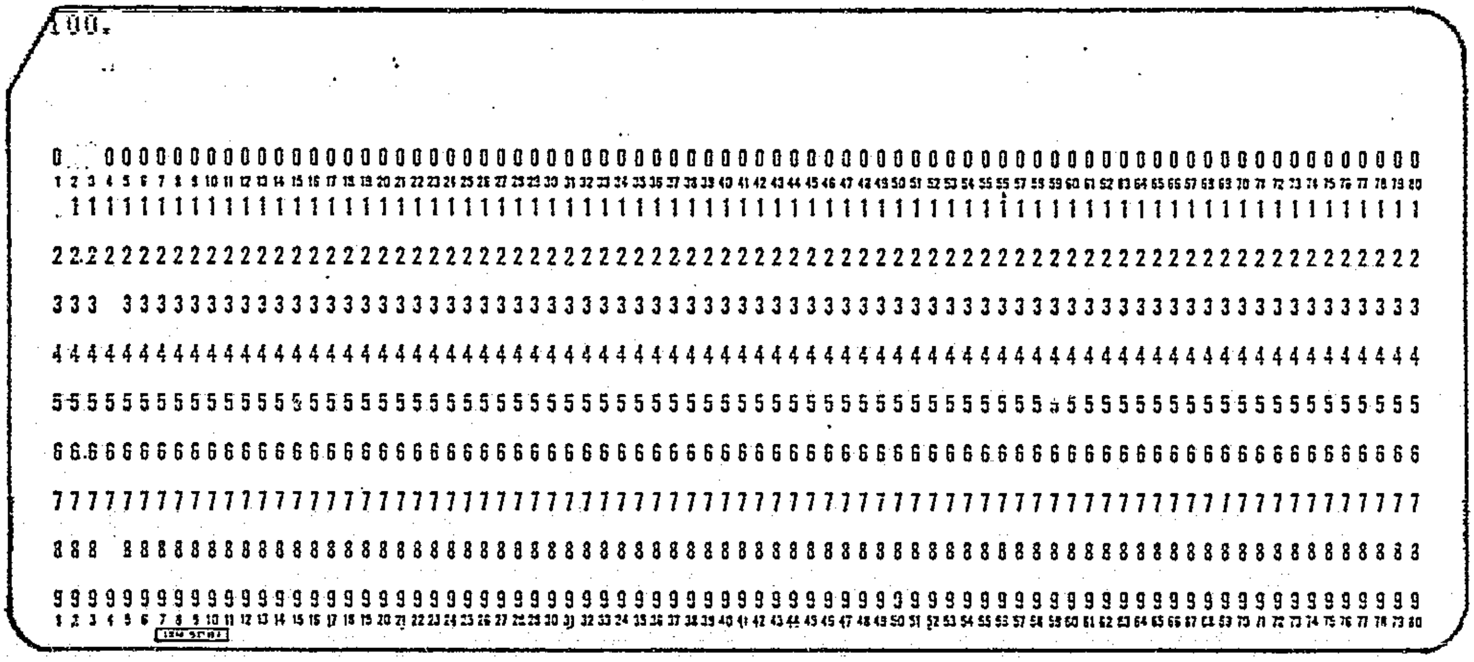
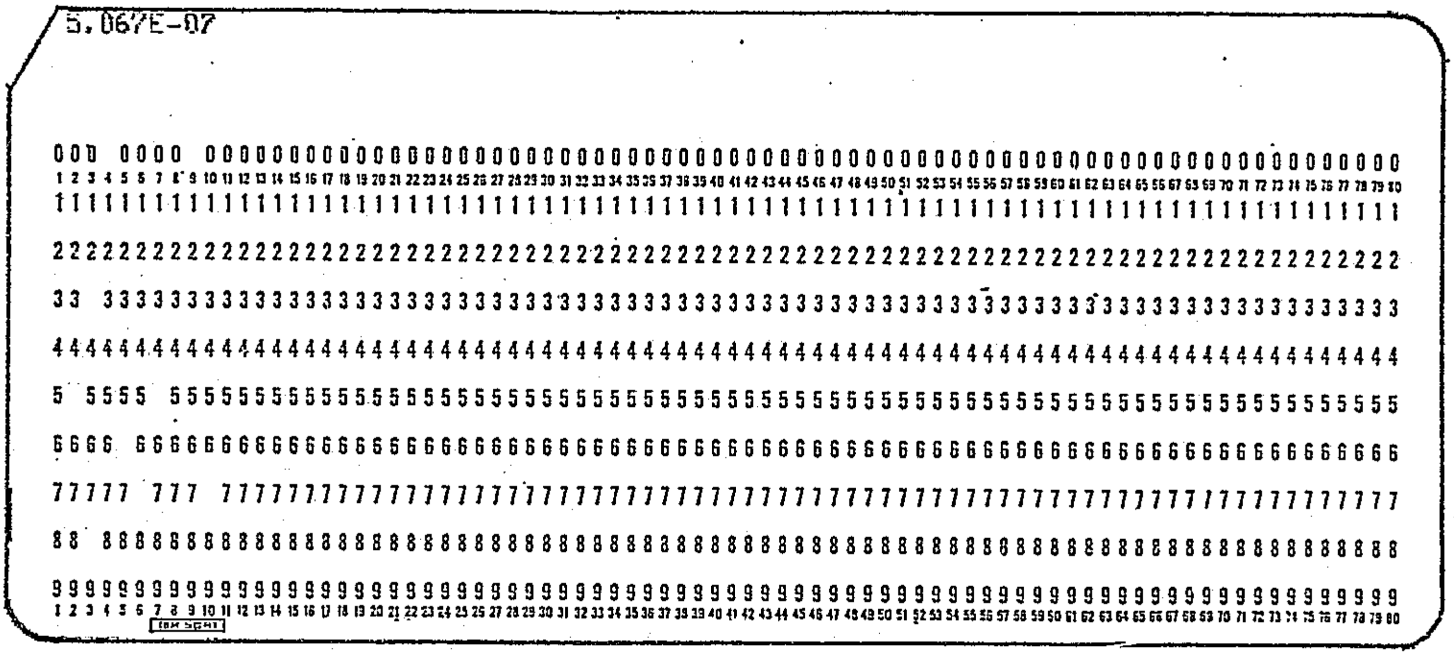


Figure 8. The Number 100.0 Read Under
An F5.0 Format



OR

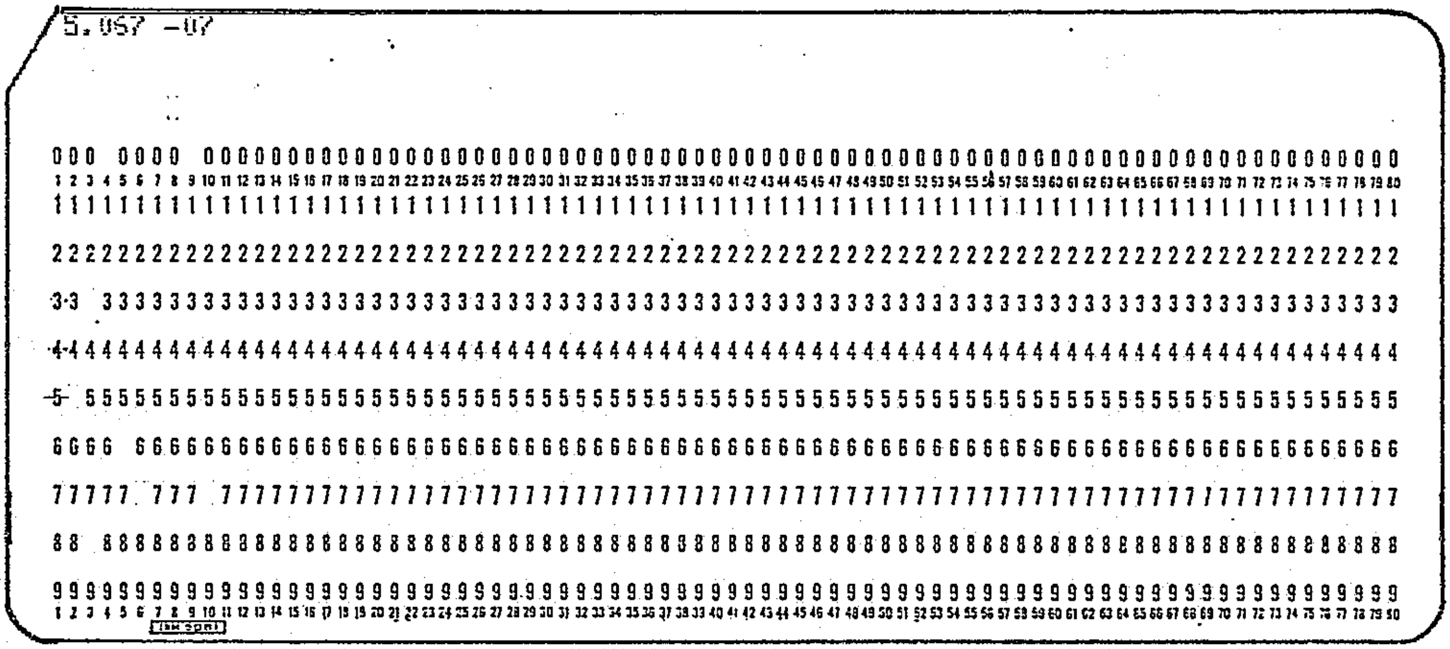


Figure 9. The Number $5.067 * 10^{-7}$ Read Under An E10.3 Format

2.2.4 A Format

The form of the A format is: Am where m is an integer greater than zero. The letter A indicates that this is an alphanumeric field. All keyboard characters are valid under the A format. The integer m gives the number of spaces allocated for the field. The A format is used to input variables which are words or groups of symbols, such as the name of a magnetic core manufacturer. For an example of the use of the A format, see Figure 10.

2.2.5 Characters

Use of characters within designated fields other than those listed below will usually result in severe errors which will either terminate the program or give invalid results.

FORMAT	VALID CHARACTERS
I	Digits, +, -
F	Digits, +, -, decimal point
E	Digits, +, -, decimal point, E
A	All keyboard characters

2.3 THE DATA DECK

The Data Deck is the total set of inputs to the program. and consists of the data base and the control cards. The programs read the data base first, followed by the control cards as shown in Figure 11. Section 3. discusses the control cards.

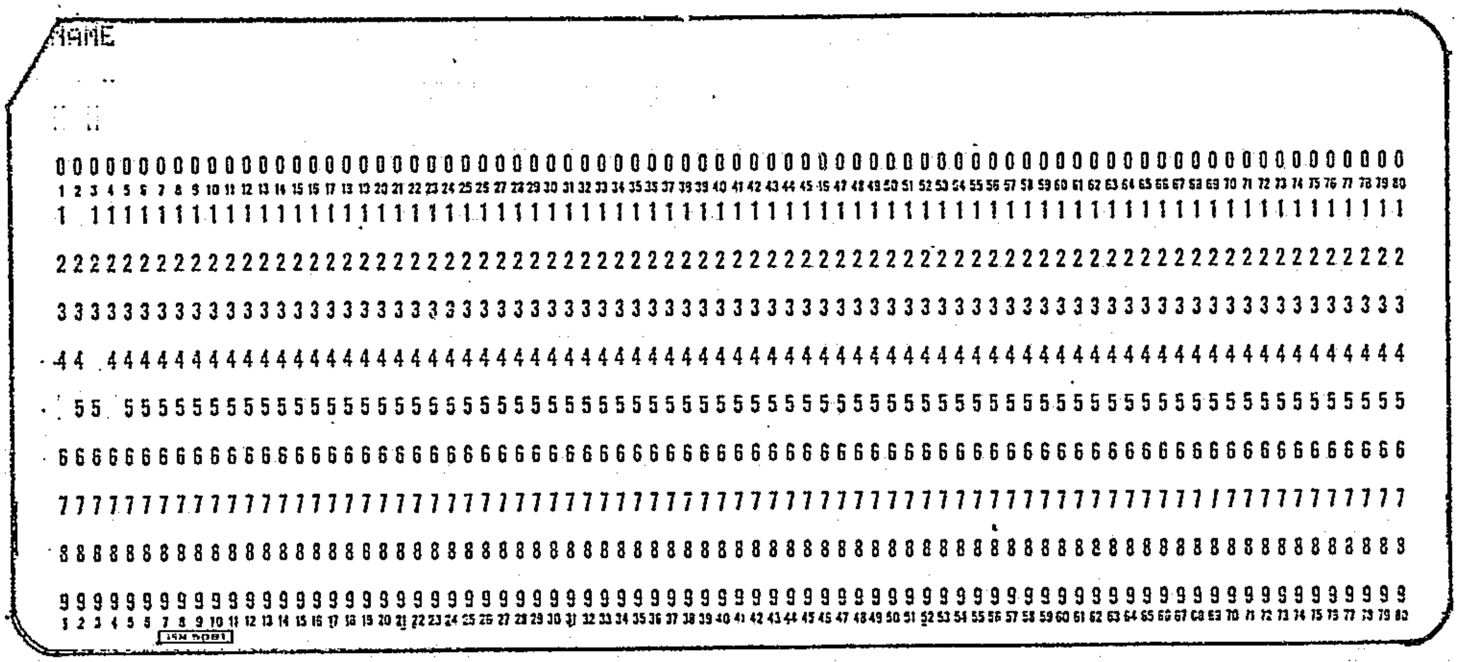


Figure 10. The Word "NAME" Read
Under An A4 Format

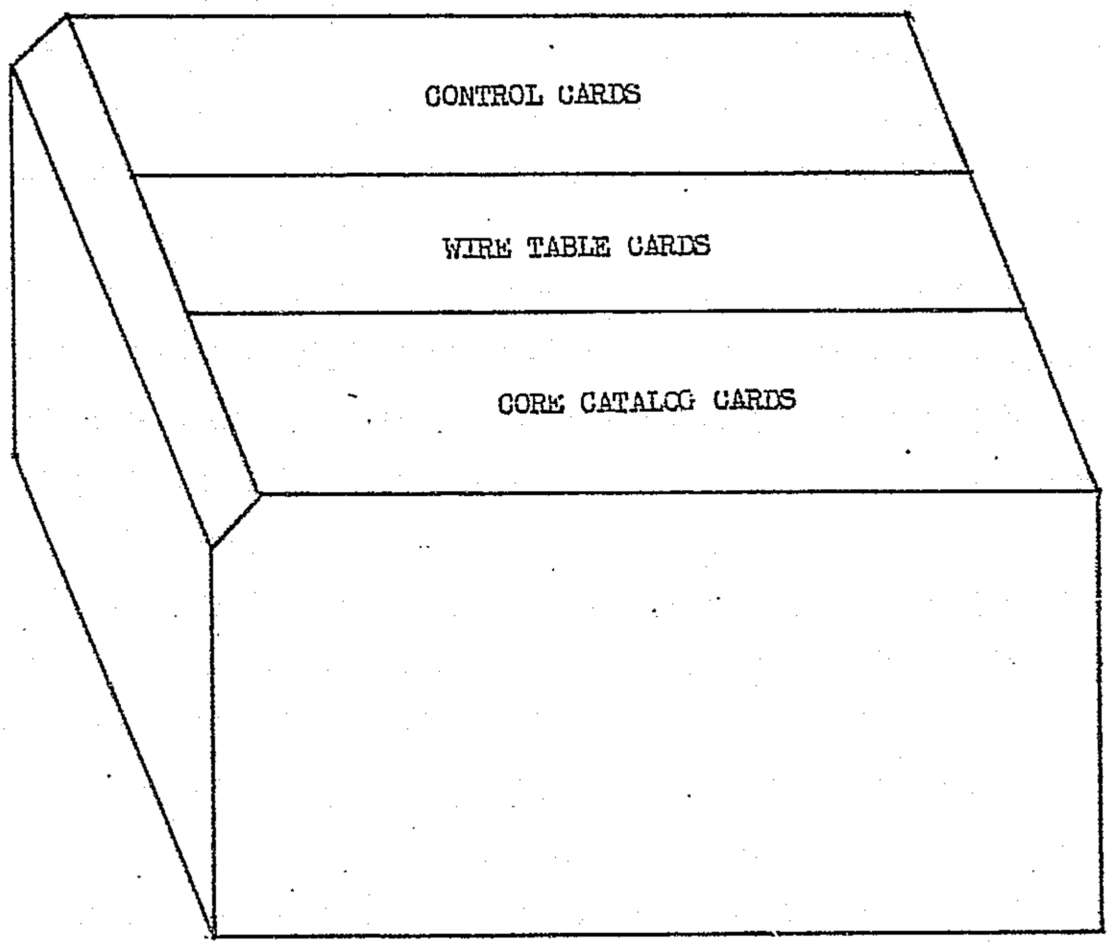


Figure 11. Order of The Data Deck

CONTROL CARDS

The control cards are read immediately after the data base and are the means by which the user inputs converter design specifications and indicates which of the three program procedures is desired. There are seven types of control cards, although all seven types need not be used on a given run. The names and order of the control cards are shown in Figure 12. Sections 3.1-3.5 give instructions for preparing the control cards for Program DC1DC. The number, order and function of the control cards for Program DC2DC are the same as those for Program DC1DC. However, in several of these cards--specifically the Type/Procedure Card, the Design Specification Card and the EVAL Card--there are slight differences between programs. Sections 3.6-3.9 give instructions for preparing the Control Cards for Program DC2DC.

In the instructions which follow (Sections 3.1-3.12), sections which apply to only one of the two programs will have titles which include the relevent program name as illustrated in the title of Section 3.1. Titles of sections which apply to both programs will not contain any reference to the program name as seen in the title of Section 3.1.2.

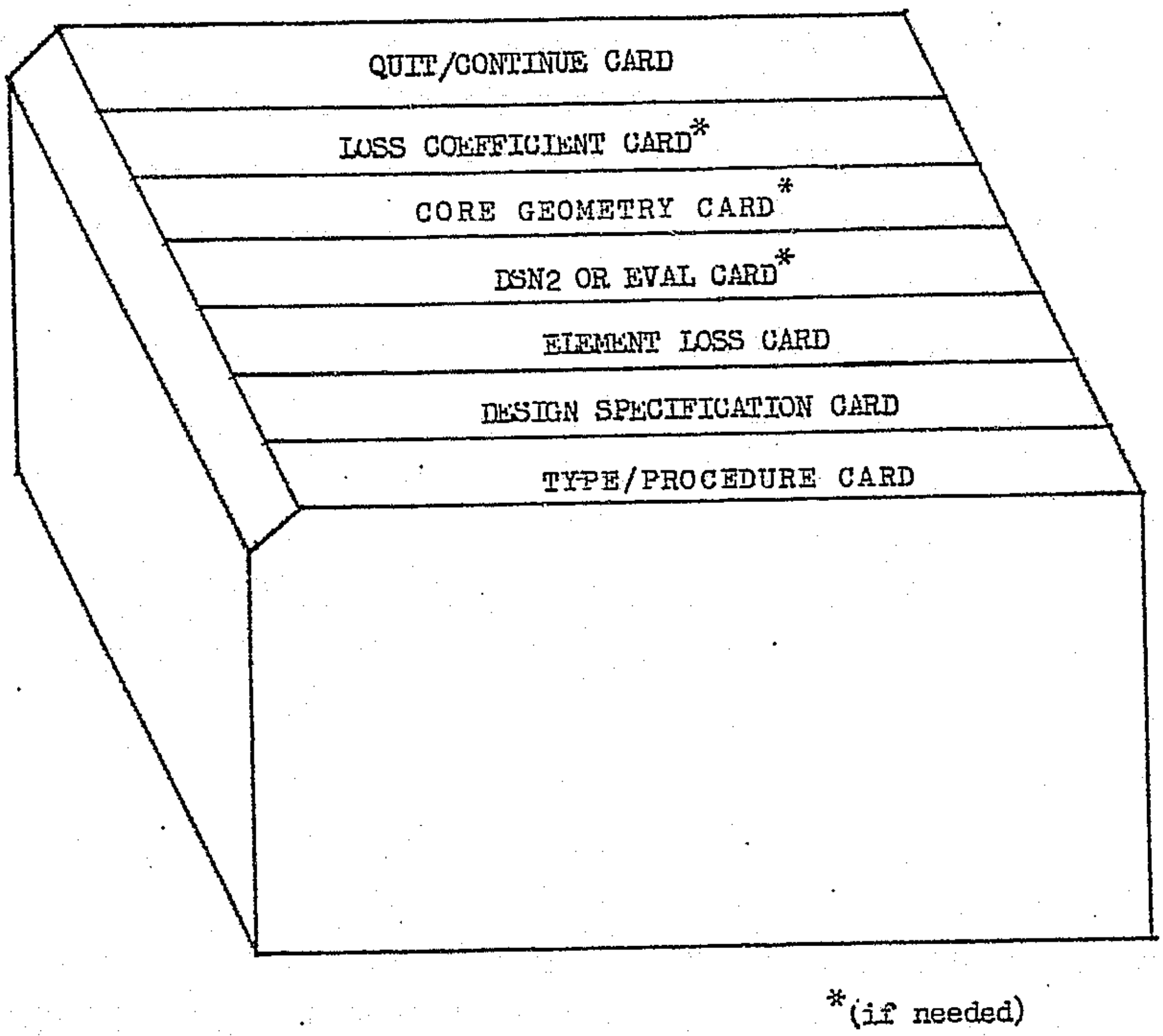


Figure 12. Order of The Control Cards

3.1 TYPE/PROCEDURE CARD--PROGRAM DC1DC

The Type/Procedure Card is the first card in the control deck. It specifies the type of converter/controller combination desired, controls the listing of the catalog, specifies the program procedure desired and gives certain parameters used in the design evaluation algorithm. The format of the Type/Procedure Card for Program DC1DC is given below (see also Figure 13). A sample card is shown in Figure 14.

COLUMNS	FORMAT	PARAMETER
2-5	A4	Converter/Controller Type
7-8	A2	Catalog Print Feature
10-13	A4	Program Procedure
14-20	I7	Maximum Number of Evaluations to be Performed (DSN1)
21-25	F5.0	Input Voltage Increment (volts)
26-30	F5.0	Output Power Increment (watts)

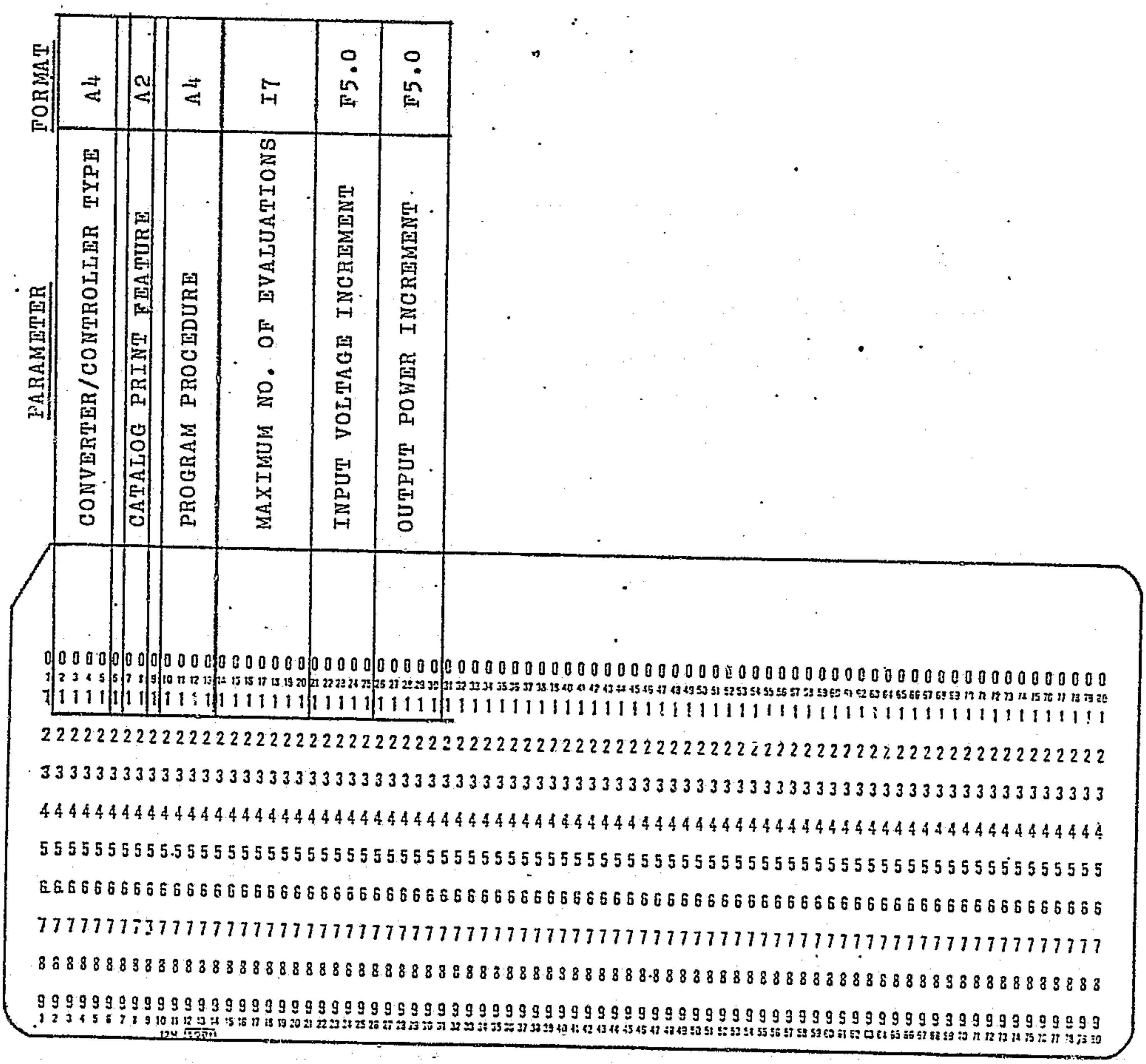


Figure 13. Type/Procedure Card--Program DC1DC

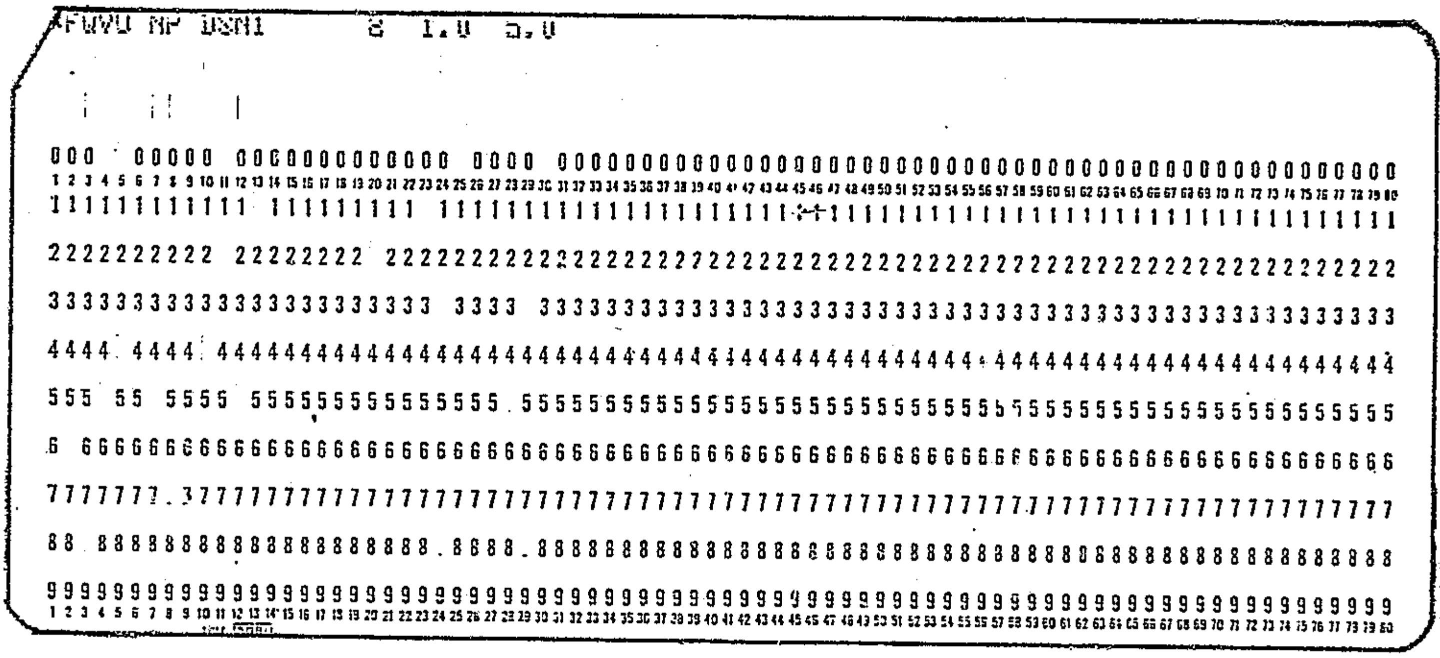


Figure 14. Example: Type/Procedure Card
Program DC1DC

3.1.1 Converter/Controller Types--Program DC1DC

The type of converter/controller combination that is to be designed and/or evaluated is indicated on the Type/Procedure Card by the use of the proper converter/controller code. DC1DC may be used to aid in the design of any one of the three circuit configurations shown in Figure 1 in conjunction with any one of three different types of controllers. The correct converter/controller code for each of the nine possible converter systems is given below.

CODE	CONVERTER TYPE	CONTROLLER TYPE
FQVU	Voltage Step-up	Constant Frequency
TNVU	Voltage Step-up	Constant On-time
TFVU	Voltage Step-up	Constant Off-time
FQCU	Current Step-up	Constant Frequency
TNCU	Current Step-up	Constant On-time
TFCU	Current Step-up	Constant Off-time
FQUD	Voltage Step-up/ Current Step-up	Constant Frequency
TNUD	Voltage Step-up/ Current Step-up	Constant On-time
TFUD	Voltage Step-up/ Current Step-up	Constant Off-time

3.1.4 Evaluation Parameters

The Input Voltage Increment and the Output Power Increment determine the conditions under which the design will be evaluated. First, the input voltage is set to its minimum value and the design is evaluated first for the minimum output power, then for the minimum power plus the power increment. The power is incremented until the maximum output power is reached or exceeded. Then, the input voltage is increased by the input voltage increment and the process is repeated. When the input voltage reaches or exceeds its maximum value, the evaluation routine is terminated. If the Input Voltage Increment and/or the Output Power Increment are set equal to zero, the program will assume a default value. The default value for the Input Voltage Increment is one third of the specified input voltage range and the default value for the Output Power Increment is one fifth of the specified output power range. The minimum and maximum values for the input voltage and the output power are specified on the Design Specification Card.

3.2 DESIGN SPECIFICATION CARD--PROGRAM DC1DC

The second card in the control deck is the Design Specification Card. The design specifications are entered on this card in the format given below (see also Figure 15). A sample Design Specification Card is shown in Figure 16. The meaning of the design specifications is discussed in Section 3.2.1.

COLUMNS	FORMAT	PARAMETER
1-5	F5.0	Output Voltage (volts)
6-10	F5.0	Minimum Input Voltage (volts)
11-15	F5.0	Maximum Input Voltage (volts)
16-20	F5.0	Minimum Output Power (watts)
21-25	F5.0	Maximum Output Power (watts)
26-30	F5.0	On-time, Off-time or Freq. (depending on Controller) (μsec or KHz)
31-35	F5.0	Residual Flux Density (tesla)
36-40	F5.0	Minimum Flux Density (tesla)
41-45	F5.0	Maximum Flux Density (tesla)
46-50	F5.0	Maximum Winding Factor
51-55	I5	Min. No. of Cores in Stack
56-60	I5	Max. No. of Cores in Stack
61-70	E10.3	Reciprocal Current Density (m^2/ampere)
72-75	A4	Wire Type
76-80	I5	Min. No. of Strands of Wire

3.2.1 Design Specifications

The maximum flux density specification sets an upper limit for the flux excursion. The computer design algorithm is such that the peak flux density of a computed design will reach this specified maximum at some point within the design range of input voltage and output power.

PARAMETER	FORMAT
OUTPUT VOLTAGE (VOLTS)	F5.0
MINIMUM INPUT VOLTAGE (VOLTS)	F5.0
MAXIMUM INPUT VOLTAGE (VOLTS)	F5.0
MINIMUM OUTPUT POWER (WATTS)	F5.0
MAXIMUM OUTPUT POWER (WATTS)	F5.0
ON TIME, OFF TIME OR FREQ. (μSEC OR KHZ)	F5.0
RESIDUAL FLUX DENSITY (TESLA)	F5.0
MINIMUM FLUX DENSITY (TESLA)	F5.0
MAXIMUM FLUX DENSITY (TESLA)	F5.0
MAXIMUM WINDING FACTOR	F5.0
MINIMUM NUMBER OF CORES IN STACK	I5
MAXIMUM NUMBER OF CORES IN STACK	I5
RECIPROCAL CURRENT DENSITY (M^2/AMP)	E10.3
WIRE TYPE CODE	A4
MINIMUM NUMBER OF STRANDS OF WIRE	I5

Figure 15. Design Specification Card
Program DC1DC

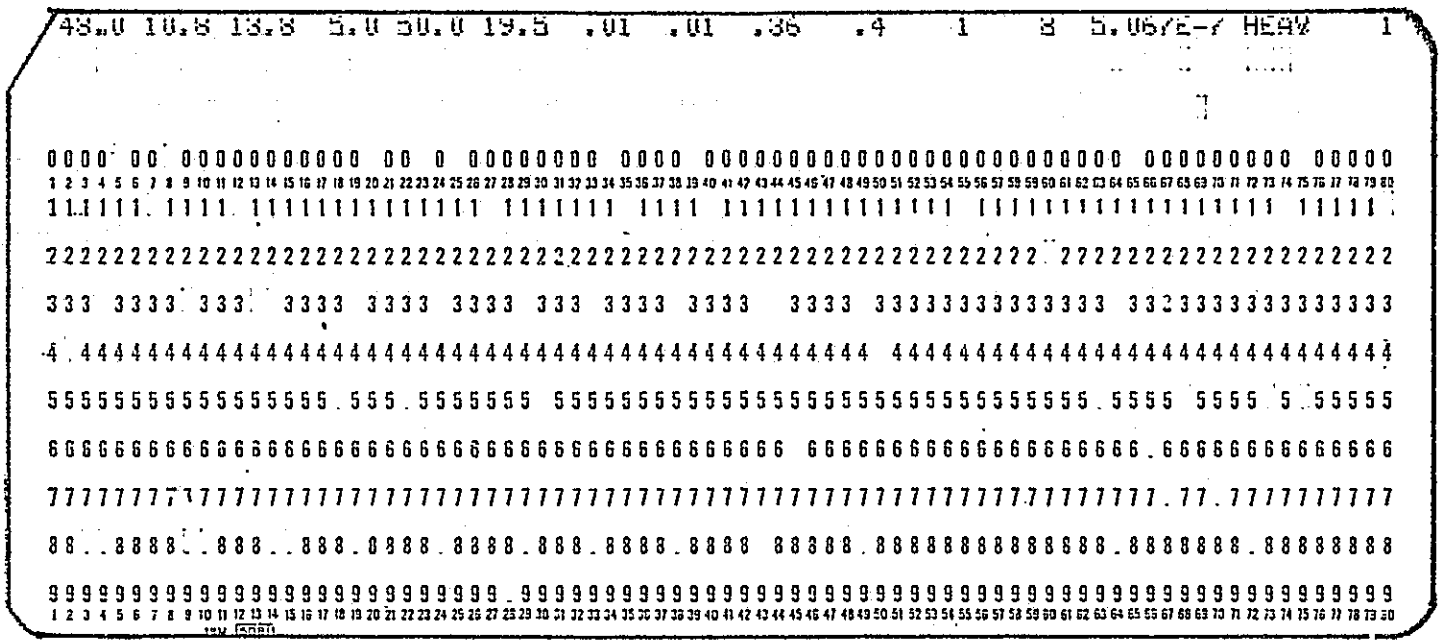


Figure 16. Example: Design Specification Card
Program DC1DC

The minimum flux density establishes a lower limit for the flux excursion. The design algorithm insures that the minimum instantaneous flux density of a computed design will exceed or equal this specified minimum at every point within the design range. This specification may not be chosen to be less than the specified residual flux density of the magnetic material. If the minimum flux density specification is chosen to be greater than the residual flux density, all computer generated designs will operate in Mode 1 (continuous conduction mode) over their entire design range. However, if the minimum flux density specification is chosen to be equal to the residual, then the generated designs may operate in Mode 1 over the entire design range; or, in Mode 2 (discontinuous conduction mode) over the entire range; or, in Mode 1 over some portion of the range and in Mode 2 elsewhere. It should be noted however, that while it is possible to force completely Mode 1 operation by choosing the minimum flux density specification to be greater than the residual, it is not possible to force the program to generate designs which operate in Mode 2 over the entire design range of input voltage and output power.

The maximum winding factor determines which cores are acceptable designs. The winding factor is computed by taking the area of the winding(s) (based on the cross-sectional area of the insulated wire) and dividing by the window area of the magnetic core. This corresponds to the fractional part of the core window which is filled by the winding(s). Cores which require winding factors greater than the specified maximum are rejected. This parameter is ignored in the evaluation portion of the programs. Winding factors greater than one are not allowed in Procedures DSN1 and DSN2.

The <u>minimum number of cores in the stack</u> and the <u>maximum number of cores in the stack</u> allow designs with stacked cores to be generated. If fifty usable designs are not found for the specified minimum core stack, the stack height is automatically increased by one and the design procedure is repeated. The stack height will be increased in this fashion until fifty designs are found or until the specified maximum number of cores in the stack is reached.

Often, it may be desired to use more than one strand of wire for the core winding(s). The <u>minimum strands of wire</u> parameter(s) allows designs to be made with stranded wire. If the largest wire size in the wire table will not meet the <u>reciprocal current density</u> specification with the specified minimum number of strands, the number of strands is automatically increased by the design algorithm until this specification is met. There is an internal <u>default value</u> of one for the minimum number of strands. When using <u>Procedure EVAL</u>, the minimum strands of wire parameter <u>must</u> be set equal to the number of strands actually used in the design being evaluated. In Program DC2DC, there is a minimum strands of wire specification for both primary and secondary windings of the two-winding reactor (see Section 3.7).

3.2.2 Wire Types

Four types of wire coating are available in the program. The user selects the desired type by entering the correct wire type code in the field provided for this purpose on the Design Specification Card. The wire type codes are given in the table below.

CODE	WIRE TYPE
SING	Single Coating--Synthetic Film Insulation
HEAV	Double Coating--Synthetic Film Insulation
TRIP	Triple Coating--Synthetic Film Insulation
QUAD	Quad Coating--Synthetic Film Insulation

3.3 ELEMENT LOSS CARD

The Element Loss Card gives parameters used to calculate approximate power losses in the elements of the converter circuit other than the magnetic core. The format for this card is given in the table below (see also Figure 17). A sample Element Loss Card is shown in Figure 18. Section 1.2 discusses the device models and power loss calculations. If any of the parameters on the Element Loss Card are entered as zero (or left blank), the program will assume that the corresponding device is lossless.

COLUMNS	FORMAT	PARAMETER
1-5	F5.0	Transistor Saturation Voltage (volts)
6-10	F5.0	Collector Current for above (amperes)
11-15	F5.0	Diode Forward Drop (volts)
16-20	F5.0	Capacitor Effective Series Resistance (ohms)

3.4 DSN2 CARD AND EVAL CARD

3.4.1 DSN2 Card

In Procedure DSN2, the program attempts to compute a design using a specified magnetic core. The DSN2 card is used only if the DSN2 procedure has been specified on the Type/ Procedure Card (see Section 3.1). It contains the integer size number and the relative permeability of the core for which a design is desired. The integer core number may be obtained from the catalog listing produced by the program. This information is found on the catalog listing under the heading "SIZE NO.". The format of the DSN2 Card is given in the table below (see also Figure 19). A sample DSN2 Card is shown in Figure 20.

COLUMNS	FORMAT	PARAMETER
1-5	I5	Core Size Number from Catalog
6-10	F5.0	Relative Permeability of Core
11-15	I5	Number of Cores in Stack

PARAMETER	FORMAT
TRANSISTOR SATURATION VOLTAGE (VOLTS)	F5.0
COLLECTOR CURRENT (AMPS)	F5.0
DIODE FORWARD DROP (VOLTS)	F5.0
CAPACITOR ESR	F5.0

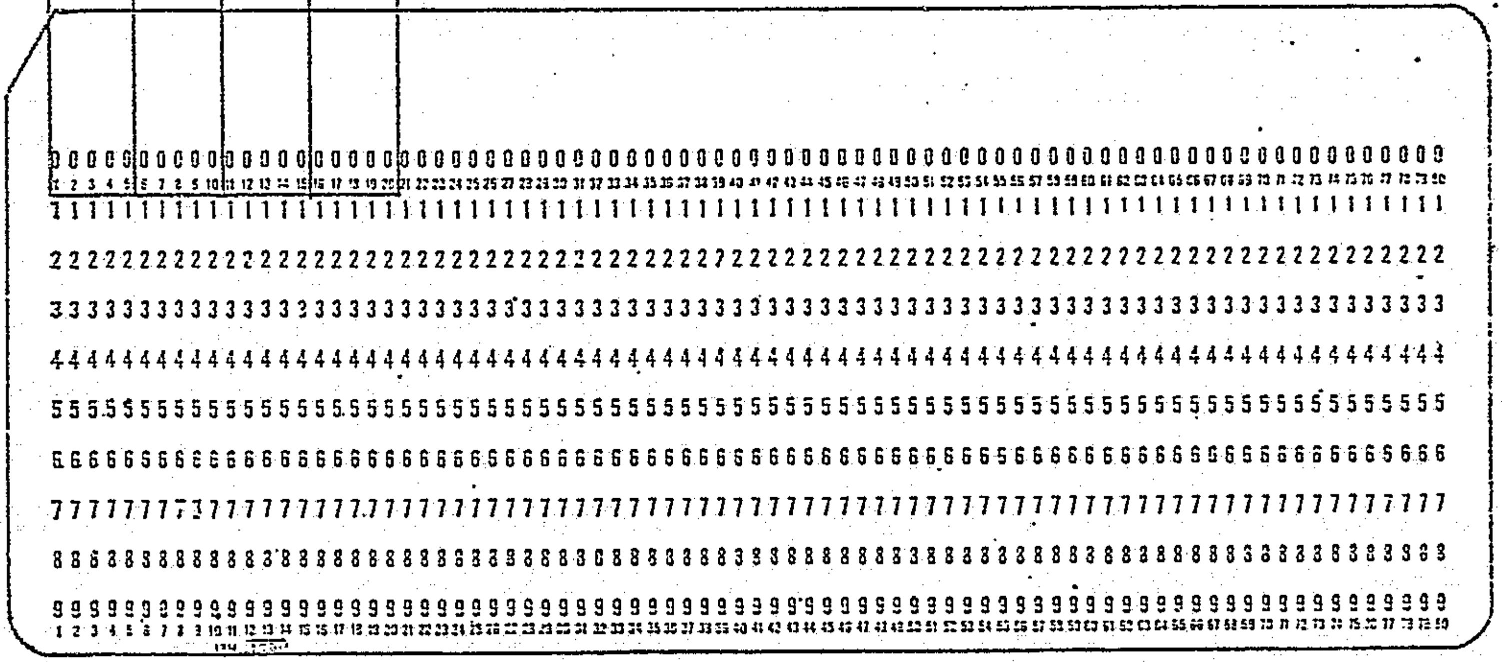


Figure 17. Element Loss Card

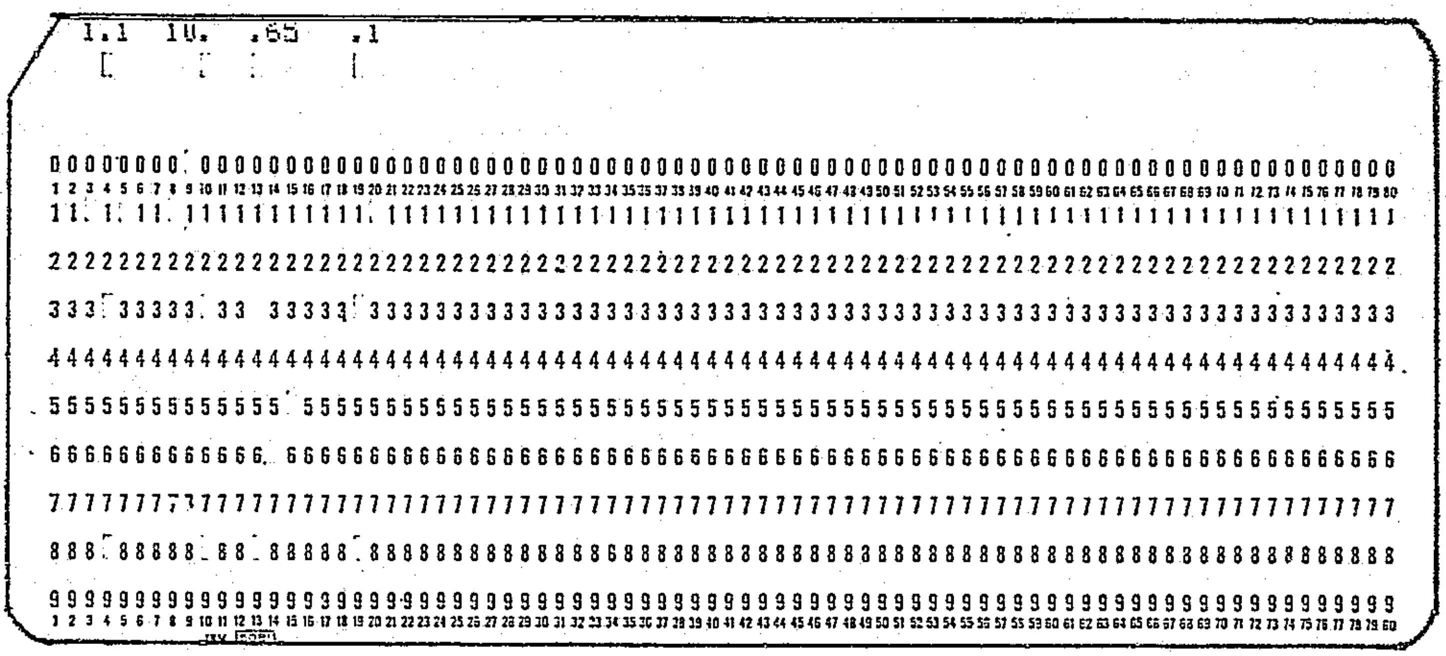


Figure 18. Example: Element Loss Card

PARAMETER	FORMAT
CORE SIZE NUMBER (INTEGER)	I5
RELATIVE PERMEABILITY	F5.0
NUMBER OF CORES IN STACK	I5

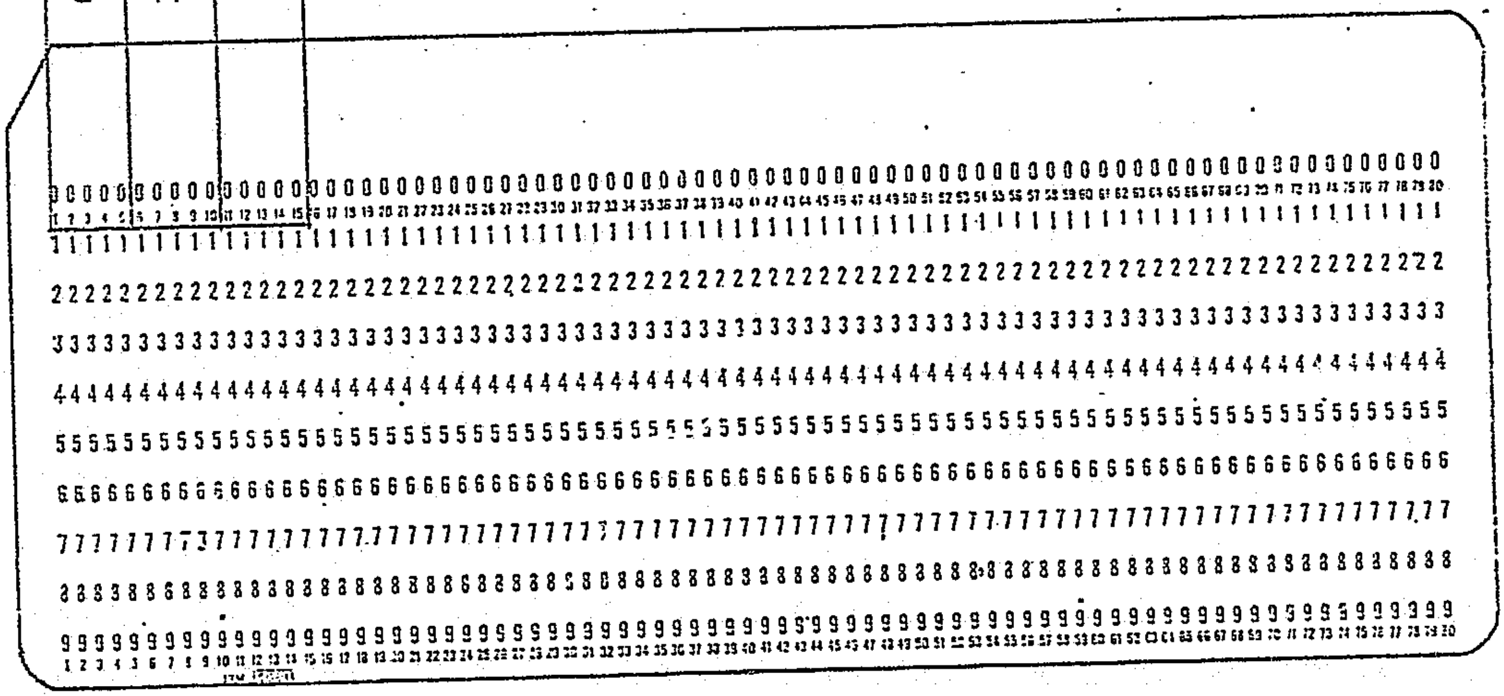


Figure 19. DSN2 Card

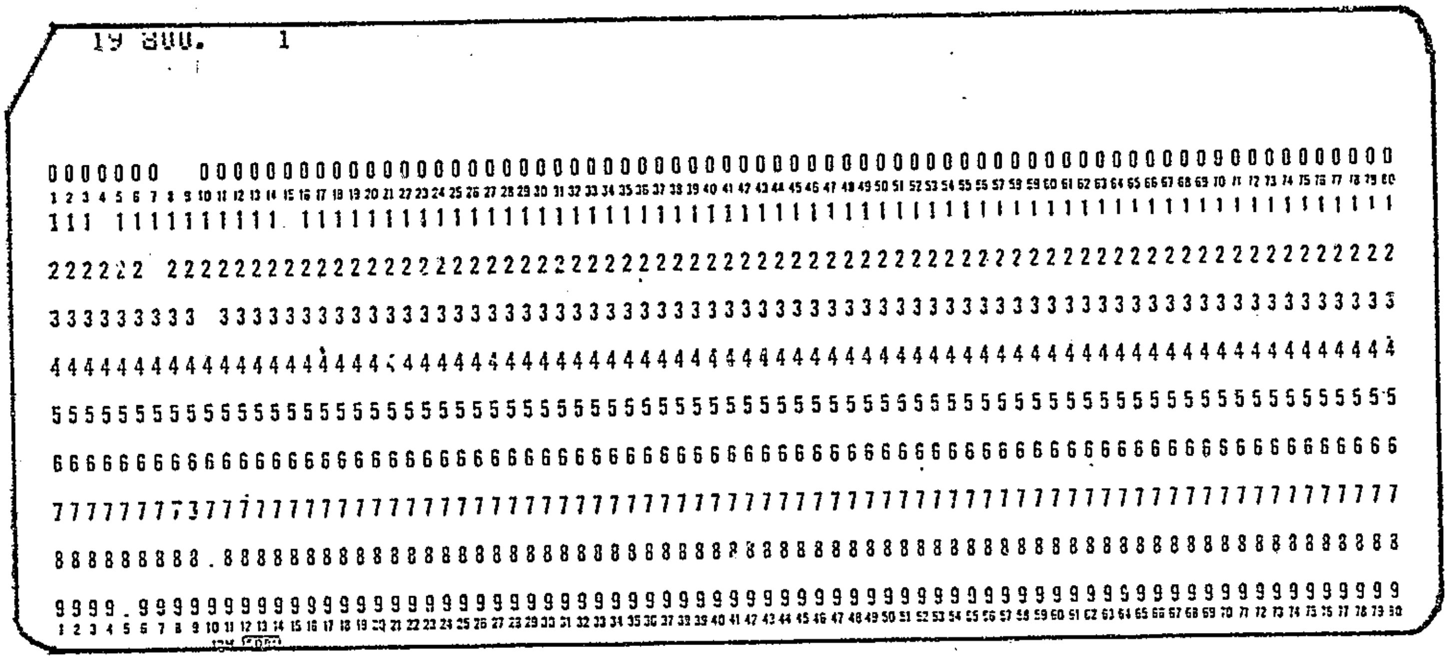


Figure 20. Example: DSN2 Card

3.4.2 EVAL Card--Program DC1DC

In Procedure EVAL, Program DC1DC evaluates a design entered by the user. The EVAL card is used only if the EVAL procedure was specified on the Type/Procedure Card (see Section 3.1). The EVAL Card contains the integer size number of the core, the relative permeability, the number of turns, wire size and number of cores in the stack. The integer core number may be obtained from the catalog listing produced by the program. This information is found on the catalog listing under the heading "SIZE NO.". The format of the EVAL Card for Program DC1DC is given in the table below (see also Figure 21). A sample EVAL Card for Program DC1DC is shown in Figure 22.

COLUMNS	FORMAT	PARAMETER
1-5	I5	Core Size Number from Catalog
6-10	F5.0	Relative Permeability of Core
11-15	I5	Number of Cores in Stack
16-20	I5	Number of Turns of Wire
21-25	I5	Wire Size (AWG number)

PARAMETER	FORMAT
CORE SIZE NUMBER (INTEGER)	I5
RELATIVE PERMEABILITY	F5.0
NUMBER OF CORES IN STACK	I5
NUMBER OF TURNS	I5
WIRE SIZE (AWG NUMBER)	I5

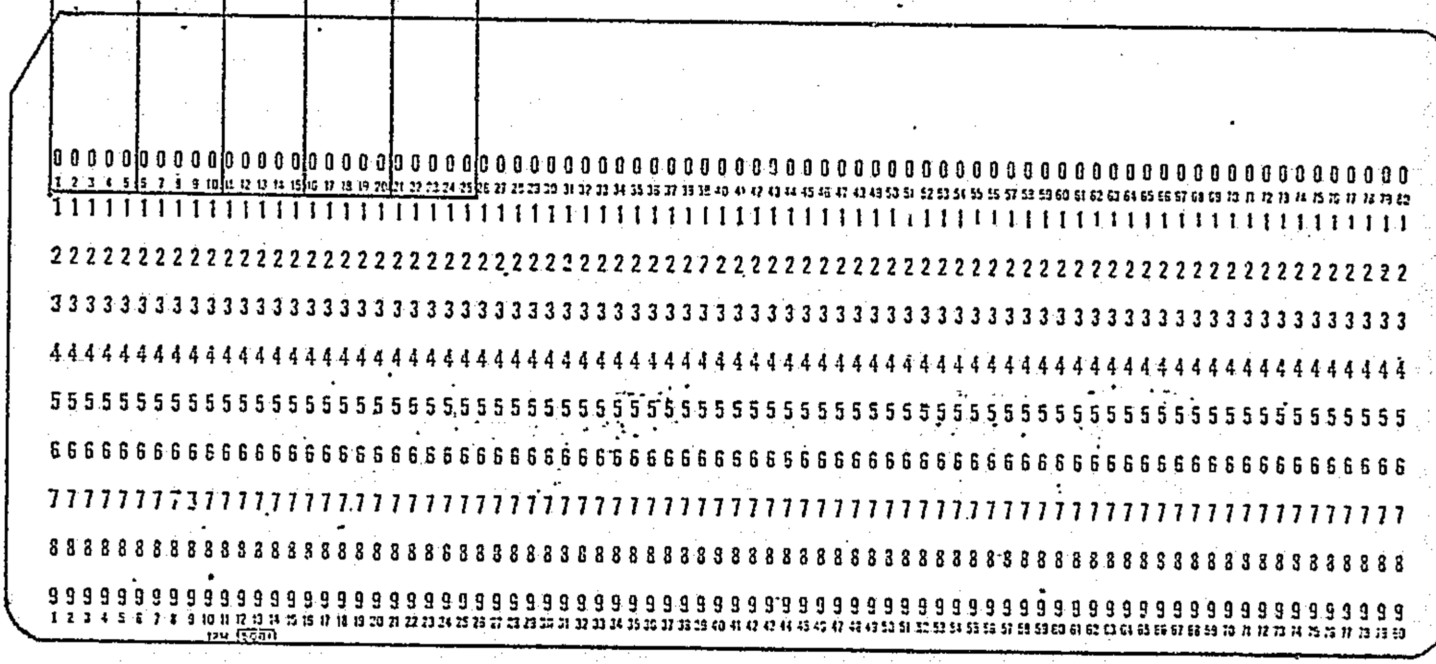


Figure 21. EVAL Card--Program DC1DC

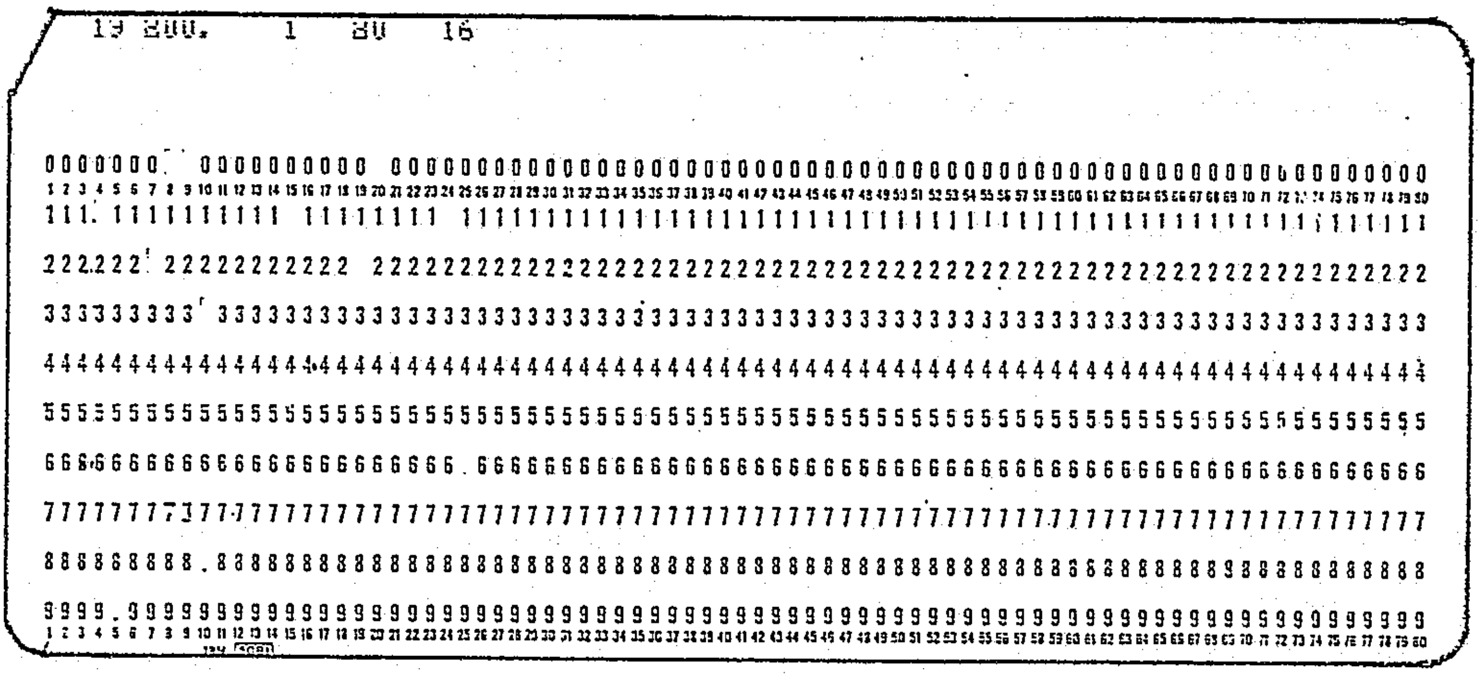


Figure 22. Example: EVAL Card
Program DC1DC

3.4.3 Procedures DSN2 and EVAL with Cores not in the Catalog

If either a core size or a relative permeability value (or both) is not in the catalog, it is still possible to use Procedures DSN2 and EVAL. Simply enter a zero or blank for the core size and/or permeability on the DSN2 or EVAL Card. If a zero (or blank) was entered for the core size number, an additional card must be added immediately following the DSN2 or EVAL Card which gives the dimensional information for the core used. If a zero (or blank) was entered for the value of relative permeability, an additional card must be added giving loss coefficient information on the entered core and its value of relative permeability. If both parameters are entered as zero (or blank), then both extra cards are needed. The <u>dimensional data card</u> follows the DSN2 or EVAL Card and the <u>loss coefficient data card</u> follows the dimensional data card. The formats of these extra cards are the same as those of the <u>Core Geometry Card</u> (Section 6.4.2) and the <u>Loss-Coefficient</u> Card (Section 6.3). The loss coefficient information is used only in the evaluation algorithm. If loss coefficients for an entered value of relative permeability are given as zero (or left blank), the programs will use values from the catalog which are for the cataloged value of relative permeability which is closest to the entered value.

3.5 QUIT/CONTINUE CARD

The final card in the control deck should have a zero in column one. If more than one design and/or evaluation is desired on a given run, use a card with a one in column one followed by another set of control cards. This may be repeated for as many design and/or evaluation requests as desired.

PROGRAM DC2DC

3.6 TYPE/PROCEDURE CARD--PROGRAM DC2DC

The Type/Procedure Card is the first card in the Control Deck for Program DC2DC. It specifies the type of controller desired, controls the listing of the catalog and gives the desired design constraint option and the design constraint. In addition, the Type/Procedure card lists the evaluation parameters described in Section 3.1.4. The format of the Type/Procedure Card is given in the table below (see also Figure 23). A sample Type/Procedure Card for Program DC2DC is shown in Figure 24.

COLUMNS	FORMAT	PARAMETER
2-6	A5	Converter/Controller Type
8-9	A2	Catalog Print Feature
11-14	A4	Program Procedure

COLUMNS	FORMAT	PARAMETER
15-20	I6	Design Constraint Option
21-25	F5.0	Design Constraint Value
26-30	I5	Max. No. of Evaluations to be performed (DSN1)
31-35	F5.0	Input Voltage Increment (volts)
36-40	F5.0	Output Power Increment (watts)

3.6.1 Converter/Controller Types--Program DC2DC

Program DC2DC may be used for the design of the reactor element and/or the evaluation of the operating characteristics of the two-winding voltage step-up/current step-up converter configuration shown in Figure 2. This converter circuit may be coupled with any one of three types of controllers--constant frequency, constant transistor on-time or constant transistor off-time. The converter/controller code indicates which of these three possible systems is to be designed and/or evaluated. The correct converter/controller code for each possible type of controller is given below.

CODE	TYPE OF CONTROLLER
FQ2UD	Constant Frequency
TN2UD	Constant On-time
TF2UD	Constant Off-time

PARAMETER	FORMAT
CONVERTER/CONTROLLER TYPE	A5
CATALOG PRINT FEATURE	A2
PROGRAM PROCEDURE	A4
DESIGN CONSTRAINT OPTION	I6
DESIGN CONSTRAINT VALUE	F5.0
MAXIMUM NO. OF EVALUATIONS	I5
INPUT VOLTAGE INCREMENT	F5.0
OUTPUT POWER INCREMENT	F5.0

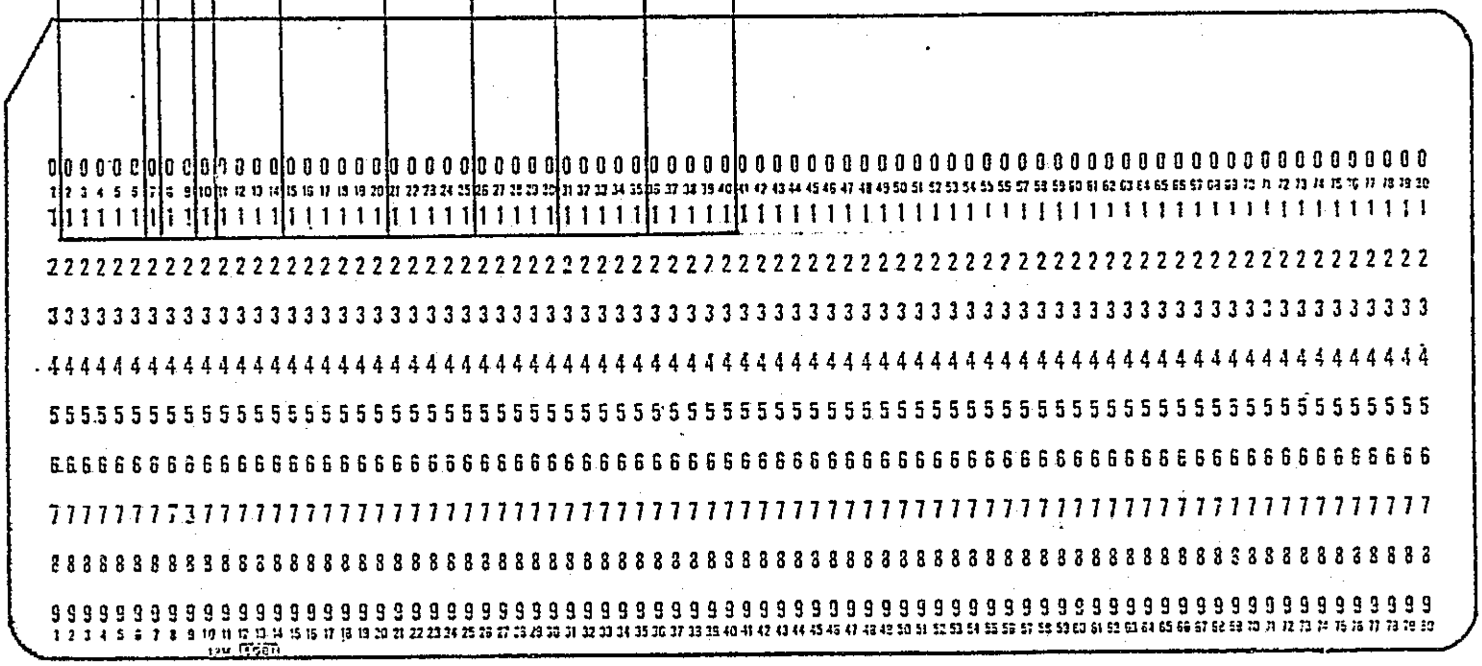


Figure 23. Type/Procedure Card
Program DC2DC

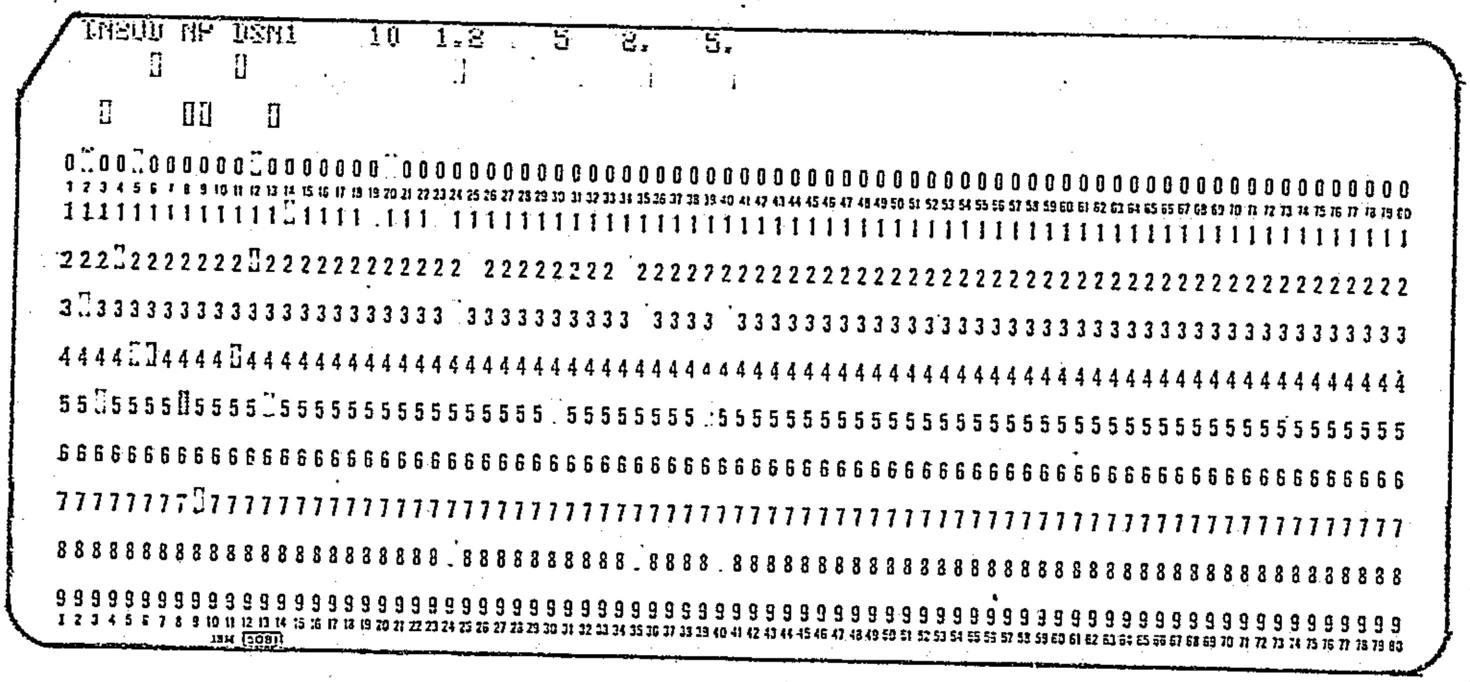


Figure 24. Example: Design Specification Card
Program DC2DC

3.6.2 Catalog Print Feature

On request, Program DC2DC will print out a listing of the core catalog and wire table. The use of this feature is identical to that of the Catalog Print Feature in Program DC1DC and is discussed in Section 3.1.2.

3.6.3 Program Procedure Codes

The Program Procedure Codes indicate which program procedure is desired. These codes are identical to those for Program DC1DC and are given in Section 3.1.4. The Program Procedures are discussed in Section 2.1.

3.6.4 Design Constraint Options--Program DC2DC

For the two-winding voltage step-up/current step-up circuit configuration shown in Figure 2, knowledge of the converter operating range and the magnetic core parameters is not sufficient to uniquely determine values for N_S and N_P [4]. This provides an additional degree of freedom in the design which may be useful to the designer. Program DC2DC makes use of this extra degree of freedom by allowing the user to select any one of ten <u>Design Constraint Options</u>. Each of these options places a constraint on the allowable values of certain converter system parameters. The actual numerical value of the particular constraint is refered to as the <u>Design Constraint Value</u>. The user specifies the desired Design Constraint Option by entering the integer option number from the list below in the field provided on the Type/Procedure Card (see Section 3.6). The Design Constraint Value, U_i, is also entered on the Type/Procedure Card.

OPTION NO.	DESIGN CONSTRAINT OPTION
1	Duty Cycle* Centered at U_1
2	Minimum Duty Cycle = U_2
3	Range of Duty Cycle Variation = U_3
4	Max. Transistor Collector-Emitter Voltage = U_4 volts
5	Max Reverse Diode Voltage = U_5 volts
6	Max. Peak Transistor Current = U_6 amps
7	Max. Peak Diode Current = U_7 amps
8	Maximum Duty Cycle = U_8
9	Total Number of Turns = $N_S + N_P = U_9$
10	Turns Ratio = $N_S/N_P = U_{10}$

*Duty Cycle is defined as the ratio of transistor on-time to the total period.

3.6.5 Evaluation Parameters

The Evaluation Parameters consist of the Input Voltage Increment and the Output Power Increment. These Parameters are discussed in Section 3.1.4 and serve the same function in both Program DC1DC and DC2DC.

3.7 DESIGN SPECIFICATION CARD--PROGRAM DC2DC

The design specifications are entered on the Design Specification Card as indicated in the table below (see also Figure 25). A sample Design Specification Card for Program DC2DC is shown in Figure 26.

COLUMNS	FORMAT	PARAMETER
1-5	F5.0	Output Voltage (volts)
6-10	F5.0	Minimum Input Voltage (volts)
11-15	F5.0	Maximum Input Voltage (volts)
16-20	F5.0	Minimum Output Power (watts)
21-25	F5.0	Maximum Output Power (watts)
26-30	F5.0	On-time, Off-time or Freq. (depending on controller) (μsec or KHz)
31-35	F5.0	Residual Flux Density (tesla)
36-40	F5.0	Minimum Flux Density (tesla)
41-45	F5.0	Maximum Flux Density (tesla)
46-50	F5.0	Maximum Winding Factor
51-55	I5	Minimum No. of Cores in Stack
56-60	I5	Maximum No. of Cores in Stack
61-70	E10.3	Reciprocal Current Density (m^2/ampere)
72-75	A4	Wire Type
77-78	I2	Min. No. Strands--Primary
79-80	I2	Min. No. Strands--Secondary

PARAMETER	FORMAT
OUTPUT VOLTAGE (VOLTS)	F5.0
MINIMUM INPUT VOLTAGE (VOLTS)	F5.0
MAXIMUM INPUT VOLTAGE (VOLTS)	F5.0
MINIMUM OUTPUT POWER (WATTS)	F5.0
MAXIMUM OUTPUT POWER (WATTS)	F5.0
ON-TIME, OFF-TIME OR FREQ. (μSEC OR KHZ)	F5.0
RESIDUAL FLUX DENSITY (TESLA)	F5.0
MINIMUM FLUX DENSITY (TESLA)	F5.0
MAXIMUM FLUX DENSITY (TESLA)	F5.0
MAXIMUM WINDING FACTOR	F5.0
MINIMUM NUMBER OF CORES IN STACK	I5
MAXIMUM NUMBER OF CORES IN STACK	I5
RECIPROCAL CURRENT DENSITY (M^2/AMPERE)	E10.3
WIRE TYPE CODE	A4
MIN. NO. PRI. WIRE STRANDS	I5
MIN. NO. SEC. WIRE STRANDS	I5

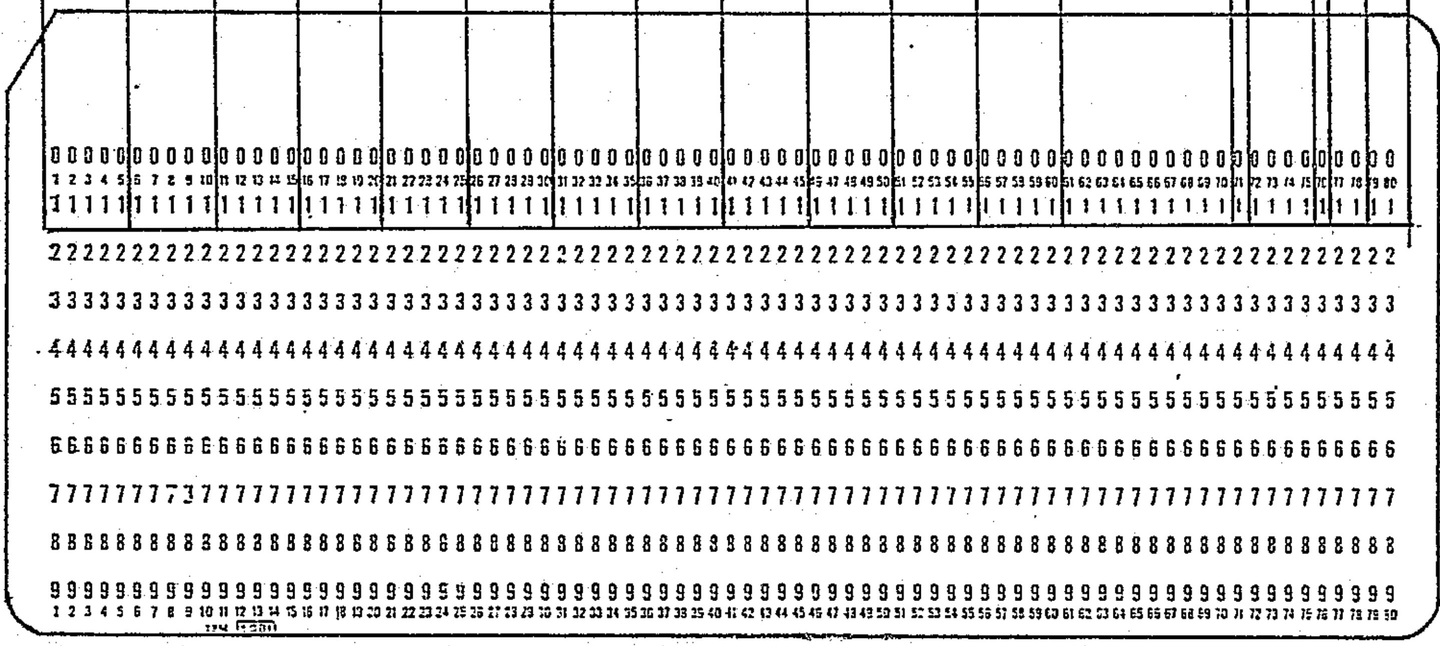


Figure 25. Design Specification Card
Program DC2DC

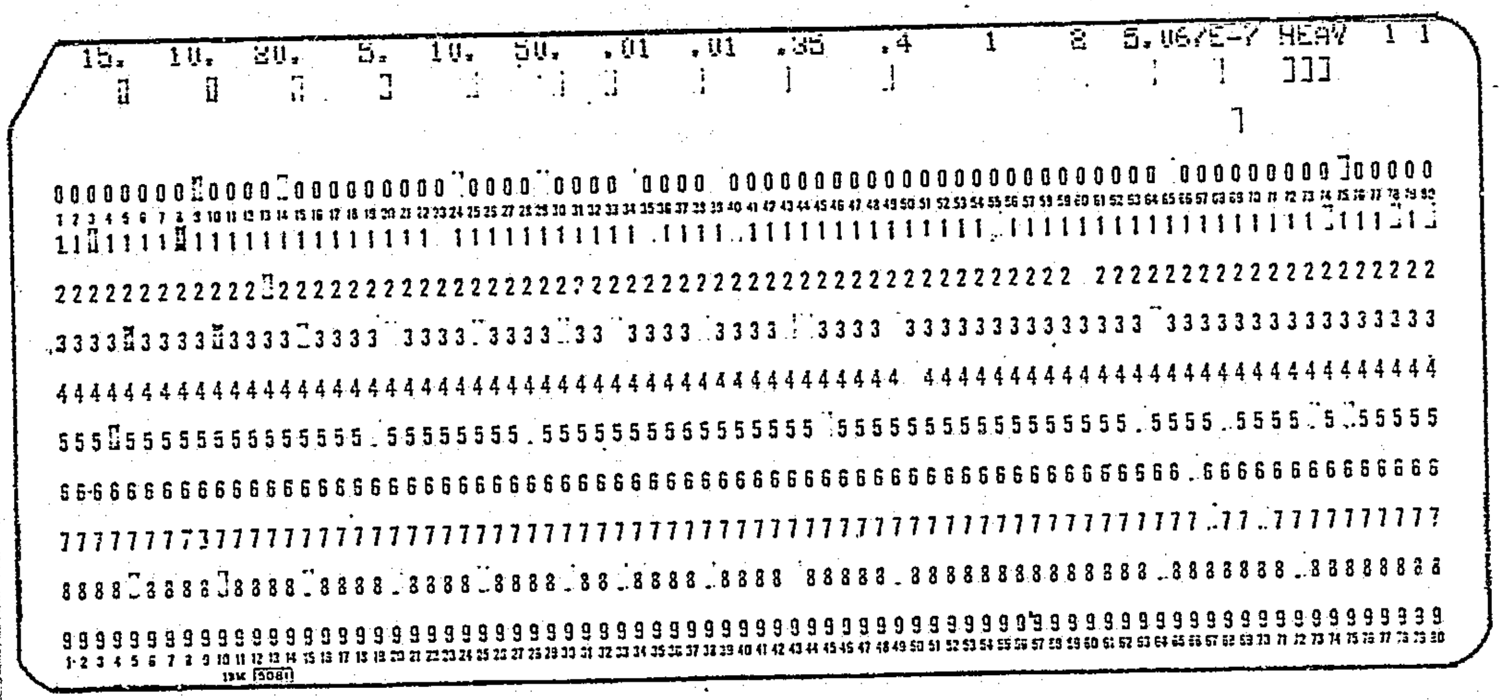


Figure 26. Example: Design Specification Card--Program DC2DC

3.7.1 Design Specifications

The meaning of certain of the design specifications is discussed in Section 3.2.1.

3.7.2 Wire Types

Four types of wire coating are available in the program. The user selects the desired type by entering the correct wire type code in the field provided for this purpose on the Design Specification Card. The wire type codes are given in Section 3.2.2 and are identical to those used in Program DC1DC.

3.8 ELEMENT LOSS CARD

The Element Loss Card gives parameters used in computing approximate power loss in the transistor, diode and capacitor. The format of this card is given in Section 3.3 and is the same as that used in Program DC1DC.

3.9 DSN2 AND EVAL CARD

3.9.1 DSN2 Card

In Procedure DSN2, the program attempts to compute a design using a specific magnetic core. The DSN2 Card is used only if the DSN2 procedure was specified on the Type/Procedure Card (Section 3.6). The format of the DSN2 Card is identical to that used in Program DC1DC and is discussed in Section 3.4.1.

3.9.2 EVAL Card--Program DC2DC

In Procedure EVAL, the program evaluates a design entered by the user. The EVAL Card is used only if the EVAL procedure was specified on the Type/Procedure Card (Section 3.6). The EVAL Card gives the integer size number of the core, the relative permeability, the number of cores in the stack, the wire sizes, and the number of primary and secondary turns. The integer core size number may be obtained from the "SIZE NO." column on the catalog listing produced by the program. The format of the EVAL Card is given in the table below (see also Figure 27). A sample EVAL Card is shown in Figure 28.

COLUMNS	FORMAT	PARAMETER
1-5	I5	Core Size Number from Catalog
6-10	F5.0	Relative Permeability of Core
11-15	I5	Number of Cores in Stack
16-20	I5	Number of Primary Turns
21-25	I5	Wire Size of Primary Winding
26-30	I5	Number of Secondary Turns
31-35	I5	Wire Size of Secondary Winding

PARAMETER	FORMAT
CORE SIZE NUMBER (INTEGER)	I5
RELATIVE PERMEABILITY	F5.0
NUMBER OF CORES IN STACK	I5
NUMBER OF PRIMARY TURNS	I5
PRIMARY WIRE SIZE	I5
NUMBER OF SECONDARY TURNS	I5
SECONDARY WIRE SIZE	I5

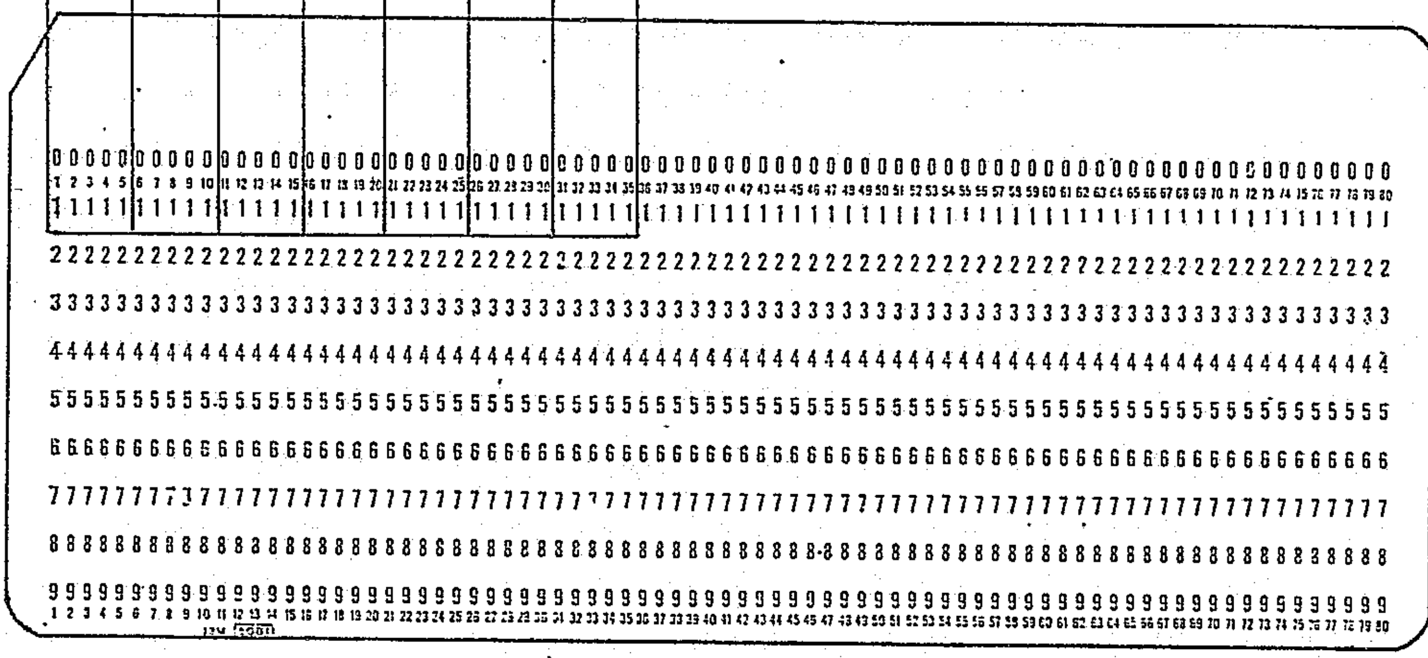


Figure 27. EVAL Card--Program DC2DC

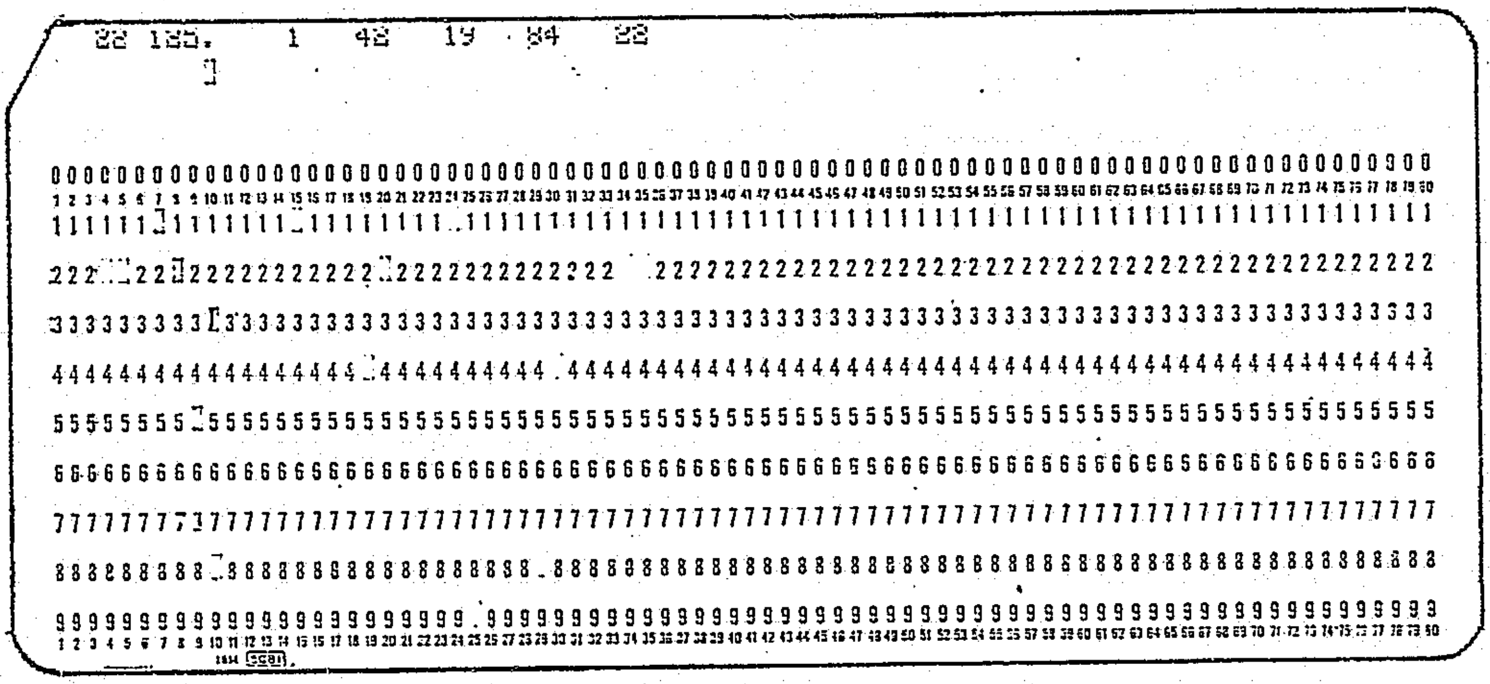


Figure 28. Example: EVAL Card--Program DC2DC

3.9.3 Procedures DSN2 and EVAL with Cores not in the Catalog

If either a core size or a relative permeability value (or both) is not in the catalog, it is still possible to use Procedures DSN2 and EVAL. The method for using this feature is identical to that used in Program DC1DC and is discussed in Section 3.4.3.

3.10 QUIT/CONTINUE CARD

The final card in the control deck should have a zero in column one. If more than one design or evaluation is desired on a given run, a card with a one in column one may be used followed by another set of control cards. This may be repeated if desired. This feature is identical to that used in Program DC1DC.

3.11 ASSEMBLING THE CONTROL CARDS

The Control Cards for Programs DC1DC and DC2DC should be placed in the following order as shown before in Figure 12:

1. Type/Procedure Card -- For Program desired (DC1DC or DC2DC)
2. Design Specification Card -- For Program desired (DC1DC or DC2DC)
3. Element Loss Card
4. DSN2 or EVAL Card -- Only used if Procedure DSN2 or Procedure EVAL was specified on the Type/Procedure Card
5. Core Geometry Card -- Only used in Procedures DSN2 and EVAL when the core size is not in the Catalog

6. Loss-Coefficient Card--Only used in Procedures DSN2 and EVAL when the value of relative permeability is not in the catalog

7. Quit/Continue Card

3.12 ASSEMBLING THE DATA DECK

The data cards should be placed in the following order as shown before in Figure 11:

1. Core Catalog Cards
2. Wire Table Cards

The Data Base

3. Control Cards

PROGRAM OUTPUT

Figures 29 and 30 show sample outputs from Programs DC1DC and DC2DC respectively. The values of the output variables in these figures have been replaced by integer note numbers. Section 4.1 relates the integer note number to the meaning of the output variable or symbol. The output variables and symbols are also defined in the Appendix. Many of the output variables have the same meaning in both programs. Thus, in these cases, the particular variable in Figures 29 and 30 will be referenced to the same note number in Section 4.1. If a note applies to only one of the programs, the correct program will be clearly indicated in the text of the note. Otherwise, program names will not appear in the note.

```
****************************************************************************************
****************************************************************************************
        1 --CONSTANT                2                    STEP-UP CONVERTER DESIGN
                  I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS
****************************************************************************************
****************************************************************************************
                                  CONVERTER SPECIFICATIONS
  V     V IN  V IN  P OUT  P OUT   V      I      V     CAP              B        B       B      WIND    MAX
 OUT    MIN   MAX   MIN    MAX    SAT   COIL.  DIODE   ESR          RESIDUAL    MIN     MAX    FACTOR  CORES
  4      5     6     7      8      9     10     11     12     13       14        15      16      17      18
****************************************************************************************
        WIRE TYPE= 19     MIN. STRANDS= 21    RECIPROCAL CURRENT DENSITY= 20     SQ.M/AMP
****************************************************************************************
****************************************************************************************

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A   -CORE STACK
SIZE          MAGNETICS    ARNOLD      MU     N    AWG   IND.   WDG   DSN   OP    IB    IXRMS  ICRMS
NO.                                                      MH     FAC   MODE  MODE  MAX   MAX    MAX
 25              26          27        28    29    31    33     38    39    40    41    44     47


****************************************************************************************
****************************************************************************************
                                  DESIGN EVALUATION
                                MAX. NO. OF EVALUATIONS =
****************************************************************************************
****************************************************************************************

EVALUATION FOR DESIGN NO.
SIZE          MAGNETICS    ARNOLD      MU     N    AWG   IND.   WDG   DSN   OP    IB    IXRMS  ICRMS
NO.                                                      MH     FAC   MODE  MODE  MAX   MAX    MAX
 25              26          27        28    29    31    33     38    39    40    41    44     47
  REACTOR    PATH       CORE       REACTOR          STACK         REACTOR       REACTOR        REACTOR
   AREA     LENGTH    WN.AREA    LENGTH/TURN        HEIGHT         MASS        WIRE LEN.      WIRE RES.
   SQ.M       M        SQ.M          M                M             KG             M             OHMS
    48        49        50           51               52            53             54             56
V IN=
  PO    IA    IB          FREQ  IXAVE  IXRMS  ICRMS  ************ LOSSES (WATTS) ************   EFF   EFF/MASS
 WATTS AMPS  AMPS         KHZ   AMPS   AMPS   AMPS   TRANS  DIODE  WIRE  CORE  CAPAC  TOTAL    %     %/KG
  60    61    64    67    68    70     71     74     75     76     77    78    79     80       81     82
```

Figure 29. Output of Program DC1DC

```
*********************************************************************************************
     (1)  --CONSTANT(3)  TWO-WINDING VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN
                  I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS
*********************************************************************************************
                                   CONVERTER SPECIFICATIONS

  V     V IN   V IN  P OUT  P OUT   V      V      V    CAP          B         B      B     WIND   MAX
 OUT    MIN    MAX    MIN    MAX   SAT   COLL.  DIODE  ESR       RESIDUAL    MIN    MAX   FACTOR CCRES
 (4)    (5)    (6)    (7)    (8)   (9)   (10)   (11)  (12)  (13)   (14)      (15)   (16)   (17)   (18)
*********************************************************************************************
WIRE TYPE= (19)   MIN. PRI. STRANDS= (22)   MIN. SEC. STRANDS= (23)   RECIPROCAL CURRENT DENSITY= (20)   SQ.M/AMP
*********************************************************************************************

         (24)

*********************************************************************************************

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A    -CORE STACK

SIZE MAGNETICS   ARNOLD    MU    NP   AWG  PRI.IND  NS   AWG  SEC.IND  WDG  OP   IBP   IBS   IPRMS  ISRMS  ICRMS
 NO.                                  PRI.   MH          SEC.   MH     FAC MODE  MAX   MAX    MAX    MAX    MAX
(25)  (26)        (27)    (28)  (30)  (32)   (34)   (35) (36)   (37)   (38) (40) (42)  (43)   (45)   (46)   (47)

*********************************************************************************************
                                      DESIGN EVALUATION
                                   MAX. NO. OF EVALUATIONS =
*********************************************************************************************

EVALUATION FOR DESIGN NO.

SIZE MAGNETICS   ARNOLD    MU    NP   AWG  PRI.IND  NS   AWG  SEC.IND  WDG  OP   IBP   IBS   IPRMS  ISRMS  ICRMS
 NO.                                  PRI.   MH          SEC.   MH     FAC MODE  MAX   MAX    MAX    MAX    MAX
(25)  (26)        (27)    (28)  (30)  (32)   (34)   (35) (36)   (37)   (38) (40) (42)  (43)   (45)   (46)   (47)
   REACTOR     PATH      CORE      REACTOR      STACK    REACTOR   REACTOR    REACTOR   REACTOR   REACTOR
    AREA      LENGTH    WN.AREA  LENGTH/TURN   HEIGHT     MASS    PRI.WIRE   PRI.WIRE  SEC.WIRE  SEC.WIRE
    SQ.M        M        SQ.M        M           M         KG     LENGTH,M   RES,OHMS  LENGTH,M  RES,OHMS
    (48)       (49)      (50)       (51)        (52)      (53)      (55)       (57)      (58)      (59)
V IN=
  PO    IAP   IAS   IBP   IBS        IPRMS  ISRMS  ICRMS  ************ LOSSES (WATTS) ************  EFF  EFF/MASS
 WATTS  AMPS  AMPS  AMPS  AMPS       AMPS   AMPS   AMPS   TRANS  DIODE  WIRE   CORE   CAPAC  TOTAL   %    %/KG
 (60)   (62)  (63)  (65)  (66)  (69)  (72)  (73)   (74)   (75)   (76)   (77)   (78)   (79)   (80)  (81)  (82)
```

Figure 30. Output of Program DC2DC

4.1 PROGRAM OUTPUT VARIABLES AND SYMBOLS

NOTE NO.	OUTPUT VARIABLE	NOTE
1	Converter/Controller Code	See Sections 3.1.1 & 3.6.1
2	Type of Converter/Controller (Program DC1DC)	See Section 3.1.1
3	Type of Controller (DC2DC)	See Section 3.6.1
4	V OUT	The regulated converter output voltage (volts)
5	V IN MIN	The specified minimum input voltage (volts)
6	V IN MAX	The specified maximum input voltage (volts)
7	P OUT MIN	The specified minimum output power (watts)
8	P OUT MAX	The specified maximum output power (watts)
9	V SAT	The transistor saturation voltage (volts)
10	I COLL	The current in the collector of the transistor at which the saturation voltage was measured (amperes)
11	V DIODE	The diode forward drop (volts)
12	CAP ESR	The effective series resistance (ESR) of the capacitor (ohms)
13	T ON, T OFF or FREQ (depending on controller)	The constant parameter of the controller, either transistor on-time, transistor off-time or frequency (μsec or KHz)
14	B RESIDUAL	The residual flux density of the core material (tesla)

NOTE NO.	OUTPUT VARIABLE	NOTE
15	B MIN	The specified minimum flux density (tesla)
16	B MAX	The specified maximum flux density (tesla)
17	WIND FACTOR	The specified maximum allowable winding factor
18	MAX CORES	The specified maximum allowable number of cores in the stack
19	WIRE TYPE	See Section 3.2.2
20	RECIPROCAL CURRENT DENSITY	The specified minimum reciprocal current density (m^2/ampere)
21	MIN STRANDS	The specified minimum no. of strands of wire to be used in the winding (DC1DC)
22	MIN PRI. STRANDS	The specified minimum no. of strands of wire to be used in the primary winding (DC2DC)
23	MIN SEC. STRANDS	The specified minimum no. of strands of wire to be used in the secondary winding (DC2DC)
24	DESIGN CONSTRAINT	See Section 3.6.4 (DC2DC)
25	SIZE NO.	The integer core size no. from the catalog (see Section 6.4)
26	MANUFACTURER'S NO.	The particular core number from the catalog of the first core manufacturer (in this case, Magnetics)
27	MANUFACTURER'S NO.	The particular core number from the catalog of the second core manufacturer (in this case, Arnold Engineering)

NOTE NO.	OUTPUT VARIABLE	NOTE
28	MU	The value of relative permeability of the core
29	N	The number of turns of wire in the winding (DC1DC)
30	NP	The number of turns of wire in the primary winding (DC2DC)
31	AWG	The AWG wire size used in the winding (DC1DC)
32	AWG PRI.	The AWG wire size used in the primary winding (DC2DC)
33	IND	The computed value of inductance (mh) (DC1DC)
34	PRI. IND	The computed value of primary inductance (mh) (DC2DC)
35	NS	The number of turns of wire in the secondary winding (DC2DC)
36	AWG SEC.	The AWG wire size used in the secondary winding (DC2DC)
37	SEC. IND	The computed value of the secondary inductance (mh) (DC2DC)
38	WDG FAC	The computed value of the winding factor, defined as the ratio of the area of the core window filled by the winding(s) to the total window area of the core
39	DSN MODE	The mode of operation which occurs at the design point in the PO-VI plane [4]. A "1" denotes Mode 1 operation (continuous conduction) and a "2" implies Mode 2 (discontinuous conduction) operation. (DC1DC) (see Section 3.2.1)

NOTE NO.	OUTPUT VARIABLE	NOTE
40	OP MODE	A value of "1" for this variable indicates that the converter operates in Mode 1 (continuous conduction) everywhere within the design range. A value of "2" indicates that the converter operates in Mode 2 (discontinuous conduction) at least somewhere within the design range
41	IB MAX	The maximum value that the peak reactor current takes on over the entire design range of the converter (DC1DC)
42	IBP MAX	The maximum value that the peak primary current takes on over the entire design range of the converter (DC2DC)
43	IBS MAX	The maximum value that the peak secondary current takes on over the entire design range of the converter (DC2DC)
44	IXRMS MAX	The maximum value that the RMS reactor current takes on over the entire design range of the converter (DC1DC)
45	IPRMS MAX	The maximum value that the RMS primary current takes on over the entire design range of the converter (DC2DC)
46	ISRMS MAX	The maximum value that the RMS secondary current takes on over the entire design range of the converter (DC2DC)

NOTE NO.	OUTPUT VARIABLE	NOTE
47	ICRMS MAX	The maximum value that the RMS capacitor current takes on over the entire design range of the converter
48	REACTOR AREA	The cross-sectional area of the magnetic material in the core stack used (m^2)
49	PATH LENGTH	The mean magnetic path length of the core used (m)
50	CORE WN. AREA	The area of the core window (m^2)
51	REACTOR LENGTH/TURN	The mean length/turn of the wound reactor, computed on the same basis as the core length/turn parameter (see Sec. 6.4.2) (m)
52	REACTOR HEIGHT	The height in meters of the core stack
53	REACTOR MASS	The mass of the wound reactor, neglecting the mass of the wire insulation (kg)
54	WIRE LENGTH	The length in meters of the wire used in the winding, based on a 40% winding factor (DC1DC)
55	PRI. WIRE LENGTH	The length in meters of the wire used in the primary winding, based on a 40% winding factor (DC2DC)
56	WIRE RES.	The resistance in ohms of the winding (DC1DC)
57	PRI. WIRE RES.	The resistance in ohms of the primary winding (DC2DC)
58	SEC. WIRE LENGTH	The length in meters of the wire used in the secondary winding, based on a 40% winding factor (DC2DC)

NOTE NO.	OUTPUT VARIABLE	NOTE
59	SEC. WIRE RES	The resistance in ohms of the secondary winding (DC2DC)
60	PO	The converter output power (watts)
61	IA	The minimum value of the reactor current over a cycle (amperes) (DC1DC)
62	IAP	The value in amperes that the primary current takes on at the beginning of the transistor on-time (DC2DC)
63	IAS	The value in amperes that the secondary current takes on at the beginning of the transistor on-time (DC2DC)
64	IB	The maximum value in amperes that the reactor current takes on over a cycle (DC1DC)
65	IBP	The maximum value in amperes that the primary current takes on over a cycle (DC2DC)
66	IBS	The maximum value in amperes that the secondary current takes on over a cycle (DC2DC)
67	T ON or T'OFF (depending on controller)	The transistor on-time (T ON), or that portion of the transistor off-time during which the reactor current is greater than zero (T'OFF). (DC1DC) (μsec)
68	FREQ	The converter frequency (KHz) (DC1DC)
69	FREQ or T ON (depending on controller)	The converter frequency in KHz (FREQ) or the transistor on-time (T ON) in μsec (DC2DC)
70	IXAVE	The average value (amperes) of the reactor current (DC1DC)

NOTE NO.	OUTPUT VARIABLE	NOTE
71	IXRMS	The RMS value (amperes) of the reactor current (DC1DC)
72	IPRMS	The RMS value (amperes) of the primary current (DC2DC)
73	ISRMS	The RMS value (amperes) of the secondary current (DC2DC)
74	ICRMS	The RMS value (amperes) of the current in the capacitor
75	LOSSES TRANS	Estimated power loss (watts) in the transistor (see Sec. 1.2.1)
76	LOSSES DIODE	Estimated power loss (watts) in the diode (see Sec. 1.2.2)
77	LOSSES WIRE	Estimated power loss (watts) in the reactor winding(s) (see Sec. 1.2.3)
78	LOSSES CORE	Estimated power loss (watts) in the magnetic core material (see Sec. 1.2.3)
79	LOSSES CAPAC	Estimated power loss (watts) in the capacitor (see Sec. 1.2.4)
80	LOSSES TOTAL	Estimated total power loss (watts). Computed as the sum of the transistor, diode, wire, core and capacitor losses
81	EFF	Estimated converter effeciency (%). Computed as the ratio of the output power to output power plus losses
82	EFF/MASS	The estimated converter effeciency divided by the mass of the wound reactor

SAMPLE PROGRAMS

The five sample programs given in Sections 5.2 -5.6 offer possible uses of Program DC1DC in the solution to a hypothetical design problem. The same design problem is attacked through the use of Program DC2DC in Sections 5.7-5.9. These sets of programs begin with specified design requirements and work toward two completed reactor element designs (a single-winding design from Program DC1DC and a two-winding design from Program DC2DC) using the computer programs as tools. The procedure followed in completing these designs is structured so as to illustrate all of the available program procedures and is not intended to be illustrative of a "typical" design procedure. A single design problem was chosed so that similarities and differences in the program output could be more readily compared across the set of program procedures. Also, the use of a single design problem serves to more clearly illustrate some of the possible advantages offered by the Design Constraint Options provided by Program DC2DC. In the following sections, the previously adopted convention of including the relevent program name in the title of each section will be continued. Sections whose titles do not mention a particular program name (i.e. DC1DC or DC2DC) apply to both sets of sample programs.

5.1 SAMPLE PROBLEM

Design a reactor element for a voltage step-up/current step-up converter with a constant frequency controller which will meet the following set of design requirements:

Output Voltage	24.0 volts
Input Voltage Range	6.0 to 16.0 volts
Output Power Range	10.0 to 20.0 watts
Converter Frequency	10.0 KHz

Also given are the following parameter values for the circuit components:

Transistor Saturation Voltage	1.0 volt @ 10.0 amperes
Diode Forward Drop	0.6 volt
Capacitor ESR	0.10 ohm

By consulting manufacturers' core catalogs, it is determined that the Residual Flux Density of the core material is on the order of 0.01 tesla. From manufacturer's data a value should also be selected for the maximum operating flux density so that the program assumption that the core operates in its linear region is satisfied. Assume that a value of 0.36 tesla will satisfy this assumption.

Finally, assume the commonly used values of 0.4 for the maximum allowable winding factor, $5.067 * 10^{-7}$ m^2/ampere (= 1000 circular mils/ampere) reciprocal current density and that heavy coated wire will be used for the winding(s). The maximum value of the winding factor is determined largely by the technique used for winding the core and the wire size. Experience is the best guide for choosing a maximum allowable winding factor. The reciprocal current density value chosen may vary with application and type of package or other criteria and the type of wire coating chosen depends on turn-to-turn voltage level and possibly other factors.

5.2 SAMPLE PROGRAM #1 -- PROGRAM DC1DC

As a starting point, Sample Program #1 uses the DSN1 procedure of Program DC1DC to obtain a list of usable single-winding reactor designs for the circuit of Figure 1-c. By refering to Sections 3.1 - 3.6 it can be seen that most of the required input data has been given in Section 5.1. Now the minimum number of cores in the stack, the minimum number of strands of wire, the minimum value of flux density, and a set of parameters for use in the evaluation must be selected.

Setting the <u>minimum flux density</u> equal to the residual flux density insures that both designs which operate only in Mode 1 (continuous conduction mode) and those which operate both in Mode 1 and Mode 2 (discontinuous conduction mode) will be produced. Unless space or wire stiffness is a problem, designs with only one core and one strand of wire would normally be desired. Choosing a one core minimum stack and the minimum number of strands = 1 will allow such designs to be computed. Also, assume that designs which have a stack height of two cores or less are required.

For illustration, the first three designs are evaluated in Sample Program #1. Since both the input voltage range and the output power range cover 10 units, setting the input voltage increment and the output power increment equal to 2.0 units gives evaluations at six values of output power for each one of six values of input voltage, i.e. thirty-six evaluation points.

5.2.1 Design Requirement Input Data--Sample Program #1 (DC1DC)

The following is a complete summary of the input data:

Converter/Controller Code	FQUD
Catalog Print Code	NP
Program Procedure	DSN1
Output Voltage	24.0 volts
Input Voltage Range	6.0 to 16.0 volts
Output Power Range	10.0 to 20.0 watts
Converter Frequency	10.0 KHz
Residual Flux Density	0.01 tesla
Minimum Flux Density	0.01 tesla
Maximum Flux Density	0.36 tesla
Maximum Winding Factor	0.4
Wire Type Code	HEAV
Reciprocal Current Density	$5.067 * 10^{-7}$ m^2/ampere
Minimum No. of Cores in Stack	1
Maximum No. of Cores in Stack	2
Minimum No. of Strands of Wire	1
Transistor Saturation Voltage	1.0 volt @ 10.0 amperes

Diode Forward Drop	0.6 volt
Capacitor ESR	0.1 ohm
Maximum No. of Evaluations	3
Input Voltage Increment	2.0 volts
Output Power Increment	2.0 watts

5.2.2 Control Cards--Sample Program #1 (Program DC1DC)

The control cards for Sample Program #1 are shown below. Sections 3.1-3.6 give instructions for preparing these cards.

```
FQUD NP DSN1        3    2.    2.                                                     
 24.    6.  16.  10.  20.  10.  .01   .01  .36    .4     1      2 5.067E-07 HEAV     1
 1.0  10.  .60    .1
0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.2.3 Results of Sample Program #1--Program DC1DC

The results of Sample Program #1 are given on the following pages. Program DC1DC has produced a list of fifty single-winding reactor designs which will meet the design requirements. The list of designs gives the manufacturers' catalog numbers, relative permeability, number of turns, wire size, and winding factor for each usable design as well as other parameters. Note from the print out that all of the designs generated use only one core in the stack. Also, many of the designs operate in Mode 2 (discontinuous conduction mode) over some portion of the operating range. This can be seen from the "OP MODE" column of the design list. Note also that the actual winding factor, as seen in the "WDG FAC" column, is less than the specified maximum of 0.4 for all the listed designs. By noting the RMS value of the reactor current from the "IXRMS MAX" column and applying the reciprocal current density constraint, it can be seen that the program has chosen the correct wire size in all cases.

In the design evaluations, the output gives the same design information as was given in the design list. However, additional information on the reactor is also given. As desired, thirty-six evaluation points have been produced with six values of output power for each of six values of input voltage. Note that the value of IA is equal to zero over some part of the design range for those designs whose "OP MODE" is equal to two. The last two columns in the evaluation output give estimates of the converter efficiency and the efficiency/mass. The EFF/MASS column may be particularly useful in comparing designs in terms of performance-to-weight.

****

FOUD—CONSTANT FREQ VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

****

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT. MIN	P OUT MAX	V SAT	V COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	MAX CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.000E-02	3.600E-01	0.40	2

****

WIRE TYPE= HEAV MIN. STRANDS= 1 RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

****

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A 1-CORE STACK

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IP MAX	IRMS MAX	ICRMS MAX
21	55548	A-548127	125.	22	12	0.063	0.278	1	2	8.248	5.291	2.009
23	55324	A-324117	125.	28	13	0.093	C.228	1	2	7.168	5.399	1.923
24	55254	A-254168	125.	38	13	0.247	0.264	1	2	5.776	4.957	1.659
24	55253	A-151198	147.	31	13	0.193	0.215	1	2	6.010	4.972	1.656
24	55252	A-306215	160.	28	13	0.171	0.194	1	2	6.145	4.983	1.671
24	55248	A-179233	173.	25	13	0.148	0.174	1	2	6.340	5.000	1.678
24	55251	A-214276	200.	20	13	0.109	C.139	1	2	6.334	5.254	1.933
24		A-378336	250.	12	12	0.049	0.104	1	2	9.157	5.503	2.133
25	55089	A-089178	125.	48	13	0.418	0.233	1	2	5.430	4.942	1.652
25	55088	A-153210	147.	40	13	0.341	C.194	1	2	5.542	4.946	1.654
25	55087	A-326228	160.	36	13	0.301	0.175	1	2	5.624	4.949	1.656
25	55082	A-195246	173.	33	13	0.273	C.150	1	2	5.693	4.953	1.657
25	55086	A-216292	200.	27	13	0.212	0.131	1	2	5.915	4.966	1.663
25		A-380056	250.	21	13	0.160	0.102	1	2	6.232	4.990	1.674
25	55084	A-402427	300.	16	13	0.111	0.078	1	2	6.797	5.149	1.901
25		A-423499	350.	12	12	0.073	0.073	1	2	7.773	5.199	1.957
26	55715	A-715152	125.	52	13	0.418	0.205	1	2	5.430	4.942	1.652
26	55714	A-154179	147.	43	13	0.336	0.170	1	2	5.551	4.946	1.654
26	55713	A-327195	160.	39	13	0.301	C.154	1	2	5.624	4.949	1.656
26	55709	A-181210	173.	36	13	0.277	0.142	1	2	5.693	4.952	1.657
26	55712	A-217249	200.	30	13	0.223	0.118	1	2	5.857	4.963	1.662
26		A-382304	250.	23	13	0.164	0.091	1	2	6.204	4.998	1.673
26	55710	A-404365	300.	17	13	0.107	C.067	1	2	6.571	5.159	1.835
26		A-424426	350.	13	12	0.073	0.064	1	2	7.773	5.199	1.957
27	55109	A-109156	125.	60	13	0.569	C.188	1	1	5.298	4.938	1.650
27	55108	A-155185	147.	50	13	0.465	0.156	1	1	5.330	4.940	1.651
27	55107	A-328200	160.	46	13	0.428	0.144	1	1	5.418	4.941	1.652
27	55103	A-182219	173.	42	13	0.385	0.131	1	2	5.471	4.943	1.653
27	55106	A-218259	200.	36	13	0.328	0.113	1	2	5.567	4.947	1.655
27		A-383312	250.	27	13	0.231	0.084	1	2	5.639	4.961	1.661
27	55106	A-405374	300.	22	13	0.184	C.069	1	2	6.064	4.976	1.668
27		A-425437	350.	18	13	0.143	0.056	1	2	6.381	5.004	1.680
28	55438	A-438281	125.	45	13	0.592	0.313	1	1	5.335	4.937	1.650
28	55437	A-152330	147.	38	13	0.496	0.264	1	1	5.352	4.939	1.651
28	55436	A-325360	160.	34	13	0.432	0.236	1	1	5.414	4.941	1.652
28	55432	A-180390	173.	32	13	0.414	0.222	1	2	5.435	4.942	1.652
28	55435	A-215462	200.	27	13	0.341	0.188	1	2	5.543	4.946	1.654
28		A-379562	250.	21	13	0.258	C.146	1	2	5.740	4.955	1.658
28	55433	A-401674	300.	16	13	0.179	0.111	1	2	6.097	4.978	1.669
28		A-422787	350.	13	13	0.138	C.090	1	2	6.436	5.009	1.683
29		A-123068	60.	185	13	2.284	0.304	1	1	5.024	4.934	1.649
29		A-866142	125.	87	13	1.052	0.143	1	1	5.131	4.935	1.649
29		A-156167	147.	73	13	0.871	0.120	1	1	5.172	4.935	1.649
29		A-183197	173.	62	13	0.740	0.102	1	1	5.214	4.936	1.650
29		A-219233	205.	51	13	0.593	0.084	1	1	5.284	4.937	1.650
31		A-125112	60.	234	13	5.879	0.284	1	1	4.969	4.933	1.648
31		A-542228	125.	111	13	2.756	0.135	1	1	5.009	4.934	1.649
31		A-157268	147.	94	13	2.324	0.114	1	1	5.023	4.934	1.649
31		A-184316	173.	80	13	1.981	0.097	1	1	5.038	4.934	1.649
31		A-220374	205.	67	13	1.647	C.081	1	1	5.059	4.934	1.649

THE MAXIMUM OF 50 WINDABILITY CHECKS HAS BEEN REACHED

DESIGN EVALUATION

MAX. NO. OF EVALUATIONS = 3

EVALUATION FOR DESIGN NO. 1

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
21	55548	A-548127	125.	22	12	0.063	0.278	1	2	8.248	5.291	2.009

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN. AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
6.720E-05	8.150E-02	2.927E-04	4.270E-02	1.160E-02	7.379E-02	9.394E-01	4.993E-03

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.[illegible]	71.7	10.00	2.467	3.067	1.189	0.782	0.250	0.047	0.757	0.141	1.977	83.5	1.132E 03
12.0	0.0	6.26	78.5	10.00	2.960	3.516	1.356	1.027	0.300	0.062	0.989	0.184	2.562	62.4	1.117E 03
14.0	0.14	6.77	83.1	10.00	3.453	3.948	1.514	1.295	0.350	0.078	1.167	0.229	3.120	81.6	1.108E 03
16.0	0.63	7.26	83.1	10.00	3.947	4.386	1.675	1.599	0.400	0.096	1.167	0.281	3.542	81.9	1.110E 03
18.0	1.13	7.75	83.1	10.00	4.440	4.835	1.840	1.943	0.450	0.117	1.167	0.339	4.015	81.6	1.108E 03
20.0	1.62	8.25	83.1	10.00	4.933	5.291	2.009	2.327	0.500	0.140	1.167	0.404	4.537	81.5	1.105E 03

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.72	51.2	10.00	1.881	2.678	1.189	0.558	0.250	0.036	0.757	0.141	1.743	85.2	1.154E 03
12.0	0.0	6.26	56.1	10.00	2.257	9.070	1.356	0.734	0.300	0.047	0.989	0.184	2.254	84.[illegible]	1.141E 03
14.0	0.0	6.77	60.6	10.00	2.633	3.447	1.514	0.925	0.350	0.059	1.240	0.229	2.803	83.3	1.129E 03
16.0	0.0	7.23	64.8	10.00	3.010	3.810	1.664	1.130	0.400	0.072	1.508	0.277	3.387	62.6	1.118E 03
18.0	0.0	7.67	68.7	10.00	3.386	4.161	1.809	1.349	0.450	0.086	1.793	0.327	4.005	81.6	1.109E 03
20.0	0.0	8.09	72.4	10.00	3.762	4.504	1.949	1.579	0.500	0.101	2.094	0.380	4.654	81.1	1.099E 03

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.72	39.8	10.00	1.556	2.435	1.189	0.434	0.250	0.030	0.757	0.141	1.613	86.1	1.167E 03
12.0	0.0	6.26	43.6	10.00	1.867	2.792	1.356	0.571	0.300	0.039	0.989	0.184	2.082	85.2	1.155E 03
14.0	0.0	6.77	47.1	10.00	2.178	3.134	1.514	0.719	0.350	0.049	1.240	0.229	2.587	84.[illegible]	1.144E 03
16.0	0.0	7.23	50.4	10.00	2.489	3.464	1.664	0.879	0.400	0.060	1.508	0.277	3.124	83.7	1.134E 03
18.0	0.0	7.67	53.4	10.00	2.800	3.784	1.809	1.049	0.450	0.072	1.793	0.327	3.690	83.0	1.125E 03
20.0	0.0	8.09	56.3	10.00	3.111	4.096	1.949	1.228	0.500	0.084	2.094	0.380	4.285	82.5	1.116E 03

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.72	32.6	10.00	1.348	2.267	1.189	0.355	0.250	0.026	0.757	0.141	1.530	86.7	1.175E 03
12.0	0.0	6.26	35.7	10.00	1.618	2.600	1.356	0.467	0.300	0.034	0.989	0.184	1.973	85.9	1.164E 03
14.0	0.0	6.77	38.6	10.00	1.898	2.918	1.514	0.583	0.350	0.043	1.240	0.229	2.450	85.1	1.153E 03
16.0	0.0	7.23	41.2	10.00	2.158	3.226	1.664	0.719	0.400	0.052	1.508	0.277	2.956	84.4	1.144E 03
18.0	0.0	7.67	43.7	10.00	2.427	3.524	1.809	0.859	0.450	0.062	1.793	0.327	3.490	83.[illegible]	1.135E 03
20.0	0.0	8.09	46.1	10.00	2.697	3.813	1.949	1.005	0.500	0.073	2.094	0.380	4.051	83.2	1.127E 03

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.72	27.6	10.00	1.205	2.143	1.189	0.301	0.250	0.023	0.757	0.141	1.472	87.2	1.181E 03
12.0	0.0	6.26	30.2	10.00	1.446	2.458	1.356	0.395	0.300	0.030	0.989	0.184	1.898	86.3	1.170E 03
14.0	0.0	6.77	32.6	10.00	1.687	2.759	1.514	0.498	0.350	0.038	1.240	0.229	2.355	85.6	1.160E 03
16.0	0.0	7.23	34.9	10.00	1.928	3.049	1.664	0.608	0.400	0.046	1.508	0.277	2.840	84.9	1.151E 03
18.0	0.0	7.67	37.0	10.00	2.169	3.331	1.809	0.726	0.450	0.055	1.793	0.327	3.352	84.3	1.142E 03
20.0	0.0	8.09	39.0	10.00	2.410	3.605	1.949	0.850	0.500	0.065	2.094	0.380	3.889	83.7	1.135E 03

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	5.72	23.9	10.00	1.100	2.048	1.189	0.261	0.250	0.021	0.757	0.141	1.430	87.5	1.186E 03
12.0	0.0	6.26	26.2	10.00	1.320	2.348	1.356	0.342	0.300	0.028	0.989	0.184	1.843	86.7	1.175E 03
14.0	0.0	6.77	28.3	10.00	1.540	2.636	1.514	0.432	0.350	0.035	1.240	0.229	2.285	86.0	1.165E 03
16.0	0.0	7.23	30.2	10.00	1.760	2.913	1.664	0.527	0.400	0.042	1.508	0.277	2.755	85.3	1.156E 03
18.0	0.0	7.67	32.1	10.00	1.980	3.182	1.809	0.629	0.450	0.051	1.793	0.327	3.250	84.7	1.148E 03
20.0	0.0	8.09	33.8	10.00	2.200	3.444	1.949	0.737	0.500	0.059	2.094	0.380	3.770	84.1	1.140E 03

EVALUATION FOR DESIGN NO. 2

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
23	55324	A-324117	125.	28	13	0.093	0.228	1	2	7.168	5.099	1.923

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN. AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
6.780E-05	8.980E-02	3.644E-04	4.340E-02	1.130E-02	7.952E-02	1.215E 00	8.133E-03

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.23	4.70	83.1	10.00	2.467	2.784	1.065	0.644	0.250	0.063	0.624	0.114	1.695	85.5	1.075E 03
12.0	0.73	5.19	83.1	10.00	2.960	3.229	1.229	0.666	0.300	0.085	0.624	0.151	2.027	85.5	1.076E 03
14.0	1.22	5.69	83.1	10.00	3.453	3.686	1.398	1.129	0.350	0.111	0.624	0.196	2.410	85.3	1.073E 03
16.0	1.71	6.18	83.1	10.00	3.947	4.152	1.571	1.433	0.400	0.140	0.624	0.247	2.844	84.9	1.068E 03
18.0	2.21	6.67	83.1	10.00	4.440	4.624	1.746	1.777	0.450	0.174	0.624	0.305	3.330	84.4	1.061E 03
20.0	2.70	7.17	83.1	10.00	4.933	5.099	1.923	2.161	0.500	0.211	0.624	0.370	3.867	83.8	1.054E 03

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.0	4.70	62.8	10.00	1.881	2.427	1.063	0.458	0.250	0.048	0.721	0.113	1.591	86.3	1.085E 03
12.0	0.0	5.14	68.3	10.00	2.257	2.782	1.210	0.603	0.300	0.063	0.941	0.146	2.053	85.4	1.074E 03
14.0	0.0	5.56	73.8	10.00	2.633	3.123	1.349	0.759	0.350	0.079	1.180	0.182	2.550	84.6	1.064E 03
16.0	0.08	5.94	77.8	10.00	3.010	3.452	1.482	0.925	0.400	0.097	1.380	0.220	3.028	84.1	1.058E 03
18.0	0.46	6.32	77.8	10.00	3.386	3.785	1.616	1.115	0.450	0.117	1.380	0.261	3.323	84.4	1.062E 03
20.0	0.83	6.69	77.8	10.00	3.762	4.125	1.753	1.325	0.500	0.138	1.380	0.307	3.650	84.6	1.064E 03

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.0	4.70	48.5	10.00	1.556	2.207	1.063	0.357	0.250	0.040	0.721	0.113	1.480	87.1	1.095E 03
12.0	0.0	5.14	53.1	10.00	1.867	2.530	1.210	0.469	0.300	0.052	0.941	0.146	1.909	86.3	1.085E 03
14.0	0.0	5.56	57.4	10.00	2.178	2.840	1.349	0.591	0.350	0.066	1.180	0.182	2.368	85.5	1.076E 03
16.0	0.0	5.94	61.4	10.00	2.489	3.139	1.482	0.722	0.400	0.080	1.435	0.220	2.856	84.9	1.067E 03
18.0	0.0	6.30	65.1	10.00	2.800	3.429	1.609	0.861	0.450	0.096	1.706	0.259	3.371	84.2	1.059E 03
20.0	0.0	6.64	68.6	10.00	3.111	3.711	1.731	1.009	0.500	0.112	1.992	0.299	3.912	83.6	1.052E 03

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.0	4.70	39.7	10.00	1.348	2.055	1.063	0.292	0.250	0.034	0.721	0.113	1.410	87.6	1.102E 03
12.0	0.0	5.14	43.5	10.00	1.618	2.356	1.210	0.383	0.300	0.045	0.941	0.146	1.816	86.9	1.092E 03
14.0	0.0	5.56	47.0	10.00	1.888	2.644	1.349	0.483	0.350	0.057	1.180	0.182	2.252	86.1	1.083E 03
16.0	0.0	5.94	50.2	10.00	2.158	2.923	1.482	0.590	0.400	0.069	1.435	0.220	2.714	85.5	1.075E 03
18.0	0.0	6.30	53.2	10.00	2.427	3.193	1.609	0.704	0.450	0.083	1.706	0.259	3.202	84.9	1.068E 03
20.0	0.0	6.64	56.1	10.00	2.697	3.455	1.731	0.825	0.500	0.097	1.992	0.299	3.713	84.3	1.061E 03

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.0	4.70	33.6	10.00	1.205	1.942	1.063	0.247	0.250	0.031	0.721	0.113	1.362	88.0	1.107E 03
12.0	0.0	5.14	36.8	10.00	1.445	2.227	1.210	0.324	0.300	0.040	0.941	0.146	1.753	87.3	1.097E 03
14.0	0.0	5.56	39.7	10.00	1.687	2.500	1.349	0.409	0.350	0.051	1.180	0.182	2.172	86.6	1.089E 03
16.0	0.0	5.94	42.5	10.00	1.928	2.763	1.482	0.500	0.400	0.062	1.435	0.220	2.616	85.9	1.081E 03
18.0	0.0	6.30	45.1	10.00	2.169	3.018	1.609	0.596	0.450	0.074	1.706	0.259	3.085	85.4	1.074E 03
20.0	0.0	6.64	47.5	10.00	2.410	3.267	1.731	0.698	0.500	0.087	1.992	0.299	3.576	84.8	1.067E 03

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.0	4.70	29.1	10.00	1.100	1.856	1.063	0.214	0.250	0.028	0.721	0.113	1.326	88.3	1.110E 03
12.0	0.0	5.14	31.9	10.00	1.320	2.128	1.210	0.281	0.300	0.037	0.941	0.146	1.706	87.6	1.101E 03
14.0	0.0	5.56	34.4	10.00	1.540	2.388	1.349	0.354	0.350	0.046	1.180	0.182	2.113	86.9	1.093E 03
16.0	0.0	5.94	36.8	10.00	1.760	2.640	1.482	0.433	0.400	0.057	1.435	0.220	2.544	86.3	1.085E 03
18.0	0.0	6.30	39.0	10.00	1.980	2.884	1.609	0.517	0.450	0.068	1.706	0.259	2.999	85.7	1.078E 03
20.0	0.0	6.64	41.2	10.00	2.200	3.121	1.731	0.605	0.500	0.079	1.992	0.299	3.475	85.2	1.071E 03

EVALUATION FOR DESIGN NO. 3

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
24	55254	A-254168	125.	38	13	0.247	0.264	1	2	5.776	4.957	1.859

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN. AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
1.070E-04	9.840E-02	4.270E-04	5.400E-02	1.540E-02	1.385E-01	2.052E 00	1.373E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	1.62	3.31	83.1	10.00	2.467	2.514	0.946	0.525	0.250	0.087	0.121	0.069	1.072	90.3	6.523E 02
12.0	2.12	3.80	83.1	10.00	2.960	3.000	1.127	0.748	0.300	0.124	0.121	0.127	1.419	89.4	6.458E 02
14.0	2.61	4.30	83.1	10.00	3.453	3.487	1.309	1.011	0.350	0.167	0.121	0.171	1.820	88.5	6.391E 02
16.0	3.10	4.79	83.1	10.00	3.947	3.977	1.492	1.314	0.400	0.217	0.121	0.223	2.275	87.6	6.323E 02
18.0	3.60	5.28	83.1	10.00	4.440	4.467	1.676	1.659	0.450	0.274	0.121	0.281	2.783	86.6	6.255E 02
20.0	4.09	5.78	83.1	10.00	4.933	4.957	1.859	2.042	0.500	0.337	0.121	0.346	3.346	85.7	6.187E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	0.78	2.99	77.8	10.00	1.887	1.986	0.837	0.307	0.250	0.054	0.261	0.070	0.942	91.4	6.600E 02
12.0	1.15	3.36	77.8	10.00	2.257	2.346	0.984	0.429	0.300	0.076	0.261	0.097	1.162	91.2	6.585E 02
14.0	1.53	3.74	77.8	10.00	2.633	2.709	1.134	0.571	0.350	0.101	0.261	0.129	1.412	90.8	6.560E 02
16.0	1.90	4.11	77.8	10.00	3.010	3.076	1.285	0.737	0.400	0.130	0.261	0.165	1.693	90.4	6.531E 02
18.0	2.28	4.49	77.8	10.00	3.386	3.445	1.438	0.924	0.450	0.163	0.261	0.207	2.005	90.0	6.498E 02
20.0	2.66	4.87	77.8	10.00	3.762	3.816	1.591	1.133	0.500	0.200	0.261	0.253	2.348	89.5	6.463E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	0.22	2.89	73.2	10.00	1.556	1.736	0.796	0.221	0.250	0.041	0.451	0.063	1.027	90.7	6.550E 02
12.0	0.53	3.20	73.2	10.00	1.867	2.020	0.918	0.299	0.300	0.056	0.451	0.084	1.190	91.0	6.570E 02
14.0	0.84	3.51	73.2	10.00	2.178	2.310	1.044	0.391	0.350	0.073	0.451	0.109	1.374	91.1	6.577E 02
16.0	1.15	3.82	73.2	10.00	2.469	2.606	1.172	0.497	0.400	0.093	0.451	0.137	1.579	91.0	6.573E 02
18.0	1.46	4.14	73.2	10.00	2.800	2.904	1.303	0.618	0.450	0.116	0.451	0.170	1.804	90.9	6.564E 02
20.0	1.78	4.45	73.2	10.00	3.111	3.205	1.434	0.752	0.500	0.141	0.451	0.206	2.050	90.7	6.551E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	2.88	64.6	10.00	1.349	1.510	0.792	0.179	0.250	0.036	0.562	0.063	1.090	90.2	6.512E 02
12.0	0.08	3.16	69.1	10.00	1.619	1.847	0.896	0.236	0.300	0.047	0.682	0.080	1.345	89.5	6.494E 02
14.0	0.35	3.43	69.1	10.00	1.888	2.087	1.003	0.301	0.350	0.060	0.682	0.101	1.494	90.4	6.526E 02
16.0	0.62	3.70	69.1	10.00	2.158	2.334	1.113	0.376	0.400	0.075	0.682	0.124	1.657	90.6	6.544E 02
18.0	0.89	3.97	69.1	10.00	2.427	2.585	1.226	0.462	0.450	0.092	0.682	0.150	1.836	90.7	6.554E 02
20.0	1.16	4.24	69.1	10.00	2.697	2.840	1.341	0.557	0.500	0.111	0.682	0.180	2.030	90.6	6.557E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	2.88	54.7	10.00	1.205	1.522	0.792	0.152	0.250	0.032	0.562	0.063	1.059	90.4	6.531E 02
12.0	0.0	3.16	59.9	10.00	1.446	1.745	0.896	0.199	0.300	0.042	0.733	0.080	1.354	89.9	6.490E 02
14.0	0.0	3.41	64.7	10.00	1.687	1.959	0.993	0.251	0.350	0.053	0.917	0.099	1.669	89.3	6.453E 02
16.0	0.20	3.65	65.4	10.00	1.928	2.170	1.088	0.308	0.400	0.065	0.946	0.118	1.837	89.7	6.478E 02
18.0	0.45	3.89	65.4	10.00	2.169	2.387	1.186	0.373	0.450	0.078	0.946	0.141	1.988	90.1	6.504E 02
20.0	0.65	4.13	65.4	10.00	2.410	2.608	1.287	0.445	0.500	0.093	0.946	0.166	2.150	90.3	6.521E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	****** LOSSES TRANS	DIODE	WIRE	(WATTS) CORE	CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.0	0.0	2.88	47.4	10.00	1.100	1.454	0.792	0.131	0.250	0.029	0.562	0.063	1.036	90.6	6.544E 02
12.0	0.0	3.16	51.9	10.00	1.320	1.667	0.896	0.173	0.300	0.038	0.733	0.080	1.324	90.1	6.505E 02
14.0	0.0	3.41	56.1	10.00	1.540	1.871	0.993	0.218	0.350	0.048	0.917	0.099	1.631	89.6	6.469E 02
16.0	0.0	3.65	60.0	10.00	1.760	2.069	1.085	0.266	0.400	0.059	1.114	0.118	1.956	89.1	6.435E 02
18.0	0.09	3.87	62.1	10.00	1.980	2.260	1.172	0.317	0.450	0.070	1.235	0.137	2.210	89.1	6.433E 02
20.0	0.31	4.09	62.1	10.00	2.200	2.455	1.261	0.375	0.500	0.083	1.235	0.159	2.351	89.5	6.462E 02

5.3 SAMPLE PROGRAM #2--PROGRAM DC1DC

Now suppose that to the design requirements given in Section 5.1 the constraint that all designs operate in Mode 1 (continuous conduction mode) over the entire design range is added. This is satisfied simply by making the minimum flux density greater than the residual flux density. Let the minimum flux density be 0.011 tesla and make another run using the DSN1 procedure of Program DC1DC. All other design requirements will remain the same as those used in Sample Program #1.

5.3.1 Control Cards--Sample Program #2 (Program DC1DC)

The control cards for Sample Program #2 are shown below. Sections 3.1-3.6 give instructions for preparing these cards.

```
FQUD MP DSN1       3   2.   2.
 24.   6.  16.  10.  20.  10.  .01 .011  .36   .4    1    2 5.067E-07 HEAV    1
 1.0  10.  .60   .1
0


100000000000000000000000000000000000000000000000000000000000000000000000000000000
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.3.2 Results of Sample Program #2--Program DC1DC

The results of Sample Program #2 are given on the following pages. Program DC1DC has again produced a list of fifty usable designs. However, note from the "OP MODE" column that all of these designs operate in Mode 1 (continuous conduction mode) over the entire operating range. Note also that the program has added a core to the stack in order to produce fifty designs. By comparing the output to that from Sample Program #1, it can be seen that most of the Mode 1 designs produced by Sample Program #1 have also been produced by Sample Program #2. This is due to the fact that the total allowable flux density range is almost, but not quite, the same in both cases.

Note from the evaluation output that the value of IA is greater than zero over the entire design range of the converter. Also, since larger core sizes have been used, the efficiency/mass of the designs evaluated in Sample Program #2 is less than that for the designs evaluated in Sample Program #1.

FOUD—CONSTANT FREQ VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	I COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	MAX CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	2

WIRE TYPE= HEAV MIN. STRANDS= 1 RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A 1-CORE STACK

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IIRMS MAX	ICRMS MAX
27	55109	A-109156	125.	60	13	0.569	0.188	1	1	5.298	4.938	1.850
27	55108	A-155185	147.	50	13	0.465	0.156	1	1	5.390	4.940	1.851
28	55438	A-438281	125.	45	13	0.592	0.313	1	1	5.285	4.937	1.850
28	55437	A-152330	147.	38	13	0.496	0.264	1	1	5.352	4.939	1.851
28	55436	A-325360	160.	34	13	0.432	0.236	1	1	5.418	4.941	1.852
29		A-123068	60.	185	13	2.284	0.304	1	1	5.024	4.934	1.849
29		A-866142	125.	87	13	1.052	0.143	1	1	5.131	4.935	1.849
29		A-156167	147.	73	13	0.871	0.120	1	1	5.172	4.935	1.849
29		A-183197	173.	62	13	0.740	0.102	1	1	5.214	4.936	1.850
29		A-219233	205.	51	13	0.593	0.084	1	1	5.254	4.937	1.850
31		A-125112	60.	234	13	5.879	0.284	1	1	4.959	4.933	1.848
31		A-542228	125.	111	13	2.756	0.135	1	1	5.009	4.934	1.849
31		A-157268	147.	94	13	2.324	0.114	1	1	5.023	4.934	1.849
31		A-184316	173.	80	13	1.981	0.097	1	1	5.038	4.934	1.849
31		A-220374	205.	67	13	1.647	0.081	1	1	5.049	4.934	1.849
32		A-128124	60.	311	13	11.730	0.198	1	1	4.951	4.933	1.848
32		A-127259	125.	149	13	5.609	0.095	1	1	4.970	4.933	1.848
32		A-158304	147.	126	13	4.717	0.080	1	1	4.977	4.933	1.848
32		A-185358	173.	107	13	4.003	0.068	1	1	4.985	4.933	1.848
32		A-221425	205.	90	13	3.356	0.057	1	1	4.995	4.933	1.848

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A 2-CORE STACK

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IS MAX	IIRMS MAX	ICRMS MAX
24	55254	A-254168	125.	41	13	0.574	0.285	1	1	5.295	4.938	1.850
24	55253	A-151198	147.	35	13	0.492	0.243	1	1	5.356	4.939	1.851
24	55252	A-306215	160.	32	13	0.448	0.222	1	1	5.397	4.941	1.852
25	55089	A-089'78	125.	50	13	0.907	0.243	1	1	5.162	4.935	1.849
25	55088	A-153210	147.	42	13	0.753	0.204	1	1	5.229	4.936	1.850
25	55087	A-326228	160.	39	13	0.707	0.189	1	1	5.227	4.936	1.850
25	55082	A-195246	173.	35	13	0.615	0.170	1	1	5.271	4.937	1.850
25	55086	A-216292	200.	30	13	0.523	0.146	1	1	5.331	4.936	1.851
26	55715	A-715152	125.	55	13	0.935	0.217	1	1	5.155	4.935	1.849
26	55714	A-154179	147.	46	13	0.769	0.181	1	1	5.233	4.936	1.850
26	55713	A-327195	160.	42	13	0.698	0.166	1	1	5.231	4.936	1.850
26	55709	A-181210	173.	39	13	0.651	0.154	1	1	5.253	4.937	1.850
26	55712	A-217249	200.	33	13	0.539	0.130	1	1	5.319	4.938	1.851
27	55109	A-109156	125.	62	13	1.216	0.194	1	1	5.134	4.934	1.849
27	55108	A-155185	147.	53	13	1.045	0.166	1	1	5.132	4.935	1.849
27	55107	A-328200	160.	48	13	0.933	0.150	1	1	5.156	4.935	1.849
27	55103	A-182218	173.	45	13	0.887	0.141	1	1	5.158	4.935	1.849
27	55106	A-218259	200.	38	13	0.731	0.119	1	1	5.218	4.936	1.850
27		A-383312	250.	30	13	0.569	0.094	1	1	5.298	4.938	1.850
27	55106	A-405374	300.	25	13	0.475	0.078	1	1	5.371	4.940	1.851
28	55438	A-438281	125.	47	13	1.291	0.325	1	1	5.094	4.934	1.849
28	55437	A-152330	147.	40	13	1.099	0.278	1	1	5.122	4.935	1.849
28	55436	A-325360	160.	36	13	0.969	0.250	1	1	5.138	4.935	1.849
28	55432	A-180390	173.	33	13	0.881	0.229	1	1	5.169	4.935	1.849
28	55435	A-215462	200.	29	13	0.786	0.201	1	1	5.139	4.936	1.849
28		A-379562	250.	23	13	0.618	0.160	1	1	5.259	4.937	1.850
28	55433	A-401674	300.	19	13	0.506	0.132	1	1	5.344	4.939	1.851
29		A-123068	60.	186	13	4.617	0.305	1	1	4.979	4.933	1.848
29		A-866142	125.	89	13	2.202	0.146	1	1	5.028	4.934	1.849
29		A-156167	147.	75	13	1.839	0.123	1	1	5.046	4.934	1.849

THE MAXIMUM OF 50 WINDABILITY CHECKS HAS BEEN REACHED

****

DESIGN EVALUATION

MAX. NO. OF EVALUATIONS = 3

****

EVALUATION FOR DESIGN NO. 1

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
27	55109	A-109156	125.	60	13	0.569	0.188	1	1	5.298	4.938	1.850

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
1.490E-04	1.430E-01	9.480E-04	6.230E-02	1.490E-02	2.606E-01	3.738E 00	2.502E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.10	2.83	83.1	10.00	2.467	2.476	0.928	0.509	0.250	0.153	0.029	0.086	1.028	90.7	3.479E 02
12.0	2.60	3.32	83.1	10.00	2.960	2.967	1.112	0.732	0.300	0.220	0.029	0.124	1.405	89.5	3.435E 02
14.0	3.09	3.82	83.1	10.00	3.453	3.460	1.297	0.995	0.350	0.299	0.029	0.168	1.842	88.4	3.391E 02
16.0	3.58	4.31	83.1	10.00	3.947	3.952	1.481	1.298	0.400	0.391	0.029	0.219	2.338	87.3	3.348E 02
18.0	4.08	4.80	83.1	10.00	4.440	4.445	1.666	1.642	0.450	0.494	0.029	0.277	2.893	86.2	3.305E 02
20.0	4.57	5.30	83.1	10.00	4.933	4.938	1.850	2.026	0.500	0.610	0.029	0.342	3.508	85.1	3.264E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	1.40	2.36	77.8	10.00	1.881	1.901	0.792	0.281	0.250	0.090	0.061	0.063	0.746	93.1	3.571E 02
12.0	1.78	2.74	77.8	10.00	2.257	2.274	0.946	0.403	0.300	0.129	0.061	0.090	0.983	92.4	3.546E 02
14.0	2.15	3.11	77.8	10.00	2.633	2.648	1.101	0.546	0.350	0.175	0.061	0.121	1.254	91.8	3.521E 02
16.0	2.53	3.49	77.8	10.00	3.010	3.022	1.257	0.711	0.400	0.228	0.061	0.158	1.558	91.1	3.496E 02
18.0	2.91	3.86	77.8	10.00	3.386	3.397	1.412	0.898	0.450	0.289	0.061	0.199	1.897	90.5	3.471E 02
20.0	3.28	4.24	77.8	10.00	3.762	3.772	1.568	1.108	0.500	0.356	0.061	0.246	2.270	89.8	3.446E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.98	2.13	73.2	10.00	1.556	1.591	0.710	0.185	0.250	0.063	0.103	0.050	0.653	93.9	3.602E 02
12.0	1.29	2.45	73.2	10.00	1.867	1.896	0.845	0.263	0.300	0.090	0.103	0.071	0.828	93.5	3.589E 02
14.0	1.60	2.76	73.2	10.00	2.178	2.203	0.980	0.355	0.350	0.121	0.103	0.096	1.026	93.2	3.575E 02
16.0	1.91	3.07	73.2	10.00	2.489	2.511	1.116	0.462	0.400	0.158	0.103	0.124	1.247	92.8	3.559E 02
18.0	2.22	3.38	73.2	10.00	2.800	2.820	1.252	0.582	0.450	0.199	0.103	0.157	1.491	92.3	3.543E 02
20.0	2.53	3.69	73.2	10.00	3.111	3.129	1.389	0.717	0.500	0.245	0.103	0.193	1.758	91.9	3.527E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.68	2.02	69.1	10.00	1.348	1.402	0.659	0.136	0.250	0.049	0.154	0.043	0.633	94.0	3.608E 02
12.0	0.95	2.29	69.1	10.00	1.618	1.663	0.778	0.191	0.300	0.069	0.154	0.060	0.775	93.9	3.604E 02
14.0	1.22	2.56	69.1	10.00	1.888	1.927	0.898	0.257	0.350	0.093	0.154	0.081	0.934	93.7	3.597E 02
16.0	1.49	2.82	69.1	10.00	2.158	2.192	1.020	0.332	0.400	0.120	0.154	0.104	1.110	93.5	3.588E 02
18.0	1.76	3.09	69.1	10.00	2.427	2.458	1.142	0.417	0.450	0.151	0.154	0.130	1.303	93.2	3.578E 02
20.0	2.03	3.36	69.1	10.00	2.697	2.724	1.264	0.513	0.500	0.186	0.154	0.160	1.513	93.0	3.567E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.46	1.95	65.4	10.00	1.205	1.280	0.627	0.107	0.250	0.041	0.212	0.039	0.649	93.9	3.603E 02
12.0	0.70	2.19	65.4	10.00	1.446	1.509	0.733	0.149	0.300	0.057	0.212	0.054	0.772	94.0	3.605E 02
14.0	0.94	2.43	65.4	10.00	1.687	1.741	0.842	0.198	0.350	0.076	0.212	0.071	0.907	93.9	3.603E 02
16.0	1.19	2.68	65.4	10.00	1.928	1.976	0.951	0.255	0.400	0.098	0.212	0.091	1.056	93.8	3.599E 02
18.0	1.42	2.92	65.4	10.00	2.169	2.212	1.062	0.320	0.450	0.122	0.212	0.113	1.217	93.7	3.594E 02
20.0	1.66	3.16	65.4	10.00	2.410	2.449	1.174	0.392	0.500	0.150	0.212	0.138	1.392	93.5	3.587E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.28	1.92	62.1	10.00	1.100	1.197	0.608	0.089	0.250	0.036	0.275	0.037	0.686	93.6	3.590E 02
12.0	0.50	2.14	62.1	10.00	1.320	1.402	0.703	0.122	0.300	0.049	0.275	0.049	0.795	93.8	3.598E 02
14.0	0.72	2.36	62.1	10.00	1.540	1.611	0.802	0.161	0.350	0.065	0.275	0.064	0.915	93.9	3.601E 02
16.0	0.94	2.58	62.1	10.00	1.760	1.822	0.902	0.206	0.400	0.083	0.275	0.081	1.045	93.9	3.601E 02
18.0	1.16	2.80	62.1	10.00	1.980	2.036	1.004	0.257	0.450	0.104	0.275	0.101	1.186	93.8	3.599E 02
20.0	1.38	3.02	62.1	10.00	2.200	2.250	1.106	0.315	0.500	0.127	0.275	0.122	1.338	93.7	3.596E 02

C-2

EVALUATION FOR DESIGN NO. 2

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
27	55108	A-155185	147.	50	13	0.465	0.156	1	1	5.380	4.940	1.851

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
1.440E-04	1.430E-01	9.480E-04	6.230E-02	1.490E-02	2.465E-01	3.115E 00	2.085E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.02	2.91	83.1	10.00	2.467	2.480	0.930	0.511	0.250	0.128	0.048	0.087	1.024	90.7	3.679E 02
12.0	2.51	3.41	83.1	10.00	2.960	2.971	1.114	0.734	0.300	0.184	0.048	0.124	1.390	89.6	3.635E 02
14.0	3.01	3.90	83.1	10.00	3.453	3.463	1.298	0.997	0.350	0.250	0.048	0.169	1.813	88.5	3.591E 02
16.0	3.50	4.39	83.1	10.00	3.947	3.955	1.483	1.300	0.400	0.324	0.048	0.220	2.294	87.5	3.548E 02
18.0	3.99	4.89	83.1	10.00	4.440	4.447	1.667	1.644	0.450	0.412	0.048	0.278	2.832	86.4	3.505E 02
20.0	4.49	5.38	83.1	10.00	4.933	4.940	1.851	2.028	0.500	0.509	0.048	0.343	3.428	85.4	3.463E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	1.30	2.47	77.8	10.00	1.881	1.911	0.797	0.284	0.250	0.076	0.102	0.064	0.776	92.8	3.764E 02
12.0	1.67	2.84	77.8	10.00	2.257	2.282	0.951	0.406	0.300	0.109	0.102	0.090	1.006	92.3	3.742E 02
14.0	2.05	3.22	77.8	10.00	2.633	2.655	1.105	0.549	0.350	0.147	0.102	0.122	1.270	91.7	3.719E 02
16.0	2.42	3.60	77.8	10.00	3.010	3.028	1.260	0.714	0.400	0.191	0.102	0.159	1.566	91.1	3.695E 02
18.0	2.80	3.97	77.8	10.00	3.386	3.403	1.415	0.901	0.450	0.241	0.102	0.200	1.895	90.5	3.670E 02
20.0	3.18	4.35	77.8	10.00	3.762	3.777	1.570	1.111	0.500	0.297	0.102	0.247	2.257	89.9	3.645E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.85	2.26	73.2	10.00	1.556	1.608	0.721	0.189	0.250	0.054	0.174	0.052	0.719	93.3	3.784E 02
12.0	1.16	2.58	73.2	10.00	1.867	1.911	0.853	0.267	0.300	0.076	0.174	0.073	0.890	93.1	3.776E 02
14.0	1.47	2.89	73.2	10.00	2.178	2.216	0.987	0.359	0.350	0.102	0.174	0.097	1.083	92.8	3.765E 02
16.0	1.78	3.20	73.2	10.00	2.489	2.522	1.122	0.466	0.400	0.133	0.174	0.126	1.298	92.5	3.752E 02
18.0	2.09	3.51	73.2	10.00	2.800	2.830	1.258	0.586	0.450	0.167	0.174	0.158	1.535	92.1	3.738E 02
20.0	2.40	3.82	73.2	10.00	3.111	3.138	1.394	0.721	0.500	0.205	0.174	0.194	1.794	91.8	3.722E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.53	2.17	69.1	10.00	1.348	1.429	0.676	0.141	0.250	0.043	0.260	0.046	0.739	93.1	3.777E 02
12.0	0.80	2.44	69.1	10.00	1.618	1.686	0.792	0.196	0.300	0.059	0.260	0.063	0.879	93.2	3.780E 02
14.0	1.07	2.71	69.1	10.00	1.888	1.946	0.911	0.262	0.350	0.079	0.260	0.083	1.033	93.1	3.777E 02
16.0	1.34	2.97	69.1	10.00	2.158	2.209	1.031	0.337	0.400	0.102	0.260	0.105	1.205	93.0	3.772E 02
18.0	1.61	3.24	69.1	10.00	2.427	2.473	1.152	0.423	0.450	0.127	0.260	0.133	1.392	92.8	3.765E 02
20.0	1.88	3.51	69.1	10.00	2.697	2.738	1.274	0.518	0.500	0.156	0.260	0.162	1.596	92.6	3.756E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.29	2.12	65.4	10.00	1.205	1.316	0.652	0.113	0.250	0.036	0.358	0.042	0.799	92.6	3.756E 02
12.0	0.53	2.36	65.4	10.00	1.446	1.540	0.755	0.155	0.300	0.049	0.358	0.057	0.919	92.9	3.768E 02
14.0	0.77	2.60	65.4	10.00	1.687	1.768	0.860	0.204	0.350	0.065	0.358	0.074	1.051	93.0	3.773E 02
16.0	1.01	2.84	65.4	10.00	1.928	1.999	0.968	0.261	0.400	0.083	0.358	0.094	1.196	93.0	3.774E 02
18.0	1.25	3.08	65.4	10.00	2.169	2.233	1.077	0.326	0.450	0.104	0.358	0.116	1.354	93.0	3.773E 02
20.0	1.50	3.32	65.4	10.00	2.410	2.467	1.188	0.398	0.500	0.127	0.358	0.141	1.524	92.9	3.769E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.10	2.10	62.1	10.00	1.100	1.243	0.641	0.096	0.250	0.032	0.464	0.041	0.883	91.9	3.727E 02
12.0	0.32	2.32	62.1	10.00	1.320	1.441	0.733	0.129	0.300	0.043	0.464	0.054	0.990	92.4	3.747E 02
14.0	0.54	2.54	62.1	10.00	1.540	1.645	0.828	0.168	0.350	0.056	0.464	0.068	1.107	92.7	3.759E 02
16.0	0.76	2.76	62.1	10.00	1.760	1.853	0.925	0.213	0.400	0.072	0.464	0.086	1.234	92.8	3.766E 02
18.0	0.98	2.98	62.1	10.00	1.980	2.063	1.024	0.264	0.450	0.089	0.464	0.105	1.372	92.9	3.769E 02
20.0	1.20	3.20	62.1	10.00	2.200	2.275	1.125	0.321	0.500	0.108	0.464	0.127	1.520	92.9	3.770E 02

EVALUATION FOR DESIGN NO. 3

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
28	55438	A-438281	125.	45	13	0.592	0.313	1	1	5.245	4.937	1.650

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
1.990E-04	1.070E-01	4.270E-04	6.780E-02	1.890E-02	2.511E-01	3.051E 00	2.042E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.12	2.82	83.1	10.00	2.467	2.475	0.928	0.509	0.250	0.125	0.027	0.086	0.998	90.9	3.621E 02
12.0	2.61	3.31	83.1	10.00	2.960	2.967	1.112	0.732	0.300	0.180	0.027	0.124	1.362	89.8	3.577E 02
14.0	3.10	3.80	83.1	10.00	3.453	3.459	1.297	0.995	0.350	0.244	0.027	0.168	1.784	88.7	3.533E 02
16.0	3.60	4.30	83.1	10.00	3.947	3.952	1.481	1.298	0.400	0.319	0.027	0.219	2.264	87.6	3.489E 02
18.0	4.09	4.79	83.1	10.00	4.440	4.445	1.666	1.642	0.450	0.403	0.027	0.277	2.800	86.5	3.447E 02
20.0	4.58	5.28	83.1	10.00	4.933	4.937	1.850	2.026	0.500	0.498	0.027	0.342	3.394	85.5	3.405E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	1.42	2.34	77.8	10.00	1.881	1.900	0.791	0.281	0.250	0.074	0.057	0.063	0.724	93.2	3.714E 02
12.0	1.80	2.72	77.8	10.00	2.257	2.273	0.946	0.402	0.300	0.105	0.057	0.089	0.954	92.6	3.689E 02
14.0	2.17	3.09	77.8	10.00	2.633	2.647	1.101	0.545	0.350	0.143	0.057	0.121	1.217	92.0	3.664E 02
16.0	2.55	3.47	77.8	10.00	3.010	3.021	1.256	0.711	0.400	0.186	0.057	0.158	1.512	91.4	3.639E 02
18.0	2.93	3.85	77.8	10.00	3.386	3.396	1.412	0.898	0.450	0.236	0.057	0.199	1.840	90.7	3.613E 02
20.0	3.30	4.22	77.8	10.00	3.762	3.771	1.567	1.107	0.500	0.290	0.057	0.246	2.200	90.1	3.588E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	1.00	2.11	73.2	10.00	1.556	1.588	0.709	0.185	0.250	0.052	0.097	0.050	0.633	94.0	3.746E 02
12.0	1.31	2.42	73.2	10.00	1.867	1.894	0.843	0.263	0.300	0.073	0.097	0.071	0.804	93.7	3.733E 02
14.0	1.62	2.73	73.2	10.00	2.178	2.201	0.979	0.355	0.350	0.099	0.097	0.096	0.996	93.4	3.718E 02
16.0	1.93	3.05	73.2	10.00	2.489	2.510	1.115	0.461	0.400	0.129	0.097	0.124	1.211	93.0	3.703E 02
18.0	2.24	3.36	73.2	10.00	2.800	2.818	1.251	0.582	0.450	0.162	0.097	0.157	1.447	92.6	3.686E 02
20.0	2.55	3.67	73.2	10.00	3.111	3.128	1.388	0.716	0.500	0.200	0.097	0.193	1.705	92.1	3.670E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.71	1.99	69.1	10.00	1.348	1.399	0.656	0.135	0.250	0.040	0.144	0.043	0.613	94.2	3.753E 02
12.0	0.98	2.26	69.1	10.00	1.618	1.660	0.776	0.190	0.300	0.056	0.144	0.060	0.751	94.1	3.748E 02
14.0	1.25	2.53	69.1	10.00	1.888	1.924	0.896	0.256	0.350	0.076	0.144	0.080	0.906	93.9	3.741E 02
16.0	1.52	2.80	69.1	10.00	2.158	2.189	1.018	0.331	0.400	0.098	0.144	0.104	1.077	93.7	3.732E 02
18.0	1.78	3.07	69.1	10.00	2.427	2.455	1.140	0.417	0.450	0.123	0.144	0.130	1.264	93.4	3.721E 02
20.0	2.05	3.34	69.1	10.00	2.697	2.722	1.263	0.512	0.500	0.151	0.144	0.160	1.467	93.2	3.711E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.49	1.92	65.4	10.00	1.205	1.275	0.623	0.106	0.250	0.033	0.198	0.039	0.626	94.1	3.748E 02
12.0	0.73	2.17	65.4	10.00	1.446	1.505	0.730	0.148	0.300	0.046	0.198	0.053	0.746	94.1	3.750E 02
14.0	0.97	2.41	65.4	10.00	1.687	1.737	0.839	0.198	0.350	0.062	0.198	0.070	0.873	94.1	3.748E 02
16.0	1.21	2.65	65.4	10.00	1.928	1.972	0.949	0.255	0.400	0.079	0.198	0.090	1.022	94.0	3.744E 02
18.0	1.45	2.89	65.4	10.00	2.169	2.209	1.060	0.319	0.450	0.100	0.198	0.112	1.179	93.9	3.738E 02
20.0	1.69	3.13	65.4	10.00	2.410	2.446	1.172	0.391	0.500	0.122	0.198	0.137	1.349	93.7	3.731E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.31	1.89	62.1	10.00	1.100	1.190	0.603	0.088	0.250	0.029	0.257	0.036	0.660	93.8	3.736E 02
12.0	0.53	2.11	62.1	10.00	1.320	1.396	0.699	0.121	0.300	0.040	0.257	0.049	0.766	94.0	3.744E 02
14.0	0.75	2.33	62.1	10.00	1.540	1.606	0.798	0.160	0.350	0.053	0.257	0.064	0.883	94.1	3.746E 02
16.0	0.97	2.55	62.1	10.00	1.760	1.818	0.898	0.205	0.400	0.067	0.257	0.081	1.010	94.1	3.746E 02
18.0	1.19	2.77	62.1	10.00	1.980	2.032	1.000	0.256	0.450	0.084	0.257	0.100	1.147	94.0	3.744E 02
20.0	1.41	2.99	62.1	10.00	2.200	2.246	1.103	0.314	0.500	0.103	0.257	0.122	1.295	93.9	3.741E 02

5.4 SAMPLE PROGRAM #3--PROGRAM DC1DC

Note from the results of Sample Program #2 that core size number 24 is the smallest usable size even in a two core stack. To use core size #23 with a relative permeability of 125.0 in a design which will operate in Mode 1 (continuous conduction mode) over the entire design range, Sample Program #3 uses Procedure DSN2 of Program DC1DC to compute a design using core size #23 in a three core stack. Again, the minimum flux density is set equal to 0.011 tesla to insure that only a Mode 1 design will be produced. All other design specifications will remain the same as those used in Sample Program #1. If the program cannot produce a design which meets the constraints using the core size and stack height indicated, a message to this effect will be printed out instead of a design.

5.4.1 Control Cards--Sample Program #3 (Program DC1DC)

The control cards for Sample Program #3 are shown below. Sections 3.1-3.6 give instructions for preparing these cards.

```
 FQUD NP DSN2      1   2.   2.                                                  
  24.   6.  16.  10.  20.  10.  .01 .011  .36   .4    1    2 5.067E-07 HEAV     1
  1.0  10.  .60   .1
   23 125.    3
 0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.4.2 Results of Sample Program #3--Program DC1DC

The results of Sample Program #3 are given on the following page. Note from the last column under "Converter Specifications" that the number of cores, or stack height, is equal to three. Program DC1DC was able to produce a design using core size #23 in a three core stack. This design operates in Mode 1 (continuous conduction mode) over its entire design range as can be seen from the "OP MODE" column of the print out. Note that the program has taken the integer core size number which was entered as a part of the design specifications and related it to the manufacturers' core numbers form the core catalog. Also, in addition to the design information, an evaluation of the design was produced automatically.

FOOD--CONSTANT FREQ VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	T COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	NO. CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	3

WIRE TYPE= HEAV   MIN. STRANDS= 1   RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

DESIGN EVALUATION

EVALUATION FOR DESIGN NO. 0

SIZE NO.	MAGNETICS	ARNOLD	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
23	55324	A-324117	125.	37	13	0.487	0.301	1	1	5.360	4.939	1.851

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN. AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
2.034E-04	8.980E-02	3.644E-04	8.860E-02	3.390E-02	2.302E-01	3.278E 00	2.194E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	2.04	2.89	83.1	10.00	2.467	2.479	0.930	0.511	0.250	0.135	0.038	0.086	1.020	90.7	3.942E 02
12.0	2.53	3.39	83.1	10.00	2.960	2.970	1.114	0.733	0.300	0.194	0.038	0.124	1.388	89.6	3.893E 02
14.0	3.03	3.88	83.1	10.00	3.453	3.462	1.298	0.996	0.350	0.263	0.038	0.168	1.815	88.5	3.845E 02
16.0	3.52	4.37	83.1	10.00	3.947	3.954	1.482	1.300	0.400	0.343	0.038	0.220	2.300	87.4	3.798E 02
18.0	4.01	4.87	83.1	10.00	4.440	4.447	1.667	1.643	0.450	0.434	0.038	0.278	2.843	86.4	3.751E 02
20.0	4.51	5.36	83.1	10.00	4.933	4.939	1.851	2.028	0.500	0.535	0.038	0.343	3.443	85.3	3.706E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	1.32	2.44	77.8	10.00	1.881	1.908	0.796	0.284	0.250	0.080	0.079	0.063	0.756	93.0	4.038E 02
12.0	1.70	2.82	77.8	10.00	2.257	2.280	0.950	0.405	0.300	0.114	0.079	0.090	0.988	92.4	4.013E 02
14.0	2.07	3.19	77.8	10.00	2.633	2.653	1.104	0.548	0.350	0.154	0.079	0.122	1.254	91.8	3.987E 02
16.0	2.45	3.57	77.8	10.00	3.010	3.027	1.259	0.713	0.400	0.201	0.079	0.159	1.552	91.2	3.959E 02
18.0	2.83	3.95	77.8	10.00	3.386	3.401	1.414	0.900	0.450	0.254	0.079	0.200	1.884	90.5	3.932E 02
20.0	3.20	4.32	77.8	10.00	3.762	3.776	1.570	1.110	0.500	0.313	0.079	0.246	2.248	89.9	3.905E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.88	2.23	73.2	10.00	1.556	1.604	0.718	0.188	0.250	0.056	0.135	0.052	0.681	93.6	4.066E 02
12.0	1.19	2.54	73.2	10.00	1.867	1.907	0.851	0.266	0.300	0.080	0.135	0.072	0.854	93.4	4.055E 02
14.0	1.50	2.85	73.2	10.00	2.178	2.213	0.985	0.358	0.350	0.107	0.135	0.097	1.048	93.0	4.041E 02
16.0	1.81	3.17	73.2	10.00	2.489	2.519	1.121	0.465	0.400	0.139	0.135	0.126	1.265	92.7	4.025E 02
18.0	2.12	3.48	73.2	10.00	2.800	2.827	1.256	0.585	0.450	0.175	0.135	0.158	1.503	92.3	4.009E 02
20.0	2.43	3.79	73.2	10.00	3.111	3.136	1.392	0.720	0.500	0.216	0.135	0.194	1.765	91.9	3.991E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.57	2.13	69.1	10.00	1.348	1.422	0.672	0.140	0.250	0.044	0.202	0.045	0.681	93.6	4.066E 02
12.0	0.84	2.40	69.1	10.00	1.618	1.680	0.789	0.195	0.300	0.062	0.202	0.062	0.821	93.6	4.065E 02
14.0	1.11	2.67	69.1	10.00	1.888	1.941	0.908	0.260	0.350	0.083	0.202	0.082	0.978	93.5	4.060E 02
16.0	1.38	2.94	69.1	10.00	2.158	2.204	1.028	0.336	0.400	0.107	0.202	0.106	1.150	93.3	4.052E 02
18.0	1.65	3.21	69.1	10.00	2.427	2.469	1.149	0.421	0.450	0.134	0.202	0.132	1.339	93.1	4.043E 02
20.0	1.92	3.48	69.1	10.00	2.697	2.734	1.271	0.517	0.500	0.164	0.202	0.162	1.544	92.8	4.032E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.33	2.08	65.4	10.00	1.205	1.306	0.645	0.112	0.250	0.037	0.278	0.042	0.719	93.3	4.052E 02
12.0	0.57	2.32	65.4	10.00	1.446	1.531	0.749	0.153	0.300	0.051	0.278	0.056	0.839	93.5	4.060E 02
14.0	0.81	2.56	65.4	10.00	1.687	1.761	0.855	0.203	0.350	0.068	0.278	0.073	0.972	93.5	4.061E 02
16.0	1.06	2.80	65.4	10.00	1.928	1.993	0.964	0.260	0.400	0.087	0.278	0.093	1.118	93.5	4.060E 02
18.0	1.30	3.04	65.4	10.00	2.169	2.227	1.073	0.324	0.450	0.109	0.278	0.115	1.277	93.4	4.056E 02
20.0	1.54	3.28	65.4	10.00	2.410	2.462	1.184	0.397	0.500	0.133	0.278	0.140	1.448	93.2	4.050E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS W/KG
10.0	0.14	2.06	62.1	10.00	1.100	1.231	0.633	0.094	0.250	0.033	0.361	0.040	0.778	92.8	4.030E 02
12.0	0.36	2.28	62.1	10.00	1.320	1.431	0.725	0.127	0.300	0.045	0.361	0.053	0.886	93.1	4.045E 02
14.0	0.58	2.50	62.1	10.00	1.540	1.636	0.821	0.166	0.350	0.059	0.361	0.067	1.003	93.3	4.053E 02
16.0	0.80	2.72	62.1	10.00	1.760	1.845	0.919	0.211	0.400	0.075	0.361	0.084	1.132	93.4	4.057E 02
18.0	1.02	2.94	62.1	10.00	1.980	2.056	1.019	0.262	0.450	0.093	0.361	0.104	1.270	93.4	4.057E 02
20.0	1.24	3.16	62.1	10.00	2.200	2.268	1.120	0.320	0.500	0.113	0.361	0.125	1.419	93.4	4.056E 02

5.5 SAMPLE PROGRAM #4--PROGRAM DC1DC

Now assume that by some criteria it is decided that the design produced in Sample Program #3 is close to the desired result for a single-winding design. However, there is available from a different manufacturer a core with slightly different dimensions from core size #23. Also, this core has a relative permeability value of 128. Sample Program #4 uses Procedure DSN2 of Program DC1DC to produce a design for this new core size and relative permeability using a three core stack to see if any changes in number of turns or wire size must be made due to the change in core. Also, since AWG #13 wire is fairly stiff, it is decided to use two strands of smaller wire to make winding easier. Assume that the dimensions of the new core size are as follows:

Cross-Sectional Area	$7.00 * 10^{-5}$ m^2
Mean Magnetic Path Length	$9.00 * 10^{-2}$ m
Window Area	$3.704 * 10^{-4}$ m^2
Length/Turn of Wire (40% Wdg. Factor)	$4.50 * 10^{-2}$ m
Height	$1.15 * 10^{-2}$ m
Mass	$5.50 * 10^{-2}$ kg

The relative permeability value of 128.0 is close to the catalog value of 125.0. Thus, if no loss-coefficient information is entered, the program will use the loss coefficients for the catalog value of 125.0.

5.5.1 Control Cards--Sample Program #4 (Program DC1DC)

The control cards for Sample Program #4 are shown below. Sections 3.1-3.6 give instructions for preparing these cards.

```
FQUD NP DSN2       1    2.    2.
 24.   6.  16.  10.  20.  10.  .01 .011  .36   .4    1    2 5.067E-07 HEAV    2
 1.0  10.  .60   .1
                3
  7.00E-5   9.00E-2  3.704E-4   4.50E-2   1.15E-2   5.50E-2
 128.
0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.5.2 Results of Sample Program #4--Program DC1DC

The results of Sample Program #4 are given on the next page. Note that the change in core dimensions and permeability did not change the number of turns for the design. However, by using two strands of wire, the wire size has been reduced to AWG #16. By comparing the results to those of Sample Program #3, slight differences can be noted in the evaluation portion of the print out. For example, the efficiency/mass is slightly less in Sample Program #4. However, basically the same design and performance is found in both cases except for the number of strands of wire.

PQUD—CONSTANT FREQ VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	I CELL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	NO. CORES
20.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	3

WIRE TYPE= HEAV   MIN. STRANDS= 2   RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

DESIGN EVALUATION

EVALUATION FOR DESIGN NO. 0

CORRECT WIRE SIZE NOT AVAILABLE OR MULTIPLE STRANDS SPECIFIED, 2 STRANDS USED

SIZE NO.	CORE NOT IN CATALOG	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
33		128.	37	16	0.514	0.304	1	1	5.338	4.939	1.851

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN. AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
2.100E-04	9.000E-02	3.704E-04	9.100E-02	3.450E-02	2.409E-01	3.367E 00	2.264E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.06	2.87	83.1	10.00	2.467	2.578	0.929	0.510	0.250	0.139	0.036	0.086	1.021	90.7	3.766E 02
12.0	2.56	3.36	83.1	10.00	2.960	2.969	1.113	0.733	0.300	0.200	0.036	0.124	1.392	89.6	3.720E 02
14.0	3.05	3.86	83.1	10.00	3.453	3.461	1.297	0.996	0.350	0.271	0.036	0.168	1.821	88.5	3.673E 02
16.0	3.54	4.35	83.1	10.00	3.947	3.954	1.482	1.299	0.400	0.354	0.036	0.220	2.308	87.4	3.628E 02
18.0	4.04	4.84	83.1	10.00	4.440	4.446	1.666	1.643	0.450	0.448	0.036	0.278	2.854	86.3	3.583E 02
20.0	4.53	5.34	83.1	10.00	4.933	4.539	1.851	2.027	0.500	0.552	0.036	0.343	3.458	65.3	3.539E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	1.35	2.41	77.8	10.00	1.881	1.906	0.794	0.283	0.250	0.082	0.075	0.063	0.753	93.0	3.860E 02
12.0	1.73	2.79	77.8	10.00	2.257	2.278	0.948	0.404	0.300	0.117	0.075	0.090	0.987	92.4	3.836E 02
14.0	2.10	3.16	77.8	10.00	2.633	2.651	1.103	0.547	0.350	0.159	0.075	0.122	1.253	91.8	3.810E 02
16.0	2.48	3.54	77.8	10.00	3.010	3.025	1.258	0.712	0.400	0.207	0.075	0.158	1.553	91.2	3.784E 02
18.0	2.86	3.92	77.8	10.00	3.385	3.400	1.413	0.900	0.450	0.262	0.075	0.200	1.886	90.5	3.757E 02
20.0	3.23	4.29	77.8	10.00	3.762	3.774	1.569	1.109	0.500	0.323	0.075	0.246	2.253	89.9	3.731E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.91	2.20	73.2	10.00	1.556	1.599	0.715	0.187	0.250	0.058	0.128	0.051	0.674	93.7	3.889E 02
12.0	1.23	2.51	73.2	10.00	1.867	1.903	0.849	0.265	0.300	0.082	0.128	0.072	0.847	93.4	3.877E 02
14.0	1.54	2.82	73.2	10.00	2.178	2.209	0.983	0.357	0.350	0.111	0.128	0.097	1.042	93.1	3.863E 02
16.0	1.85	3.13	73.2	10.00	2.489	2.516	1.119	0.464	0.400	0.143	0.128	0.125	1.260	92.7	3.848E 02
18.0	2.16	3.44	73.2	10.00	2.800	2.824	1.255	0.584	0.450	0.181	0.128	0.157	1.500	92.3	3.832E 02
20.0	2.47	3.75	73.2	10.00	3.111	3.133	1.391	0.719	0.500	0.222	0.128	0.193	1.762	91.9	3.815E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.61	2.09	69.1	10.00	1.348	1.414	0.667	0.138	0.250	0.045	0.191	0.044	0.669	93.7	3.891E 02
12.0	0.88	2.36	69.1	10.00	1.618	1.674	0.785	0.194	0.300	0.063	0.191	0.062	0.810	93.7	3.889E 02
14.0	1.15	2.63	69.1	10.00	1.888	1.936	0.904	0.259	0.350	0.085	0.191	0.082	0.967	93.5	3.883E 02
16.0	1.42	2.90	69.1	10.00	2.158	2.199	1.025	0.334	0.400	0.110	0.191	0.105	1.140	93.3	3.875E 02
18.0	1.69	3.17	69.1	10.00	2.427	2.465	1.146	0.420	0.450	0.138	0.191	0.131	1.333	93.1	3.865E 02
20.0	1.96	3.44	69.1	10.00	2.697	2.731	1.269	0.515	0.500	0.169	0.191	0.161	1.536	92.9	3.855E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.38	2.03	65.4	10.00	1.205	1.296	0.638	0.110	0.250	0.038	0.263	0.041	0.702	93.4	3.879E 02
12.0	0.62	2.27	65.4	10.00	1.446	1.523	0.743	0.152	0.300	0.053	0.263	0.055	0.822	93.6	3.885E 02
14.0	0.86	2.51	65.4	10.00	1.687	1.754	0.850	0.201	0.350	0.070	0.263	0.072	0.956	93.6	3.886E 02
16.0	1.10	2.76	65.4	10.00	1.928	1.987	0.959	0.258	0.400	0.089	0.263	0.092	1.102	93.6	3.883E 02
18.0	1.34	3.00	65.4	10.00	2.169	2.221	1.039	0.323	0.450	0.112	0.263	0.114	1.262	93.4	3.879E 02
20.0	1.58	3.24	65.4	10.00	2.410	2.457	1.180	0.395	0.500	0.137	0.263	0.139	1.434	93.3	3.873E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	************ TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	************ CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	0.19	2.01	62.1	10.00	1.100	1.218	0.623	0.092	0.250	0.034	0.341	0.039	0.756	93.0	3.859E 02
12.0	0.41	2.23	62.1	10.00	1.320	1.420	0.717	0.125	0.300	0.046	0.341	0.051	0.863	93.3	3.872E 02
14.0	0.63	2.45	62.1	10.00	1.540	1.627	0.814	0.164	0.350	0.060	0.341	0.066	0.981	93.4	3.878E 02
16.0	0.85	2.67	62.1	10.00	1.760	1.836	0.913	0.209	0.400	0.076	0.341	0.083	1.110	93.5	3.882E 02
18.0	1.07	2.89	62.1	10.00	1.980	2.048	1.011	0.261	0.450	0.095	0.341	0.103	1.249	93.5	3.882E 02
20.0	1.29	3.11	62.1	10.00	2.200	2.261	1.115	0.318	0.500	0.116	0.341	0.124	1.399	93.5	3.880E 02

5.6 SAMPLE PROGRAM #5 -- PROGRAM DC1DC

Sample Program #5 evaluates the reactor element design produced in Sample Program #4 under a different set of operating conditions. A reactor element design for a single-winding voltage step-up/current step-up converter has been produced. From the design specifications it can be seen that this converter has been designed for voltage step-up operation since the specified output voltage of 24.0 volts is greater than the maximum input voltage of 16.0 volts. To determine how the design will perform when the controller is changed to regulate the output at 5.0 volts, Procedure EVAL of Program DC1DC is used. On the Design Specification Card, the output voltage is set equal to 5.0 volts. All of the other parameters will remain the same and the completed design will be entered on the EVAL card. Note that since we are requesting an evaluation rather than a design, the minimum and maximum flux density specifications, the maximum winding factor, and the reciprocal current density specification are not needed. Thus, it is not necessary to enter these parameters on the Design Specification Card when using Procedure EVAL.

5.61 Control Cards--Sample Program #5 (Program DC1DC)

The Control Cards for Sample Program #5 are given below. Sections 3.1-3.6 give instructions for preparing these cards.

```
FQUD NP EVAL      1    2.    2.                                         HEAV    2
  5.   6.  16.  10.  20.  10.  .01
 1.0  10.  .60   .1
            3   32   16
  7.00E-5   9.00E-2 3.704E-4   4.50E-2   1.15E-2   5.50E-2
 128.
0
```

5.6.2 Results of Sample Program #5 -- Program DC1DC

The results of Sample Program #5 are given on the next page. Note that the converter operates in Mode 1 (continuous conduction mode) over its entire operating range. However, the peak value of the reactor current, IB, is about 60% higher than in Sample Program #4. The same is true for the values of all the currents given in the evaluation. Thus, if the converter is used under these operating conditions as well as under those of the original problem, it will be necessary to use a larger wire size if the reciprocal current density specification of 5.067 * 10^{-7} m^2/A is to be met. Also, the maximum operating flux density, given by

$$B_{max} = (N/\ell)\mu IB_{max}$$

where

N = Number of Turns

ℓ = Mean Magnetic Path Length

μ = Permeability

IB_{max} = Peak Value of Reactor Current

should be checked to determine whether or not this value exceeds the saturation flux density of the magnetic material. For this case, the maximum operating flux density would be approximately 0.578 tesla. Note also that the increase in current values has led to increased losses in the transistor, diode, wire and capacitor. The core loss has decreased due to the fact that the total flux density excursion given by

$$(N/\ell)(IB - IA)\mu$$

has decreased by about 40%. Since total core loss as given by Legg's equation (see Section 1.2.3) is directly to the flux density excursion, the core loss varies directly with this excursion. The increase in total power loss over that of Sample Program #4 can also be noted in the decreased efficiency in Sample Program #5. Thus, this single-winding reactor design will work for an output voltage of 5.0 volts, but not as well as for the design output voltage of 24.0 volts.

FOUD—CONSTANT FREQ VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT. MIN	P OUT MAX	V SAT	I COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	NO. CORES
5.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02				3

WIRE TYPE= HEAV NO. STRANDS= 2

DESIGN EVALUATION

EVALUATION FOR DESIGN ENTERED

CORRECT WIRE SIZE NOT AVAILABLE OR MULTIPLE STRANDS SPECIFIED, 2 STRANDS USED

SIZE NO.	CORE NOT IN CATALOG	MU	N	AWG	IND. MH	WDG FAC	DSN MODE	OP MODE	IB MAX	IXRMS MAX	ICRMS MAX
33		128.	37	16	0.514	0.304	0	1	8.737	8.431	4.234

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR WIRE LEN. M	REACTOR WIRE RES. OHMS
2.100E-04	9.000E-02	3.704E-04	9.100E-02	3.450E-02	2.409E-01	3.367E 00	2.264E-02

V IN= 6.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	3.98	4.50	52.8	10.00	4.240	4.243	2.119	0.951	1.200	0.408	0.011	0.449	3.018	76.8	3.189E 02
12.0	4.83	5.35	52.8	10.00	5.088	5.090	2.542	1.369	1.440	0.587	0.011	0.646	4.052	74.8	3.103E 02
14.0	5.66	6.19	52.8	10.00	5.936	5.938	2.965	1.863	1.680	0.798	0.011	0.879	5.231	72.8	3.022E 02
16.0	5.53	7.04	52.8	10.00	6.784	6.786	3.388	2.433	1.920	1.043	0.011	1.148	6.554	70.9	2.945E 02
18.0	7.37	7.89	52.8	10.00	7.632	7.633	3.811	3.078	2.160	1.319	0.011	1.453	8.021	69.2	2.871E 02
20.0	8.22	8.74	52.8	10.00	8.480	8.481	4.234	3.800	2.400	1.629	0.011	1.793	9.633	67.5	2.802E 02

V IN= 8.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	3.30	3.90	44.4	10.00	3.600	3.604	1.794	0.577	1.200	0.294	0.016	0.322	2.410	80.6	3.345E 02
12.0	4.02	4.62	44.4	10.00	4.320	4.324	2.151	0.831	1.440	0.423	0.016	0.462	3.173	79.1	3.283E 02
14.0	4.74	5.34	44.4	10.00	5.040	5.043	2.508	1.130	1.680	0.576	0.016	0.629	4.031	77.6	3.223E 02
16.0	5.46	6.06	44.4	10.00	5.760	5.763	2.865	1.476	1.920	0.752	0.016	0.821	4.985	76.2	3.165E 02
18.0	6.18	6.78	44.4	10.00	6.480	6.482	3.223	1.868	2.160	0.952	0.016	1.038	6.034	74.9	3.109E 02
20.0	6.90	7.50	44.4	10.00	7.200	7.202	3.580	2.305	2.400	1.175	0.016	1.282	7.178	73.6	3.055E 02

V IN= 10.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.91	3.58	38.4	10.00	3.244	3.250	1.585	0.405	1.200	0.239	0.022	0.251	2.117	82.5	3.426E 02
12.0	3.56	4.23	38.4	10.00	3.893	3.898	1.899	0.583	1.440	0.344	0.022	0.361	2.749	81.4	3.377E 02
14.0	4.21	4.88	38.4	10.00	4.542	4.546	2.214	0.793	1.680	0.468	0.022	0.490	3.453	80.2	3.330E 02
16.0	4.86	5.53	38.4	10.00	5.191	5.195	2.529	1.035	1.920	0.611	0.022	0.639	4.227	79.1	3.284E 02
18.0	5.50	6.18	38.4	10.00	5.840	5.843	2.844	1.310	2.160	0.773	0.022	0.809	5.073	78.0	3.238E 02
20.0	6.15	6.82	38.4	10.00	6.489	6.492	3.159	1.616	2.400	0.954	0.022	0.998	5.990	77.0	3.194E 02

V IN= 12.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.66	3.38	33.7	10.00	3.018	3.025	1.437	0.309	1.200	0.207	0.026	0.207	1.949	83.7	3.474E 02
12.0	3.26	3.98	33.7	10.00	3.622	3.628	1.721	0.444	1.440	0.298	0.026	0.296	2.504	82.7	3.434E 02
14.0	3.86	4.59	33.7	10.00	4.225	4.231	2.005	0.604	1.680	0.405	0.026	0.402	3.117	81.8	3.395E 02
16.0	4.47	5.19	33.7	10.00	4.829	4.834	2.290	0.788	1.920	0.529	0.026	0.524	3.788	80.9	3.356E 02
18.0	5.07	5.79	33.7	10.00	5.433	5.437	2.574	0.997	2.160	0.669	0.026	0.663	4.515	79.9	3.319E 02
20.0	5.68	6.40	33.7	10.00	6.036	6.040	2.859	1.231	2.400	0.826	0.026	0.817	5.300	79.1	3.281E 02

V IN= 14.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.48	3.24	30.1	10.00	2.862	2.870	1.325	0.248	1.200	0.187	0.030	0.176	1.840	84.5	3.506E 02
12.0	3.05	3.81	30.1	10.00	3.434	3.441	1.586	0.356	1.440	0.268	0.030	0.252	2.346	83.6	3.472E 02
14.0	3.63	4.39	30.1	10.00	4.006	4.012	1.847	0.485	1.680	0.365	0.030	0.341	2.901	82.8	3.439E 02
16.0	4.20	4.96	30.1	10.00	4.578	4.584	2.108	0.633	1.920	0.476	0.030	0.444	3.503	82.0	3.405E 02
18.0	4.77	5.53	30.1	10.00	5.151	5.155	2.370	0.800	2.160	0.602	0.030	0.562	4.154	81.2	3.373E 02
20.0	5.34	6.10	30.1	10.00	5.723	5.727	2.632	0.988	2.400	0.743	0.030	0.693	4.853	80.5	3.340E 02

V IN= 16.0

PO WATTS	IA AMPS	IB AMPS	T ON USEC	FREQ KHZ	IXAVE AMPS	IXRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES WIRE	(WATTS) CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.0	2.35	3.14	27.2	10.00	2.747	2.756	1.238	0.207	1.200	0.172	0.034	0.153	1.766	85.0	3.528E 02
12.0	2.90	3.69	27.2	10.00	3.296	3.304	1.479	0.297	1.440	0.247	0.034	0.219	2.237	84.3	3.499E 02
14.0	3.45	4.24	27.2	10.00	3.845	3.852	1.722	0.403	1.680	0.336	0.034	0.297	2.750	83.6	3.470E 02
16.0	4.00	4.79	27.2	10.00	4.395	4.401	1.965	0.526	1.920	0.439	0.034	0.386	3.305	82.9	3.440E 02
18.0	4.55	5.34	27.2	10.00	4.944	4.949	2.208	0.666	2.160	0.555	0.034	0.488	3.902	82.2	3.412E 02
20.0	5.10	5.89	27.2	10.00	5.493	5.498	2.452	0.822	2.400	0.685	0.034	0.601	4.541	81.5	3.383E 02

5.7 SAMPLE PROGRAM #6 -- PROGRAM DC2DC

As mentioned in Section 3.6.4, Program DC2DC allows the user to select from ten Design Constraint Options which may be useful in a converter design. Sample Program #6 illustrates the use of one of these options in the design of a two-winding voltage step-up/current step-up converter with a constant frequency controller to meet the specifications given in Sections 5.1 and 5.2. For convenience, these specifications are repeated in Section 5.7.1.

Note from the output of Sample Program #4 (Section 5.5.2) that the single-winding reactor design produced by Program DC1DC requires a maximum transistor on-time (T ON) of 83.1 μsec. Since the converter frequency is 10.0 KHz, the maximum duty cycle is, therefore, 0.83. Suppose that the controller circuit which must be used in the system will produce an output with a maximum duty cycle of 0.75. With this limitation on the controller, the single-winding design produced in Sample Program #4 could not meet the design constraints. However, if Program DC2DC is used to produce a two-winding reactor design, the additional constraint that the maximum duty cycle be less than 0.75 can easily be handled. If a value of 0.74 is chosen for the Design Constraint Value, the maximum duty cycle for the designs produced by Program DC2DC will always be <u>strictly</u> less than 0.75. Since the program is allowed to choose only an integer number of turns, the Design Constraint value should be chosen to be slightly less than the desired maximum of 0.75. Sample Program #6 uses a value of 0.74 for the Design Constraint option.

5.7.1 Design Requirement Input Data--Sample Program #6 (DC2DC)

As in Sample Program #2, it is desired that the converter operate in Mode 1 (continuous mmf mode) over the entire design range. This is accomplished by making the specified minimum flux density greater than the residual flux density of the core material. The following is a complete summary of the input data to Program DC2DC for Sample Program #6.

Converter/Controller Code	FQ2UD
Catalog Print Code	NP
Program Procedure	DSN1
Output Voltage	24.0 volts
Input Voltage Range	6.0 to 16.0 volts
Output Power Range	10.0 to 20.0 watts
Converter Frequency	10.0 KHz
Residual Flux Density	0.01 tesla
Minimum Flux Density	0.011 tesla
Maximum Flux Density	0.36 tesla
Wire Type Code	HEAV
Reciprocal Current Density	$5.067 * 10^{-7}$ m^2/amp
Minimum No. of Cores in Stack	1
Maximum No. of Cores in Stack	2
Min. Strands of Wire--Primary	1
Min. Strands of Wire--Secondary	1
Transistor Saturation Voltage	1.0 volt @ 10.0 amps
Diode Forward Drop	0.60 volts
Capacitor ESR	0.10 ohm

Maximum No. of Evaluations	3
Input Voltage Increment	2.0 volts
Output Power Increment	2.0 watts
Design Constraint Option	8 (Restrict Max. Duty Cycle)
Design Constraint Value	0.74

5.7.2 Control Cards--Sample Program #6 (Program DC2DC)

The Control Cards for Sample Program #6 are shown below. Sections 3.6-3.10 give instructions for preparing these cards.

```
FQ2U0 NP DSN1      8  .74    3   2.   2.
 24.   6.  16.  10.  20.  10.  .01 .011  .36   .4     1     2 5.067E-07 HEAV  1 1
 1.0  10.  .60   .1
0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.7.3 Results of Sample Program #6--Program DC2DC

The following four pages give the results of Sample Program #6. Procedure DSN1 of Program DC2DC has produced a list of fifty usable reactor element designs. Note from the "OP MODE" column of the design list that all of the designs operate in Mode 1 (continuous mmf mode) over the entire design range as desired. Also note that the stack height was increased to two cores by DC2DC in order to produce fifty designs. From the design evaluation portion of the printout, it can be seen that the maximum transistor on-time (T ON) over the design range is less than 75.0 μsec for all the designs evaluated. Since the converter frequency is 10.0 KHz, this corresponds to a maximum duty cycle of 0.75 as desired. Also, the efficiency and the efficiency/mass of these designs are comparable to those of the single-winding designs produced in Sample Program #2 (section 5.2).

FQ2UD--CONSTANT FREQ TWO-WINDING VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	I COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	MAX CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	2

WIRE TYPE= HEAV MIN. PRI. STRANDS= 1 MIN. SEC. STRANDS= 1 RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

RESTRICTING THE MAX. DUTY CYCLE= 0.740

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A 1-CORE STACK

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AVG PRI.	PRI.IND MH	NS	AVG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
25	55089	A-089178	125.	42	13	0.320	72	17	0.941	0.348	1	6.108	3.563	4.770	1.642	1.415
26	55715	A-715152	125.	46	13	0.327	79	17	0.965	0.310	1	6.098	3.551	4.770	1.641	1.414
27	55109	A-109156	125.	53	13	0.444	91	17	1.310	0.284	1	5.948	3.464	4.766	1.640	1.412
27	55108	A-155185	147.	44	13	0.360	76	17	1.074	0.236	1	6.053	3.504	4.772	1.637	1.409
27	55107	A-329200	160.	40	13	0.324	69	17	0.964	0.214	1	6.109	3.541	4.773	1.638	1.411
27	55103	A-182218	173.	37	13	0.300	63	17	0.869	0.197	1	6.139	3.605	4.767	1.647	1.421
28	55437	A-152330	147.	33	13	0.374	57	17	1.116	0.393	1	6.034	3.493	4.772	1.637	1.409
28	55436	A-325360	160.	30	13	0.337	51	17	0.973	0.355	1	6.069	3.570	4.764	1.647	1.421
28	55432	A-180390	173.	29	13	0.317	48	17	0.932	0.332	1	6.113	3.566	4.770	1.642	1.415
29		A-866142	125.	77	13	0.824	133	17	2.459	0.217	1	5.764	3.337	4.767	1.635	1.407
29		A-156167	147.	65	13	0.691	112	17	2.051	0.183	1	5.804	3.368	4.766	1.637	1.409
29		A-183197	173.	54	13	0.551	93	17	1.664	0.152	1	5.865	3.406	4.767	1.638	1.410
29		A-219233	205.	45	13	0.462	77	17	1.352	0.126	1	5.928	3.464	4.764	1.642	1.415
31		A-542228	125.	99	13	2.192	171	17	6.541	0.206	1	5.624	3.256	4.766	1.635	1.407
31		A-157268	147.	93	13	1.912	143	17	5.379	0.173	1	5.638	3.272	4.764	1.636	1.408
31		A-184316	173.	71	13	1.551	122	17	4.608	0.148	1	5.651	3.298	4.763	1.636	1.410
31		A-220374	205.	59	13	1.277	101	17	3.742	0.122	1	5.672	3.313	4.761	1.640	1.413
32		A-128124	60.	277	13	9.305	478	17	27.709	0.302	1	5.558	3.221	4.765	1.635	1.407
32		A-127259	125.	132	13	4.402	228	17	13.134	0.144	1	5.581	3.231	4.765	1.635	1.406
32		A-158304	147.	112	13	3.727	193	17	11.067	0.122	1	5.586	3.241	4.764	1.635	1.407
32		A-185358	173.	95	13	3.156	164	17	9.405	0.104	1	5.597	3.242	4.765	1.635	1.407
32		A-221425	205.	80	13	2.652	138	17	7.891	0.087	1	5.607	3.251	4.765	1.635	1.407

THE FOLLOWING CORES MATCH THE CONSTRAINTS WHEN USED IN A 2-CORE STACK

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AVG PRI.	PRI.IND MH	NS	AVG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
24	55253	A-151198	147.	30	13	0.362	51	17	1.045	0.355	1	6.031	3.547	4.763	1.647	1.423
24	55252	A-306215	160.	28	13	0.343	48	17	1.007	0.332	1	6.069	3.540	4.763	1.642	1.415
24	55248	A-179233	173.	25	13	0.295	43	17	0.874	0.297	1	6.150	3.582	4.773	1.641	1.413
25	55089	A-089178	125.	44	13	0.703	76	17	2.096	0.366	1	5.803	3.359	4.767	1.635	1.407
25	55088	A-153210	147.	37	13	0.584	63	17	1.694	0.306	1	5.837	3.428	4.759	1.644	1.419
25	55087	A-326228	160.	34	13	0.537	58	17	1.563	0.281	1	5.867	3.439	4.761	1.643	1.415
25	55082	A-195246	173.	31	13	0.483	53	17	1.411	0.257	1	5.909	3.456	4.763	1.642	1.415
25	55086	A-216292	200.	27	13	0.423	46	17	1.229	0.223	1	5.958	3.497	4.762	1.645	1.415
25		A-380056	250.	21	13	0.320	36	17	0.941	0.174	1	6.108	3.563	4.770	1.642	1.415
26	55715	A-715152	125.	49	13	0.712	82	17	2.079	0.323	1	5.784	3.386	4.761	1.642	1.415
26	55714	A-154179	147.	41	13	0.611	70	17	1.782	0.276	1	5.826	3.413	4.761	1.643	1.415
26	55713	A-327195	160.	37	13	0.542	63	17	1.571	0.249	1	5.862	3.443	4.760	1.645	1.419
26	55709	A-181210	173.	34	13	0.495	58	17	1.440	0.229	1	5.897	3.457	4.762	1.644	1.417
26	55712	A-217249	200.	29	13	0.416	50	17	1.237	0.196	1	5.982	3.469	4.770	1.638	1.413
26		A-382304	250.	23	13	0.327	39	17	0.941	0.154	1	6.081	3.586	4.763	1.649	1.423
27	55109	A-109156	125.	55	13	0.957	95	17	2.855	0.295	1	5.733	3.319	4.767	1.635	1.407
27	55108	A-155185	147.	46	13	0.737	79	17	2.322	0.246	1	5.767	3.358	4.764	1.639	1.411
27	55107	A-328200	160.	43	13	0.749	74	17	2.217	0.230	1	5.781	3.360	4.765	1.638	1.410
27	55103	A-182218	173.	39	13	0.666	67	17	1.965	0.209	1	5.810	3.382	4.764	1.639	1.411
27	55106	A-218259	200.	34	13	0.535	58	17	1.703	0.181	1	5.839	3.423	4.761	1.643	1.415
27		A-383312	250.	26	13	0.428	44	17	1.225	0.138	1	5.945	3.513	4.758	1.649	1.422
27	55106	A-405374	300.	21	13	0.335	36	17	0.984	0.112	1	6.082	3.548	4.769	1.642	1.415
27		A-425437	350.	18	13	0.287	31	17	0.851	0.096	1	6.180	3.589	4.775	1.640	1.413
28	55436	A-325360	160.	32	13	0.766	55	17	2.262	0.380	1	5.774	3.360	4.764	1.638	1.411
28	55432	A-180390	173.	29	13	0.690	50	17	2.022	0.345	1	5.809	3.369	4.766	1.637	1.403
28	55435	A-215462	200.	25	13	0.594	43	17	1.729	0.297	1	5.850	3.401	4.766	1.639	1.410
28		A-379562	250.	20	13	0.467	34	17	1.351	0.237	1	5.914	3.479	4.760	1.646	1.419
28	55433	A-401674	300.	16	13	0.359	27	17	1.022	0.189	1	6.025	3.570	4.758	1.651	1.425

THE MAXIMUM OF 50 WINDABILITY CHECKS HAS BEEN REACHED

****

DESIGN EVALUATION

MAX. NO. OF EVALUATIONS = 3

****

EVALUATION FOR DESIGN NO. 1

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AWG PRI.	PRI.IND MH	NS	AWG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
25	55089	A-089178	125.	42	13	0.320	72	17	0.941	0.348	1	6.108	3.563	4.770	1.642	1.915

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR PRI.WIRE LENGTH,M	REACTOR PRI.WIRE RES,OHMS	REACTOR SEC.WIRE LENGTH,M	REACTOR SEC.WIRE RES,OHMS
1.340E-04	1.160E-01	6.111E-04	5.920E-02	1.610E-02	2.255E-01	2.486E 00	1.664E-02	4.262E 00	7.202E-02

V IN= 6.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	2.19	1.27	3.34	1.95	74.16	2.40	0.83	0.71	0.575	0.495	0.145	0.052	0.051	1.318	88.4	3.92E 02
12.00	2.74	1.60	3.90	2.27	74.16	2.87	0.99	0.85	0.824	0.593	0.208	0.052	0.073	1.750	87.3	3.87E 02
14.00	3.29	1.92	4.45	2.60	74.16	3.35	1.15	0.99	1.119	0.691	0.282	0.052	0.099	2.242	86.2	3.82E 02
16.00	3.84	2.24	5.00	2.92	74.16	3.82	1.32	1.13	1.459	0.789	0.367	0.052	0.129	2.796	85.1	3.77E 02
18.00	4.40	2.56	5.55	3.24	74.16	4.29	1.48	1.27	1.844	0.887	0.464	0.052	0.162	3.410	84.1	3.73E 02
20.00	4.95	2.89	6.11	3.56	74.16	4.77	1.64	1.42	2.275	0.985	0.573	0.052	0.200	4.086	83.0	3.68E 02

V IN= 8.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	1.44	0.84	2.91	1.70	67.21	1.82	0.74	0.61	0.331	0.445	0.095	0.101	0.038	1.009	90.8	4.03E 02
12.00	1.88	1.10	3.35	1.95	67.21	2.17	0.88	0.73	0.471	0.531	0.135	0.101	0.053	1.291	90.3	4.00E 02
14.00	2.32	1.35	3.78	2.21	67.21	2.52	1.03	0.85	0.637	0.617	0.182	0.101	0.072	1.609	89.7	3.98E 02
16.00	2.75	1.60	4.22	2.46	67.21	2.88	1.17	0.96	0.829	0.704	0.237	0.101	0.093	1.964	89.1	3.95E 02
18.00	3.19	1.86	4.66	2.72	67.21	3.23	1.32	1.08	1.046	0.790	0.299	0.101	0.117	2.353	88.4	3.92E 02
20.00	3.62	2.11	5.09	2.97	67.21	3.59	1.46	1.20	1.288	0.877	0.368	0.101	0.144	2.779	87.6	3.89E 02

V IN= 10.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.99	0.58	2.72	1.59	61.46	1.50	0.70	0.56	0.226	0.417	0.072	0.159	0.031	0.906	91.7	4.07E 02
12.00	1.36	0.79	3.09	1.80	61.46	1.79	0.83	0.66	0.319	0.495	0.102	0.159	0.043	1.119	91.5	4.06E 02
14.00	1.73	1.01	3.46	2.02	61.46	2.07	0.96	0.76	0.429	0.574	0.137	0.159	0.058	1.357	91.2	4.04E 02
16.00	2.10	1.23	3.83	2.23	61.46	2.36	1.09	0.86	0.556	0.653	0.178	0.159	0.074	1.620	90.8	4.03E 02
18.00	2.47	1.44	4.20	2.45	61.46	2.64	1.22	0.96	0.699	0.733	0.224	0.159	0.093	1.908	90.4	4.01E 02
20.00	2.84	1.66	4.57	2.67	61.46	2.93	1.35	1.07	0.860	0.813	0.275	0.159	0.114	2.221	90.0	3.99E 02

V IN= 12.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.67	0.39	2.62	1.53	56.61	1.31	0.67	0.52	0.171	0.401	0.061	0.223	0.027	0.883	91.8	4.07E 02
12.00	1.00	0.58	2.95	1.72	56.61	1.55	0.79	0.61	0.239	0.473	0.085	0.223	0.037	1.057	91.9	4.08E 02
14.00	1.33	0.78	3.28	1.91	56.61	1.79	0.91	0.70	0.318	0.547	0.113	0.223	0.049	1.250	91.8	4.07E 02
16.00	1.66	0.97	3.61	2.10	56.61	2.03	1.03	0.79	0.411	0.621	0.145	0.223	0.063	1.462	91.6	4.06E 02
18.00	1.99	1.16	3.94	2.30	56.61	2.27	1.16	0.88	0.515	0.695	0.182	0.223	0.078	1.693	91.4	4.05E 02
20.00	2.32	1.35	4.26	2.49	56.61	2.51	1.28	0.98	0.631	0.770	0.224	0.223	0.095	1.943	91.1	4.04E 02

V IN= 14.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.44	0.26	2.57	1.50	52.47	1.18	0.65	0.50	0.138	0.392	0.054	0.289	0.025	0.898	91.8	4.07E 02
12.00	0.74	0.43	2.87	1.67	52.47	1.38	0.77	0.58	0.190	0.460	0.074	0.289	0.034	1.047	92.0	4.08E 02
14.00	1.04	0.61	3.17	1.85	52.47	1.59	0.88	0.66	0.252	0.529	0.098	0.289	0.044	1.212	92.0	4.08E 02
16.00	1.34	0.78	3.47	2.02	52.47	1.80	1.00	0.74	0.323	0.599	0.126	0.289	0.055	1.392	92.0	4.08E 02
18.00	1.64	0.96	3.77	2.20	52.47	2.01	1.12	0.83	0.404	0.669	0.157	0.289	0.068	1.587	91.9	4.08E 02
20.00	1.94	1.13	4.07	2.37	52.47	2.22	1.23	0.91	0.494	0.740	0.192	0.289	0.083	1.798	91.6	4.07E 02

V IN= 16.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.25	0.15	2.54	1.48	48.89	1.08	0.64	0.49	0.117	0.387	0.049	0.356	0.024	0.933	91.5	4.06E 02
12.00	0.53	0.31	2.82	1.65	48.89	1.26	0.75	0.56	0.159	0.451	0.067	0.356	0.032	1.064	91.9	4.07E 02
14.00	0.81	0.47	3.10	1.81	48.89	1.44	0.86	0.63	0.209	0.517	0.088	0.356	0.040	1.209	92.0	4.08E 02
16.00	1.09	0.64	3.38	1.97	48.89	1.63	0.97	0.71	0.266	0.583	0.112	0.356	0.050	1.368	92.1	4.09E 02
18.00	1.37	0.80	3.66	2.14	48.89	1.82	1.08	0.78	0.331	0.651	0.140	0.356	0.061	1.539	92.1	4.09E 02
20.00	1.65	0.96	3.94	2.30	48.89	2.01	1.20	0.86	0.403	0.719	0.170	0.356	0.074	1.722	92.1	4.08E 02

EVALUATION FOR DESIGN NO. 2

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AWG PRI.	PRI.IND MH	NS	AWG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
26	55715	A-715152	125.	46	13	0.327	79	17	0.965	0.310	1	6.098	3.551	4.770	1.641	1.414

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR PRI.WIRE LENGTH,M	REACTOR PRI.WIRE RES,OHMS	REACTOR SEC.WIRE LENGTH,M	REACTOR SEC.WIRE RES,OHMS
1.250E-04	1.270E-01	7.519E-04	5.770E-02	1.440E-02	2.340E-01	2.654E 00	1.776E-02	4.558E 00	7.702E-02

V IN= 6.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	2.20	1.28	3.33	1.94	74.13	2.40	0.82	0.71	0.575	0.495	0.155	0.050	0.051	1.325	88.3	3.77E 02
12.00	2.75	1.60	3.89	2.26	74.13	2.87	0.99	0.85	0.824	0.593	0.222	0.050	0.073	1.761	87.2	3.73E 02
14.00	3.31	1.92	4.44	2.58	74.13	3.35	1.15	0.99	1.119	0.691	0.301	0.050	0.098	2.259	86.1	3.68E 02
16.00	3.86	2.25	4.99	2.91	74.13	3.82	1.31	1.13	1.459	0.789	0.392	0.050	0.128	2.818	85.0	3.63E 02
18.00	4.41	2.57	5.54	3.23	74.13	4.30	1.48	1.27	1.845	0.887	0.496	0.050	0.162	3.439	84.0	3.59E 02
20.00	4.96	2.89	6.10	3.55	74.13	4.77	1.64	1.41	2.276	0.985	0.612	0.050	0.200	4.122	82.9	3.54E 02

V IN= 8.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	1.46	0.85	2.90	1.69	67.17	1.82	0.74	0.61	0.331	0.444	0.101	0.097	0.037	1.010	90.8	3.88E 02
12.00	1.90	1.10	3.33	1.94	67.17	2.17	0.88	0.73	0.471	0.530	0.144	0.097	0.053	1.295	90.3	3.86E 02
14.00	2.33	1.36	3.77	2.20	67.17	2.52	1.03	0.85	0.637	0.616	0.194	0.097	0.072	1.617	89.6	3.83E 02
16.00	2.77	1.61	4.21	2.45	67.17	2.88	1.17	0.96	0.829	0.703	0.253	0.097	0.093	1.975	89.0	3.80E 02
18.00	3.21	1.87	4.64	2.70	67.17	3.23	1.32	1.08	1.046	0.790	0.319	0.097	0.117	2.369	88.4	3.78E 02
20.00	3.64	2.12	5.08	2.96	67.17	3.59	1.46	1.20	1.288	0.877	0.393	0.097	0.144	2.799	87.7	3.75E 02

V IN= 10.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	1.01	0.59	2.70	1.57	61.41	1.50	0.69	0.55	0.226	0.416	0.077	0.153	0.031	0.903	91.7	3.92E 02
12.00	1.38	0.80	3.07	1.79	61.41	1.79	0.82	0.65	0.319	0.494	0.109	0.153	0.043	1.118	91.5	3.91E 02
14.00	1.75	1.02	3.44	2.00	61.41	2.07	0.96	0.76	0.429	0.573	0.146	0.153	0.057	1.358	91.2	3.90E 02
16.00	2.12	1.24	3.81	2.22	61.41	2.36	1.09	0.86	0.555	0.653	0.190	0.153	0.074	1.624	90.8	3.88E 02
18.00	2.49	1.45	4.18	2.44	61.41	2.64	1.22	0.96	0.699	0.732	0.239	0.153	0.093	1.915	90.4	3.86E 02
20.00	2.86	1.67	4.55	2.65	61.41	2.93	1.35	1.07	0.859	0.812	0.294	0.153	0.114	2.231	90.0	3.85E 02

V IN= 12.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	0.70	0.41	2.60	1.51	56.56	1.31	0.67	0.52	0.171	0.400	0.064	0.214	0.027	0.876	91.9	3.93E 02
12.00	1.03	0.60	2.93	1.70	56.56	1.54	0.79	0.61	0.238	0.472	0.090	0.214	0.037	1.051	91.9	3.93E 02
14.00	1.36	0.79	3.26	1.90	56.56	1.78	0.91	0.70	0.318	0.546	0.120	0.214	0.049	1.247	91.8	3.92E 02
16.00	1.68	0.98	3.59	2.09	56.56	2.02	1.03	0.79	0.410	0.620	0.155	0.214	0.062	1.461	91.6	3.92E 02
18.00	2.01	1.17	3.92	2.28	56.56	2.27	1.16	0.88	0.514	0.694	0.195	0.214	0.078	1.695	91.4	3.91E 02
20.00	2.34	1.36	4.25	2.47	56.56	2.51	1.28	0.97	0.631	0.769	0.239	0.214	0.095	1.947	91.1	3.90E 02

V IN= 14.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	0.46	0.27	2.55	1.48	52.42	1.17	0.65	0.50	0.138	0.390	0.057	0.277	0.025	0.887	91.9	3.93E 02
12.00	0.76	0.44	2.85	1.66	52.42	1.39	0.76	0.58	0.190	0.458	0.079	0.277	0.033	1.037	92.0	3.93E 02
14.00	1.06	0.62	3.15	1.83	52.42	1.59	0.88	0.66	0.251	0.528	0.104	0.277	0.043	1.204	92.1	3.94E 02
16.00	1.36	0.79	3.45	2.01	52.42	1.80	1.00	0.74	0.323	0.598	0.134	0.277	0.055	1.386	92.0	3.93E 02
18.00	1.67	0.97	3.75	2.18	52.42	2.01	1.11	0.82	0.403	0.668	0.167	0.277	0.068	1.583	91.9	3.93E 02
20.00	1.97	1.15	4.05	2.36	52.42	2.22	1.23	0.91	0.493	0.739	0.205	0.277	0.082	1.796	91.8	3.92E 02

V IN= 16.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	****** TRANS	****** DIODE	LOSSES WIRE	(WATTS) CORE	****** CAPAC	****** TOTAL	EFF %	EFF/MASS %/KG
10.00	0.28	0.16	2.52	1.47	48.85	1.08	0.64	0.49	0.116	0.385	0.052	0.341	0.024	0.918	91.6	3.91E 02
12.00	0.56	0.33	2.80	1.63	48.85	1.26	0.75	0.56	0.158	0.449	0.071	0.341	0.031	1.051	91.9	3.93E 02
14.00	0.84	0.49	3.08	1.79	48.85	1.44	0.86	0.63	0.208	0.515	0.094	0.341	0.040	1.197	92.1	3.94E 02
16.00	1.12	0.65	3.36	1.96	48.85	1.63	0.97	0.70	0.265	0.582	0.120	0.341	0.050	1.357	92.2	3.94E 02
18.00	1.40	0.81	3.64	2.12	48.85	1.82	1.08	0.78	0.330	0.650	0.149	0.341	0.061	1.530	92.2	3.94E 02
20.00	1.68	0.98	3.92	2.28	48.85	2.01	1.20	0.86	0.403	0.718	0.182	0.341	0.074	1.716	92.1	3.94E 02

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EVALUATION FOR DESIGN NO. 3

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AWG PRI.	PRI.IND MH	NS	AWG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
27	55109	A-109156	125.	53	13	0.444	91	17	1.310	0.284	1	5.948	3.464	4.766	1.640	1.412

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR PRI.WIRE LENGTH,M	REACTOR PRI.WIRE RES,OHMS	REACTOR SEC.WIRE LENGTH,M	REACTOR SEC.WIRE RES,OHMS
1.440E-04	1.430E-01	9.480E-04	6.230E-02	1.490E-02	3.016E-01	3.302E 00	2.210E-02	5.669E 00	9.579E-02

V IN= 6.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	2.35	1.37	3.18	1.85	74.13	2.39	0.82	0.71	0.571	0.493	0.191	0.030	0.050	1.336	88.2	2.93E 02
12.00	2.90	1.69	3.74	2.18	74.13	2.86	0.99	0.85	0.821	0.591	0.274	0.030	0.072	1.788	87.0	2.89E 02
14.00	3.45	2.01	4.29	2.50	74.13	3.34	1.15	0.99	1.115	0.689	0.373	0.030	0.098	2.306	85.9	2.85E 02
16.00	4.01	2.33	4.84	2.82	74.13	3.82	1.31	1.13	1.456	0.788	0.487	0.030	0.128	2.888	84.7	2.81E 02
18.00	4.56	2.66	5.39	3.14	74.13	4.29	1.48	1.27	1.841	0.886	0.616	0.030	0.162	3.534	83.6	2.77E 02
20.00	5.11	2.98	5.95	3.46	74.13	4.77	1.64	1.41	2.272	0.984	0.760	0.030	0.200	4.245	82.5	2.74E 02

V IN= 8.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	1.65	0.96	2.71	1.58	67.18	1.80	0.73	0.60	0.325	0.441	0.124	0.057	0.037	0.984	91.0	3.02E 02
12.00	2.09	1.22	3.14	1.83	67.18	2.16	0.88	0.72	0.466	0.527	0.177	0.057	0.052	1.279	90.4	3.00E 02
14.00	2.52	1.47	3.58	2.09	67.18	2.51	1.02	0.84	0.632	0.614	0.240	0.057	0.071	1.614	89.7	2.97E 02
16.00	2.96	1.72	4.02	2.34	67.18	2.87	1.17	0.96	0.823	0.701	0.313	0.057	0.092	1.986	89.0	2.95E 02
18.00	3.39	1.98	4.45	2.59	67.18	3.23	1.31	1.08	1.040	0.788	0.395	0.057	0.116	2.397	88.2	2.93E 02
20.00	3.83	2.23	4.89	2.85	67.18	3.58	1.46	1.20	1.283	0.875	0.487	0.057	0.143	2.845	87.5	2.90E 02

V IN= 10.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	1.23	0.72	2.48	1.44	61.42	1.48	0.68	0.54	0.219	0.410	0.093	0.090	0.029	0.841	92.2	3.06E 02
12.00	1.60	0.93	2.85	1.66	61.42	1.77	0.82	0.64	0.312	0.489	0.133	0.090	0.041	1.065	91.8	3.05E 02
14.00	1.97	1.15	3.22	1.87	61.42	2.05	0.95	0.75	0.422	0.569	0.179	0.090	0.056	1.315	91.4	3.03E 02
16.00	2.34	1.37	3.59	2.09	61.42	2.34	1.08	0.85	0.549	0.649	0.233	0.090	0.072	1.592	90.9	3.02E 02
18.00	2.72	1.58	3.96	2.31	61.42	2.63	1.21	0.96	0.692	0.729	0.294	0.090	0.091	1.895	90.5	3.00E 02
20.00	3.09	1.80	4.33	2.52	61.42	2.92	1.35	1.06	0.853	0.809	0.362	0.090	0.112	2.226	90.0	2.98E 02

V IN= 12.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.95	0.55	2.35	1.37	56.57	1.28	0.65	0.50	0.163	0.391	0.077	0.125	0.025	0.780	92.8	3.08E 02
12.00	1.28	0.74	2.68	1.56	56.57	1.52	0.77	0.59	0.230	0.465	0.108	0.125	0.035	0.963	92.6	3.07E 02
14.00	1.61	0.94	3.01	1.75	56.57	1.76	0.90	0.68	0.310	0.539	0.146	0.125	0.047	1.167	92.3	3.06E 02
16.00	1.94	1.13	3.34	1.94	56.57	2.01	1.02	0.78	0.402	0.614	0.189	0.125	0.060	1.390	92.0	3.05E 02
18.00	2.26	1.32	3.67	2.13	56.57	2.25	1.15	0.87	0.507	0.689	0.238	0.125	0.076	1.634	91.7	3.04E 02
20.00	2.59	1.51	3.99	2.33	56.57	2.50	1.27	0.96	0.623	0.764	0.293	0.125	0.093	1.898	91.3	3.03E 02

V IN= 14.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.74	0.43	2.27	1.32	52.43	1.14	0.63	0.47	0.129	0.378	0.066	0.161	0.022	0.757	93.0	3.08E 02
12.00	1.04	0.60	2.57	1.50	52.43	1.35	0.75	0.55	0.181	0.448	0.093	0.161	0.031	0.914	92.9	3.08E 02
14.00	1.34	0.78	2.87	1.67	52.43	1.56	0.86	0.64	0.243	0.519	0.125	0.161	0.041	1.088	92.8	3.08E 02
16.00	1.64	0.95	3.17	1.85	52.43	1.77	0.98	0.72	0.314	0.590	0.162	0.161	0.052	1.279	92.6	3.07E 02
18.00	1.94	1.13	3.47	2.02	52.43	1.99	1.10	0.81	0.394	0.661	0.203	0.161	0.065	1.485	92.4	3.06E 02
20.00	2.24	1.31	3.77	2.20	52.43	2.20	1.22	0.89	0.485	0.733	0.250	0.161	0.080	1.708	92.1	3.05E 02

V IN= 16.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	LOSSES (WATTS) TRANS	DIODE	WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.57	0.33	2.22	1.29	48.85	1.03	0.62	0.45	0.107	0.369	0.060	0.198	0.021	0.754	93.0	3.08E 02
12.00	0.85	0.50	2.50	1.46	48.85	1.22	0.73	0.53	0.149	0.436	0.083	0.198	0.028	0.894	93.1	3.09E 02
14.00	1.13	0.66	2.78	1.62	48.85	1.41	0.84	0.60	0.198	0.504	0.111	0.198	0.036	1.047	93.0	3.09E 02
16.00	1.41	0.82	3.06	1.78	48.85	1.60	0.95	0.68	0.256	0.572	0.144	0.198	0.046	1.215	92.9	3.08E 02
18.00	1.69	0.99	3.34	1.95	48.85	1.79	1.07	0.76	0.321	0.640	0.180	0.198	0.058	1.396	92.8	3.08E 02
20.00	1.97	1.15	3.62	2.11	48.85	1.98	1.18	0.84	0.393	0.709	0.221	0.198	0.070	1.591	92.6	3.07E 02

****

5.8 SAMPLE PROGRAM #7 -- PROGRAM DC2DC

It can be seen from the output of Sample Program #6 that core size #24 is the smallest core in the core catalog which will meet the design constraints when used in a stack of two cores or less. Sample Program #7 uses Procedure DSN2 of Program DC2DC to attempt to produce a design using core size #23 with a relative permeability of 125.0 in a three-core stack. All other design requirements remain the same as in Sample Program #6.

5.8.1 Control Cards--Sample Program #7 (Program DC2DC)

The Control Cards for Sample Program #7 are shown below. Sections 3.6-3.10 give instructions for preparing these cards.

```
 F02UD NP DSN2      8  .74     1    2.    2.
  24.   6.  16.  10.  20.  10.  .01  .011  .36   .4    1     2 5.067E-07 HEAV  1 1
  1.0  10.  .60   .1
   23 125.    3
0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.8.2 Results of Sample Program #7--Program DC2DC

The results of Sample Program #7 are shown below. It can be seen from the print out that core size #23 with a relative permeability of 125.0 used in a three core stack will not meet the design requirement regarding maximum winding factor. Thus, the design is rejected by the program. The actual computed winding factor of 0.46 is shown on the program output.

FO2UD--CONSTANT FREQ TWO-WINDING VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	I COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	NO. CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	3

WIRE TYPE= HEAV MIN. PRI. STRANDS= 1 MIN. SEC. STRANDS= 1 RECIPROCAL CURRENT DENSITY= 5.067E-07 SQ.M/AMP

RESTRICTING THE MAX. DUTY CYCLE= 0.740

DESIGN EVALUATION

EVALUATION FOR DESIGN NO. 0

CORE ENTERED IS NOT WINDABLE—WF= 0.460

5.9 SAMPLE PROGRAM #8 -- PROGRAM DC2DC

Sample Program #8 uses Procedure DSN2 of Program DC2DC to attempt to produce a design for the same core size, relative permeability and stack height as used in Sample Program #7. In Sample Program #7, the reactor design produced was rejected because the winding factor of 0.46 was greater than the maximum winding factor of 0.40. Sample Program #8 uses the same design requirement data as Sample Program #7 except that the Reciprocal Current Density Specification is lowered to $3.8 * 10^{-7}$ m^2/ampere ($\simeq$750 circular mils/ampere) to allow smaller wire to be used. Also, it is desired that a minimum of two strands of wire be used for the primary winding. A minimum of one strand of wire is to be used for the secondary winding.

5.9.1 Control Cards--Sample Program #8 (Program DC2DC)

The Control Cards for Sample Program #8 are shown below. Sections 3.6-3.10 give instructions for preparing these cards.

```
FQ2UD NP DSN2      8  .74    1   2.   2.
 24.   6.  16.  10.  20.  10.  .01 .011  .36   .4    1     2 3.800E-07 HEAV  2 1
  1.0  10.  .60   .1
   23 125.    3
0
```

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
11111111111111111111111111111111111111111111111111111111111111111111111111111111
```

5.9.2 Results of Sample Program #8--Program DC2DC

The results of Sample Program #8 are given on the following page. Lowering the Reciprocal Current Density Specification allowed Program DC2DC to use wire of smaller cross-sectional area in the windings. Thus, the winding factor was lowered to 0.346 which is less than the specified maximum winding factor. Therefore, the design was acceptable. The smaller wire area has, however, caused a slight increase in the winding resistances over the designs evaluated in Sample Program #6.

FO2UD--CONSTANT FREQ TWO-WINDING VOLTAGE STEP-UP/CURRENT STEP-UP CONVERTER DESIGN

I/O IN VOLTS, AMPERES, WATTS, TESLAS, MICROSEC, KHZ, OHMS

CONVERTER SPECIFICATIONS

V OUT	V IN MIN	V IN MAX	P OUT MIN	P OUT MAX	V SAT	I COLL.	V DIODE	CAP ESR	CONV FREQ	B RESIDUAL	B MIN	B MAX	WIND FACTOR	NO. CORES
24.0	6.0	16.0	10.0	20.0	1.00	10.00	0.60	0.10	10.0	1.000E-02	1.100E-02	3.600E-01	0.40	3

WIRE TYPE= HEAVY MIN. PRI. STRANDS= 2 MIN. SEC. STRANDS= 1 RECIPROCAL CURRENT DENSITY= 3.800E-07 SQ.M/AMP

RESTRICTING THE MAX. DUTY CYCLE= 0.740

DESIGN EVALUATION

EVALUATION FOR DESIGN NO. 0

CORRECT WIRE SIZE NOT AVAILABLE OR MULTIPLE STRANDS SPECIFIED, 2 STRANDS USED FOR PRIMARY WINDING

SIZE NO.	MAGNETICS	ARNOLD	MU	NP	AWG PRI.	PRI.IND MH	NS	AWG SEC.	SEC.IND MH	WDG FAC	OP MODE	IBP MAX	IBS MAX	IPRMS MAX	ISRMS MAX	ICRMS MAX
23	55324	A-324117	125.	33	17	0.387	57	19	1.156	0.346	1	6.017	3.484	4.772	1.637	1.409

REACTOR AREA SQ.M	PATH LENGTH M	CORE WN.AREA SQ.M	REACTOR LENGTH/TURN M	STACK HEIGHT M	REACTOR MASS KG	REACTOR PRI.WIRE LENGTH,M	REACTOR PRI.WIRE RES,OHMS	REACTOR SEC.WIRE LENGTH,M	REACTOR SEC.WIRE RES,OHMS
2.034E-04	8.980E-02	3.644E-04	8.860E-02	3.390E-02	2.368E-01	2.924E 00	2.470E-02	5.050E 00	1.360E-01

V IN= 6.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	2.29	1.33	3.25	1.88	74.02	2.39	0.82	0.71	0.573	0.493	0.233	0.037	0.050	1.387	87.9	3.71E 02
12.00	2.85	1.65	3.80	2.20	74.02	2.87	0.98	0.85	0.823	0.591	0.335	0.037	0.072	1.858	86.6	3.66E 02
14.00	3.40	1.97	4.36	2.52	74.02	3.34	1.15	0.99	1.118	0.688	0.455	0.037	0.098	2.397	85.4	3.60E 02
16.00	3.95	2.29	4.91	2.84	74.02	3.82	1.31	1.13	1.459	0.786	0.594	0.037	0.127	3.004	84.2	3.55E 02
18.00	4.51	2.61	5.46	3.16	74.02	4.30	1.47	1.27	1.845	0.884	0.751	0.037	0.161	3.679	83.0	3.51E 02
20.00	5.06	2.93	6.02	3.48	74.02	4.77	1.64	1.41	2.277	0.982	0.927	0.037	0.198	4.422	81.9	3.46E 02

V IN= 8.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	1.58	0.91	2.79	1.62	67.05	1.81	0.74	0.61	0.328	0.441	0.155	0.072	0.037	1.032	90.6	3.83E 02
12.00	2.02	1.17	3.23	1.87	67.05	2.16	0.88	0.72	0.469	0.527	0.221	0.072	0.052	1.341	89.9	3.80E 02
14.00	2.45	1.42	3.66	2.12	67.05	2.52	1.02	0.84	0.635	0.614	0.299	0.072	0.071	1.690	89.2	3.77E 02
16.00	2.89	1.67	4.10	2.37	67.05	2.88	1.17	0.96	0.827	0.700	0.390	0.072	0.092	2.081	88.5	3.74E 02
18.00	3.33	1.93	4.54	2.63	67.05	3.23	1.31	1.08	1.044	0.787	0.492	0.072	0.116	2.511	87.8	3.71E 02
20.00	3.76	2.18	4.97	2.88	67.05	3.59	1.46	1.19	1.287	0.874	0.606	0.072	0.143	2.982	87.0	3.67E 02

V IN= 10.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	1.15	0.66	2.57	1.49	61.28	1.49	0.69	0.54	0.222	0.411	0.119	0.113	0.030	0.895	91.8	3.88E 02
12.00	1.52	0.88	2.94	1.70	61.28	1.78	0.82	0.65	0.315	0.490	0.169	0.113	0.042	1.129	91.4	3.86E 02
14.00	1.89	1.09	3.31	1.92	61.28	2.06	0.95	0.75	0.425	0.569	0.228	0.113	0.056	1.391	91.0	3.84E 02
16.00	2.26	1.31	3.69	2.13	61.28	2.35	1.08	0.85	0.552	0.649	0.296	0.113	0.073	1.682	90.5	3.82E 02
18.00	2.63	1.52	4.06	2.35	61.28	2.64	1.21	0.96	0.696	0.729	0.373	0.113	0.091	2.002	90.0	3.80E 02
20.00	3.01	1.74	4.43	2.56	61.28	2.93	1.35	1.06	0.857	0.808	0.459	0.113	0.112	2.349	89.5	3.78E 02

V IN= 12.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.85	0.49	2.45	1.42	56.42	1.29	0.66	0.51	0.166	0.393	0.099	0.158	0.026	0.842	92.2	3.89E 02
12.00	1.18	0.68	2.78	1.61	56.42	1.53	0.78	0.60	0.234	0.467	0.140	0.158	0.035	1.033	92.1	3.89E 02
14.00	1.51	0.87	3.11	1.80	56.42	1.77	0.90	0.69	0.314	0.541	0.188	0.158	0.047	1.247	91.8	3.88E 02
16.00	1.84	1.07	3.44	1.99	56.42	2.02	1.03	0.78	0.406	0.615	0.243	0.158	0.061	1.483	91.5	3.86E 02
18.00	2.17	1.26	3.77	2.18	56.42	2.26	1.15	0.87	0.511	0.690	0.306	0.158	0.076	1.740	91.2	3.85E 02
20.00	2.50	1.45	4.10	2.38	56.42	2.51	1.27	0.96	0.628	0.765	0.376	0.158	0.093	2.019	90.8	3.84E 02

V IN= 14.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.63	0.37	2.39	1.38	52.28	1.15	0.64	0.48	0.132	0.382	0.088	0.204	0.023	0.829	92.3	3.90E 02
12.00	0.93	0.54	2.69	1.56	52.28	1.36	0.75	0.56	0.185	0.451	0.122	0.204	0.031	0.993	92.4	3.90E 02
14.00	1.23	0.71	2.99	1.73	52.28	1.57	0.87	0.64	0.246	0.521	0.163	0.204	0.041	1.176	92.3	3.90E 02
16.00	1.54	0.89	3.29	1.90	52.28	1.78	0.99	0.73	0.318	0.592	0.211	0.204	0.053	1.377	92.1	3.89E 02
18.00	1.84	1.06	3.59	2.08	52.28	2.00	1.10	0.81	0.399	0.663	0.264	0.204	0.066	1.595	91.9	3.88E 02
20.00	2.14	1.24	3.89	2.25	52.28	2.21	1.22	0.90	0.489	0.734	0.324	0.204	0.080	1.831	91.6	3.87E 02

V IN= 16.0

PO WATTS	IAP AMPS	IAS AMPS	IBP AMPS	IBS AMPS	T ON USEC	IPRMS AMPS	ISRMS AMPS	ICRMS AMPS	TRANS	DIODE	LOSSES (WATTS) WIRE	CORE	CAPAC	TOTAL	EFF %	EFF/MASS %/KG
10.00	0.46	0.27	2.35	1.36	48.70	1.05	0.62	0.46	0.110	0.374	0.080	0.250	0.022	0.837	92.3	3.90E 02
12.00	0.74	0.43	2.63	1.52	48.70	1.23	0.73	0.54	0.152	0.440	0.111	0.250	0.029	0.982	92.4	3.91E 02
14.00	1.02	0.59	2.91	1.68	48.70	1.42	0.85	0.61	0.202	0.507	0.147	0.250	0.037	1.144	92.4	3.90E 02
16.00	1.30	0.75	3.19	1.85	48.70	1.61	0.96	0.69	0.260	0.575	0.189	0.250	0.047	1.321	92.4	3.90E 02
18.00	1.58	0.92	3.47	2.01	48.70	1.80	1.07	0.76	0.325	0.643	0.236	0.250	0.059	1.513	92.2	3.89E 02
20.00	1.86	1.08	3.75	2.17	48.70	1.99	1.19	0.84	0.398	0.711	0.289	0.250	0.071	1.719	92.1	3.87E 02

PART II -- THE DATA BASE

THE DATA BASE

The first block of data read by the programs forms the data base for the execution of design and evaluation tasks. The data base is a group of cards (records) divided into two sections. The first section, the core catalog, contains information on the magnetic cores and includes catalog numbers, dimensional data, relative permeability and loss coefficient information. The second section consists of a table of wire data containing the cross-sectional area and resistivity information on the available sizes of magnet wire. Usually, once the data base has been constructed, the information in it will not be changed often. Thus, it may be advantageous to store the data base on magnetic disk or tape. Additions to the core catalog or the wire table may be made at any time without having to construct an entirely new data base.

THE CORE CATALOG

The core catalog cards list the necessary data on the magnetic cores and are the first cards read by the program. The core catalog cards are ordered as shown in Figure 31.

6.1 HEADING CARDS

The first two cards in the core catalog are used to generate headings for the output. They are the Title Card and the Manufacturers' Names Card.

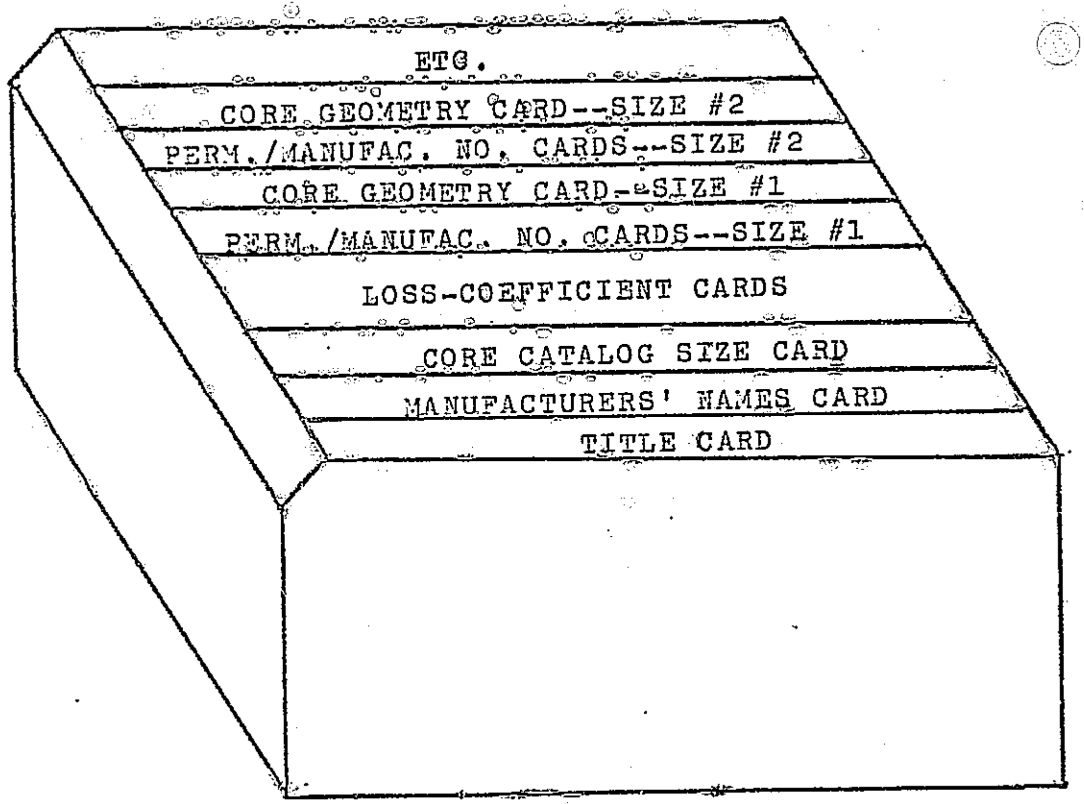

Figure 31. Order of the Core Catalog Cards

6.1.1 Title Card

The Title Card is read as a block of twenty consecutive A4 formats to provide for a user specified title up to eighty characters in length. It may be used to list identifying information such as manufacturers' names, date of catalog and etc. This information is used as a heading for the catalog list (see Section 3.1.2). A sample Title Card is shown in Figure 32.

6.1.2 Manufacturers' Names Card

The Manufacturers' Names Card is read as two A10 formats. Thus, two manufacturers' names may be used, with ten spaces allocated for each name. This information is used to provide headings for the lists of manufacturers' core catalog numbers which appear on the output. A sample Manufacturers' Names Card is shown in Figure 34. Figure 33 shows the format of the card.

6.2 CORE CATALOG SIZE CARD

The Core Catalog Size Card is read as two I5 formats. Columns 1-5 give the number of core sizes available and columns 6-10 give the number of relative permeability values available. (see Figure 35). These numbers are read in as integers and must be right justified. The catalog may contain up to forty core sizes and up to fifteen values of relative permeability. A sample Core Catalog Size Card is shown in Figure 36.

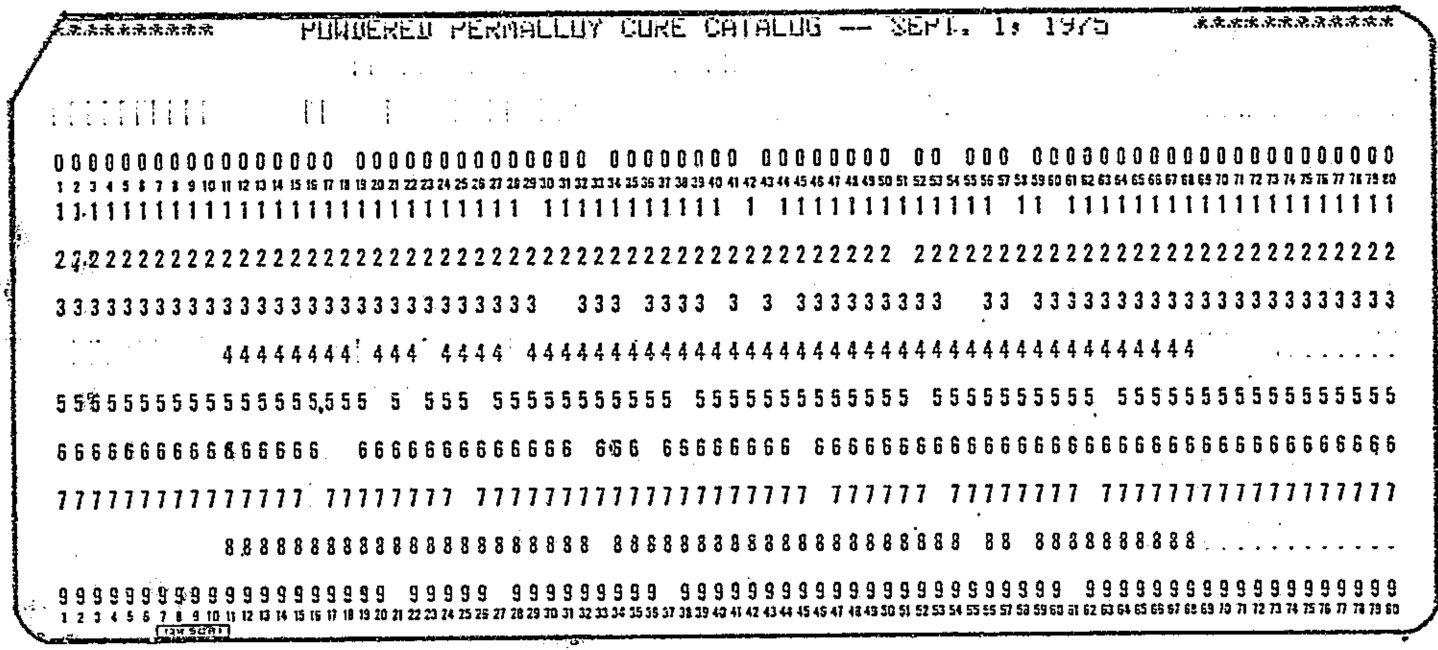

Figure 32. Example: Title Card

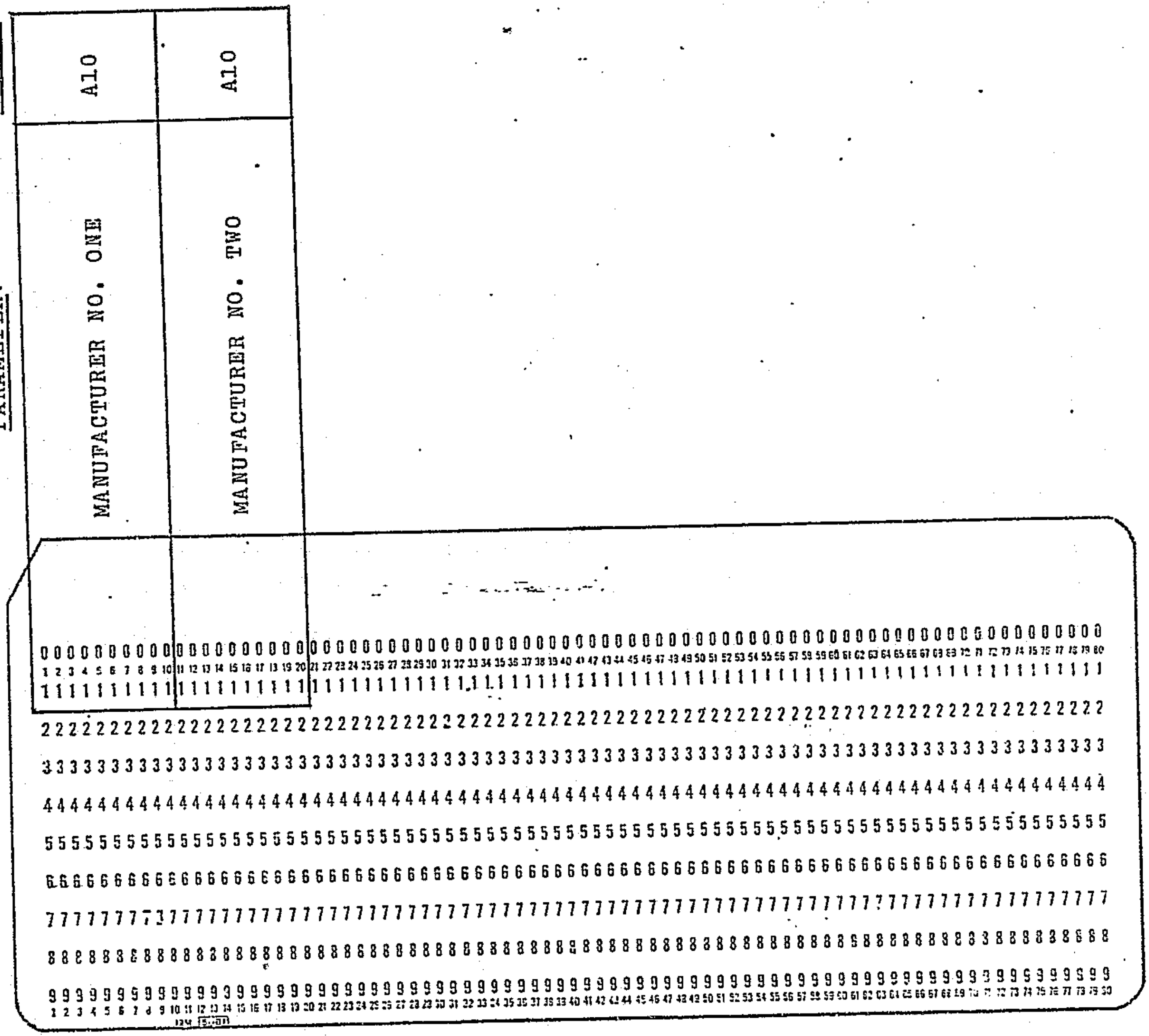

Figure 33. Manufacturers' Names Card

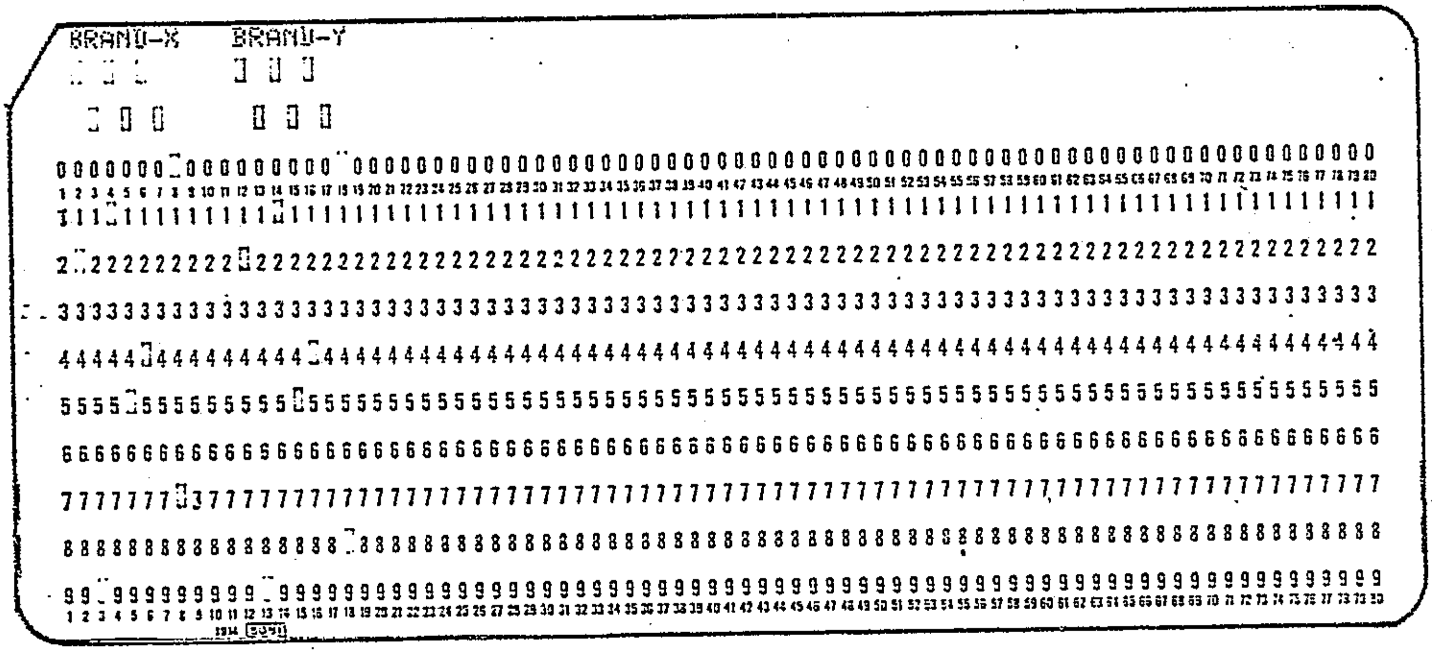

Figure 34. Example: Manufacturers'
Names Card

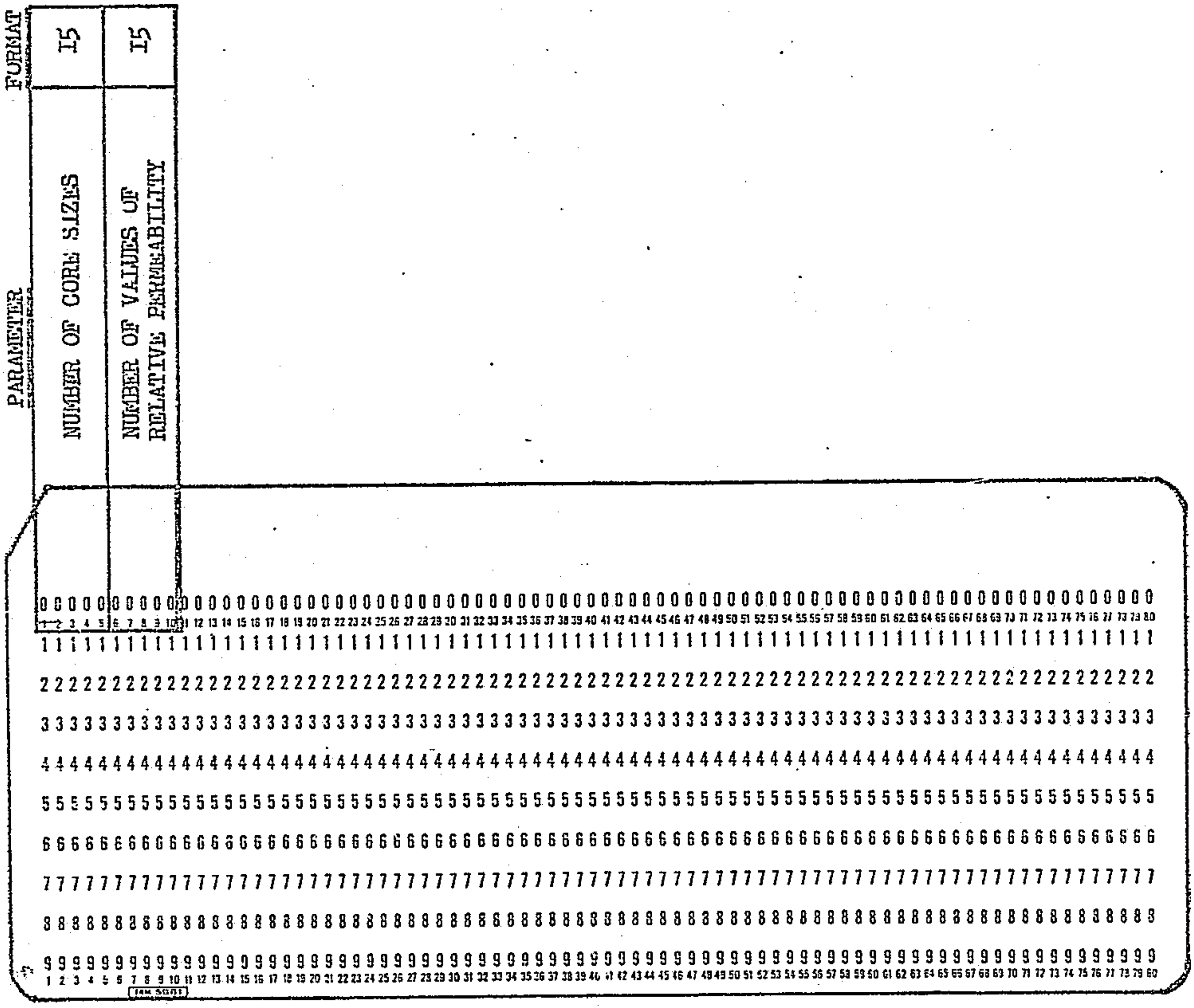

Figure 35. Core Catalog Size Card

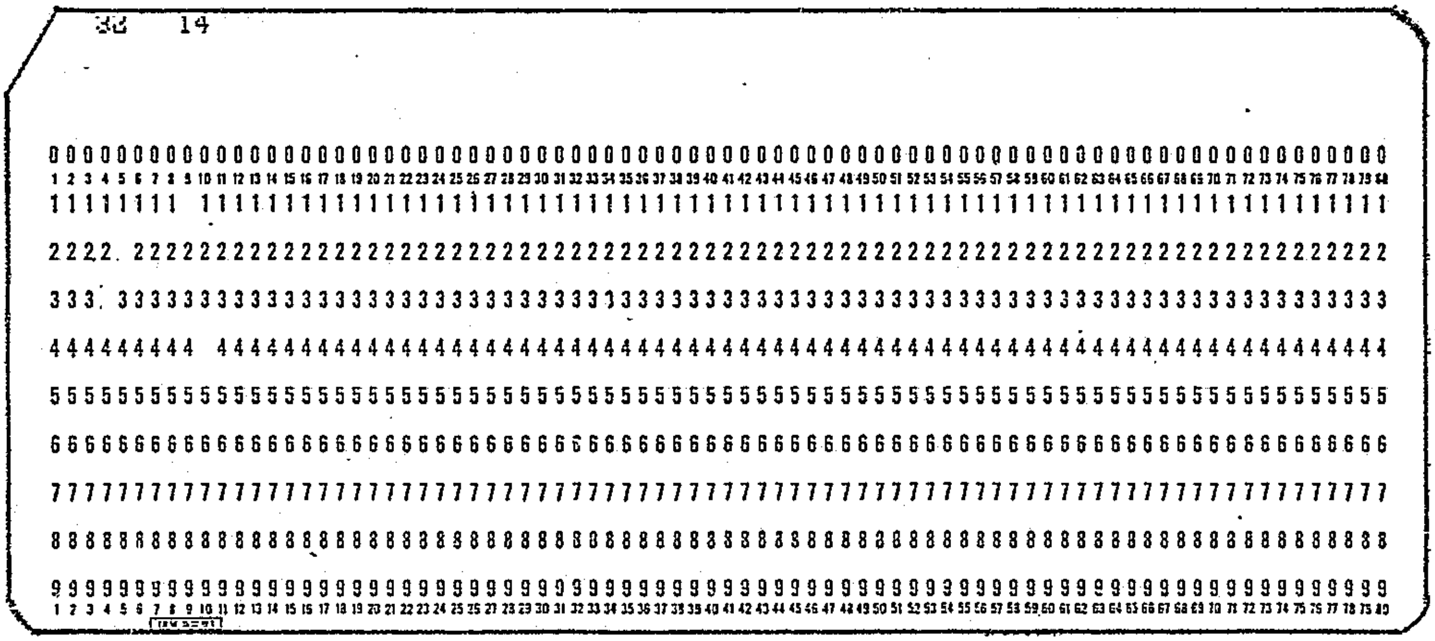

Figure 36. Example: Core Catalog Size Card

6.3 LOSS-COEFFICIENT CARDS

Core losses are estimated in the program by the use of Legg's equation [2] . One Loss-Coefficient Card should be used for each value of relative permeability in the core catalog. These cards should be arranged in order from lowest to highest value of relative permeability. Loss-Coefficient Cards are formated as follows (see also Figure 37). Figure 38 shows a sample Loss-Coeffiecint Card.

COLUMNS	FORMAT	PARAMETER
1-5	F5.0	Relative Permeability
6-15	E10.3	Eddy Current Loss Coefficient
16-25	E10.3	Hysteresis Loss Coefficient
26-35	E10.3	Residual Loss Coefficient

6.4 PERMEABILITY/CORE GEOMETRY CARDS

The Permeability/Core Geometry Cards consist of a subgroup of cards for each core size and relate the size number and relative permeability of a core to its specific catalog number(s) and actual dimensions. As a general rule, core manufacturers supply cores of several sizes and a core of a given size may be available in different values of relative permeability.

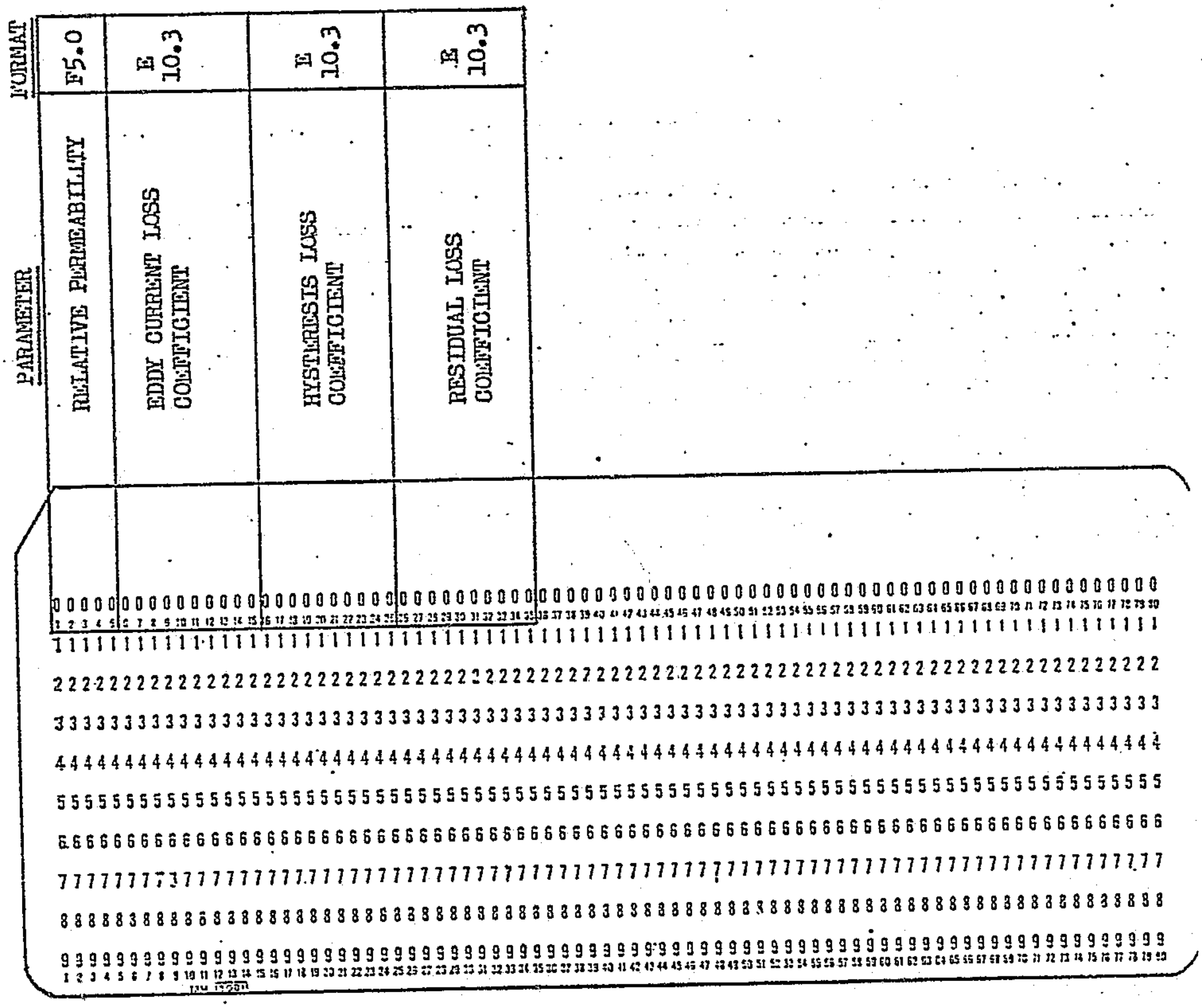

Figure 37. Loss-Coefficient Card

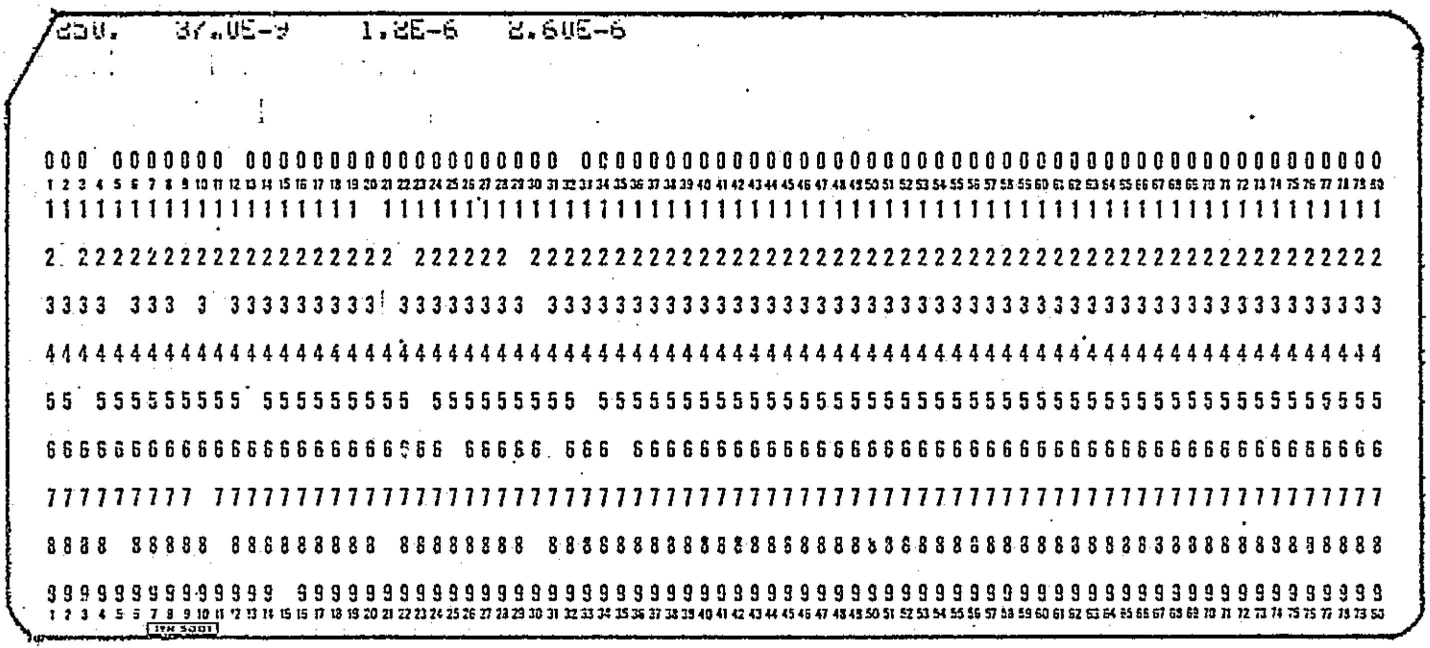

Figure 38. Example: Loss-Coefficient Card

Thus, in the instructions that follow, the "core size number" will uniquely identify a set of core dimensions and the pair (core size number, relative permeability) will uniquely identify one particular core. In order for the program to work most effectively, it is assumed that the core sizes are ordered by assending volume: i.e. the volume of core size number n is less than that of core size number n+1. If this assumption is violated when assembling the catalog, all designs generated will be valid. However, some possible design of lower size and mass may be "overlooked." Because the integer core size number is assigned by the program, new core sizes may be added to the catalog at any time. However, these additions should be made so as to maintain the ordering by volume of the core sizes. Presently, both programs DC1DC and DC2DC will allow up to forty core sizes and up to fifteen values of relative permeability. Thus, the core catalog may contain up to six hundred cores with each core being identified by up to two numbers from manufacturers' catalogs or other identifiers. The Permeability/Manufacturers' Numbers Card(s) and the Core Geometry Card give complete information on each core.

6.4.1 Permeability/Manufacturers' Numbers Card(s)

For a given core size, the Permeability/Manufacturers' Numbers Card(s) list the available values of relative permeability and their respective manufacturers' catalog numbers. The format of these cards is 4(F3.0,4A4). This format allows the user to list four cores on a single card with three spaces for the relative permeability and two groups of eight spaces for numbers from manufacturers' catalogs or other identifiers. The manufacturers' catalog numbers should be listed in the same order as the names on the Manufacturers' Names Card. Continue listing cores in the same fashion, using as many cards as needed, until all the cores for a particular core size have been listed. On the last card used, place a "1" in column 80 to indicate the end of the listing for that core size and that a Core Geometry Card is to be read next. The Permeability/Manufacturers' Numbers Card is formated as shown in the table below (see also Figure 39). A sample Permeability/Manufacturers' Numbers Card is shown in Figure 40.

COLUMN	FORMAT	PARAMETER
1-3	F3.0	Relative Permeability--Core A
4-11	A8	Catalog Number--Manufacturer 1
12-19	A8	Catalog Number--Manufacturer 2
20-22	F3.0	Relative Permeability--Core B
23-30	A8	Catalog Number--Manufacturer 1
31-38	A8	Catalog Number--Manufacturer 2
39-41	F3.0	Relative Permeability--Core C
42-49	A8	Catalog Number--Manufacturer 1
50-57	A8	Catalog Number--Manufacturer 2
58-60	F3.0	Relative Permeability--Core D
61-68	A8	Catalog Number--Manufacturer 1
69-76	A8	Catalog Number--Manufacturer 2

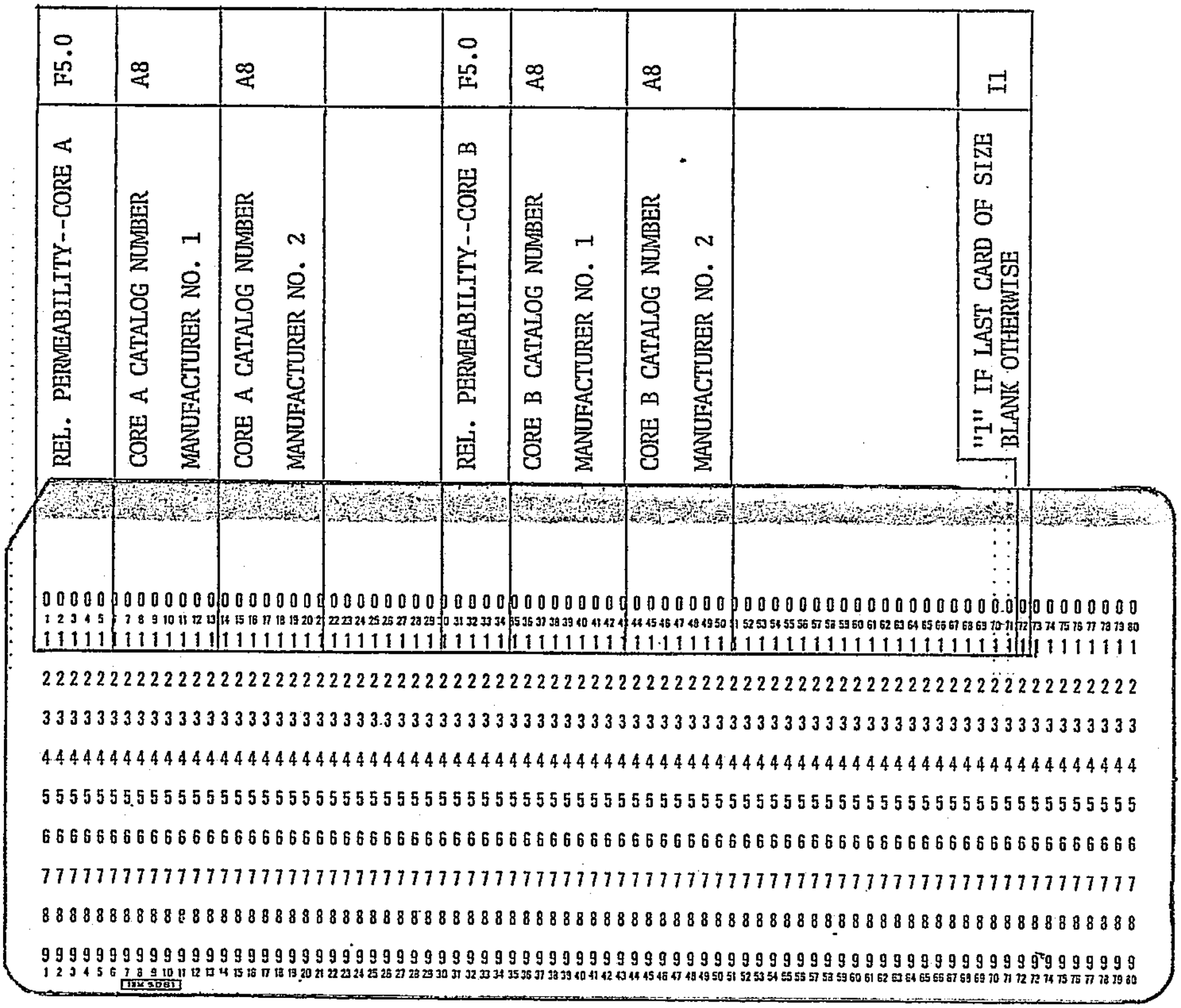

Figure 39. Permeability/Manufacturer's Numbers Card

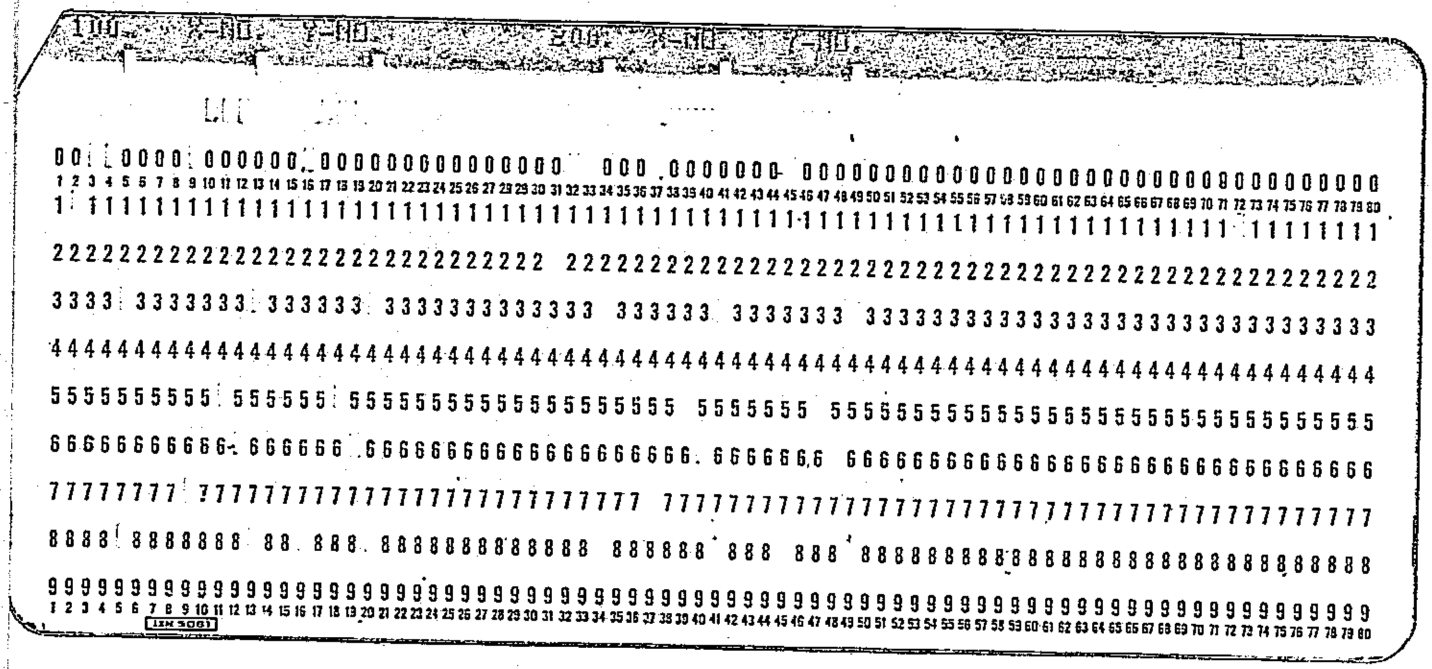

Figure 40. Example: Permeability/Manufacturers' Numbers Card

6.4.2 Core Geometry Card

A Core Geometry Card immediately follows the Permeability/ Manufacturers' Numbers Card(s) for each core size and gives the core cross-sectional area, mean magnetic path length, window area, length/turn of wire, height, and mass of the core size. These parameters are usually readily found in manufacturers' core catalogs. The length/turn of wire is usually given assuming a 40% winding factor. The format of the Core Geometry Card is as follows (see also Figure 41). A sample Core Geometry Card is shown in Figure 42.

COLUMN	FORMAT	PARAMETER
1-10	E10.3	Core Cross-Sectional Area (m^2)
11-20	E10.3	Mean Magnetic Path Length (m)
21-30	E10.3	Window Area (m^2)
31-40	E10.3	Length/Turn of Wire (m)
41-50	E10.3	Height (m)
51-60	E10.3	Mass (kg)

PARAMETER	FORMAT
CORE CROSS SECTIONAL AREA (m^2)	E10.3
MEAN MAGNETIC PATH LENGTH (m)	E10.3
WINDOW AREA (m^2)	E10.3
LENGTH/TURN OF WIRE (m)	E10.3
HEIGHT (m)	E10.3
MASS (kg)	E10.3

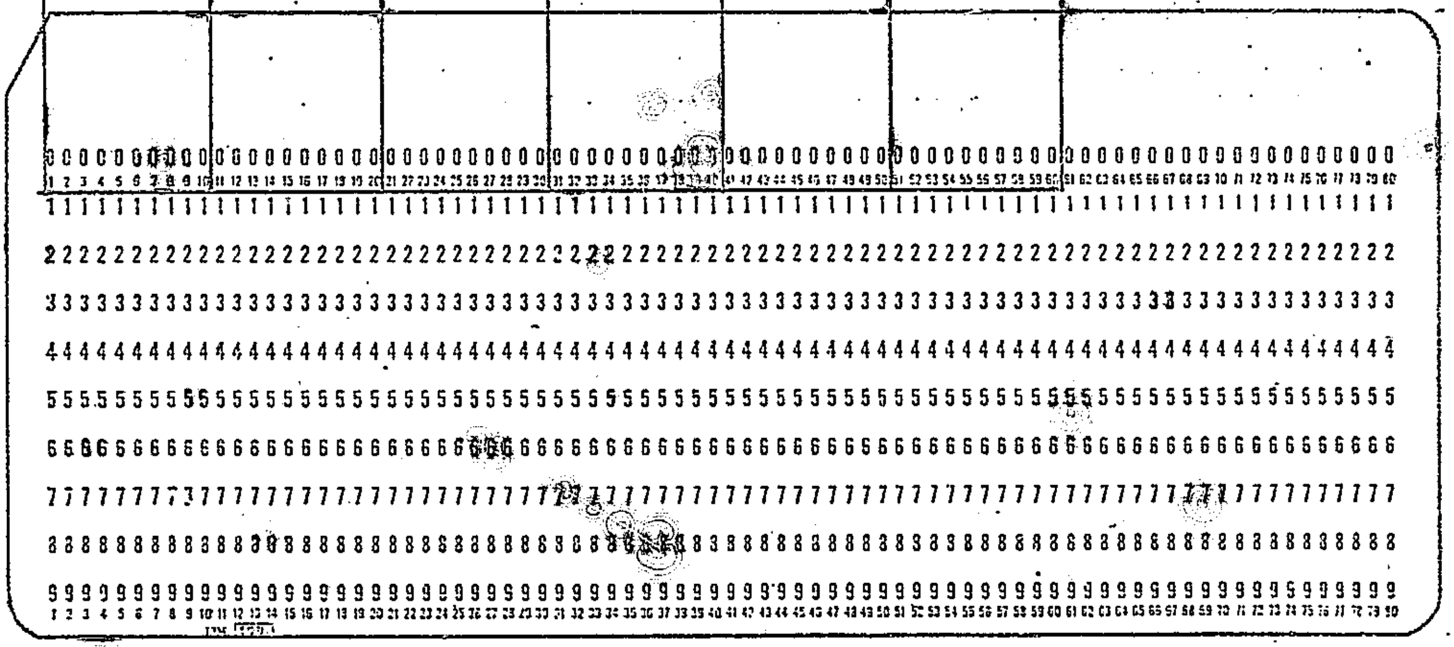

Figure 41. Core Geometry Card

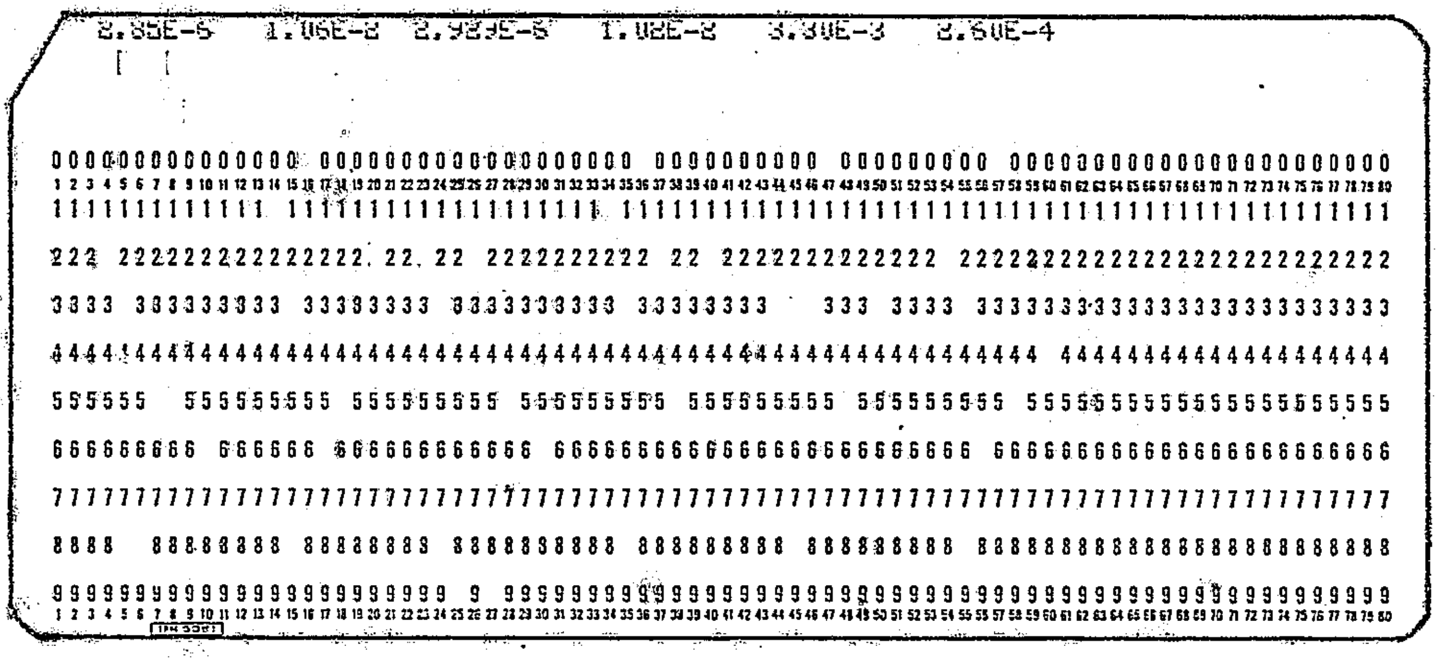

Figure 42. Example: Core Geometry Card

6.5 ASSEMBLING THE CORE CATALOG

As shown in Figure 31, the Core Catalog Cards should be arranged as follows:

1. Title Card--one card containing any desired information.
2. Manufacturers' Names Card--one card containing the names of up to two manufacturers.
3. Core Catalog Size Card--one card giving the number of core sizes and the number of values of relative permeability in the catalog.
4. Loss-Coefficient Cards--one card for each value of relative permeability in the catalog listing loss coefficients.
5. Permeability/Manufacturers' Names Card(s)--for Core Size #1 (smallest volume).
6. Core Geometry Card--one card giving the dimensions of core size #1.
7. Permeability/Manufacturers' Names Card(s)--for Core Size #2 (next to smallest volume).
8. Core Geometry Card--one card giving the dimensions of core size #2.

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Permeability/Manufacturers' Names Card(s)--for Core Size #n (largest volume).

Core Geometry Card--one card giving the dimensions of core size #n.

THE WIRE TABLE

The Wire Table immediately follows the core catalog cards. The first card in the wire table is in a (I2,1x,I2) format. The first variable gives the largest wire size (smallest AWG number) and the second variable gives the smallest wire size (largest AWG number). The format of this Wire Table Size Card is shown in Figure 43. A sample Wire Table Size Card is shown in Figure 44.

The remaining cards in the Wire Table give the cross-sectional area and resistivity of each wire size. These Wire Data Cards should be arranged in order of increasing AWG number (decreasing wire cross-sectional area). One Wire Data Card should be used for each wire size. The format of the Wire Data Cards is shown in the table below (see also Figure 45). A sample Wire Data Card is shown in Figure 46.

COLUMNS	FORMAT	PARAMETER
1-12	E12.5	Area of Bare Wire (m^2)
13-24	E12.5	Area of Single Coated Wire (m^2)
25-36	E12.5	Area of Double Coated Wire (m^2)
37-48	E12.5	Area of Triple Coated Wire (m^2)
49-60	E12.5	Area of Quad Coated Wire (m^2)
61-72	E12.5	Resistivity of Wire Size (ohms/meter)

If a wire size is not available in a particular coating, indicate this by entering zero (or blank) for the cross-sectional area of the unavailable wire type. This insures that the unavailable wire type will not be chosen for a design.

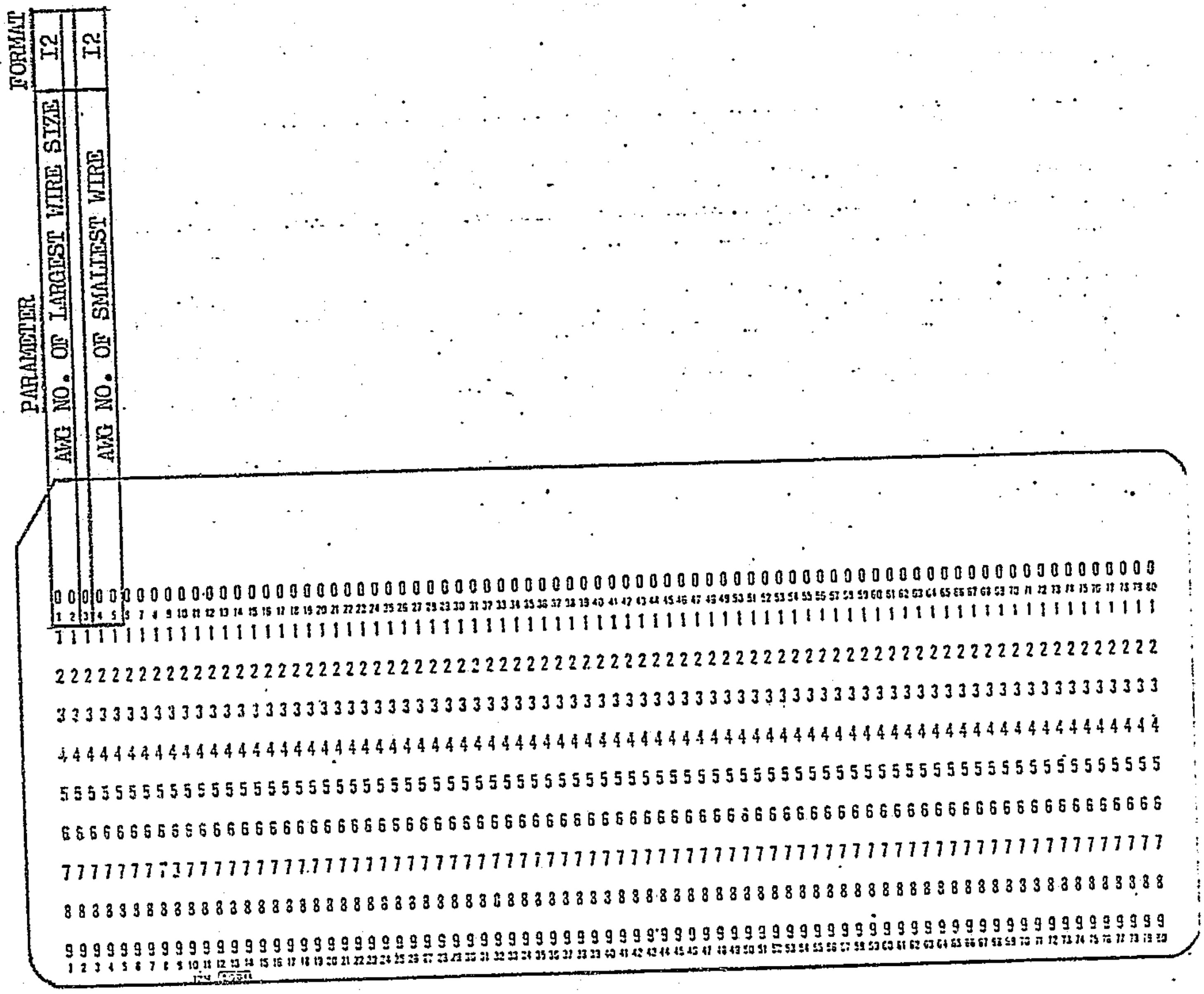

Figure 43. Wire Table Size Card

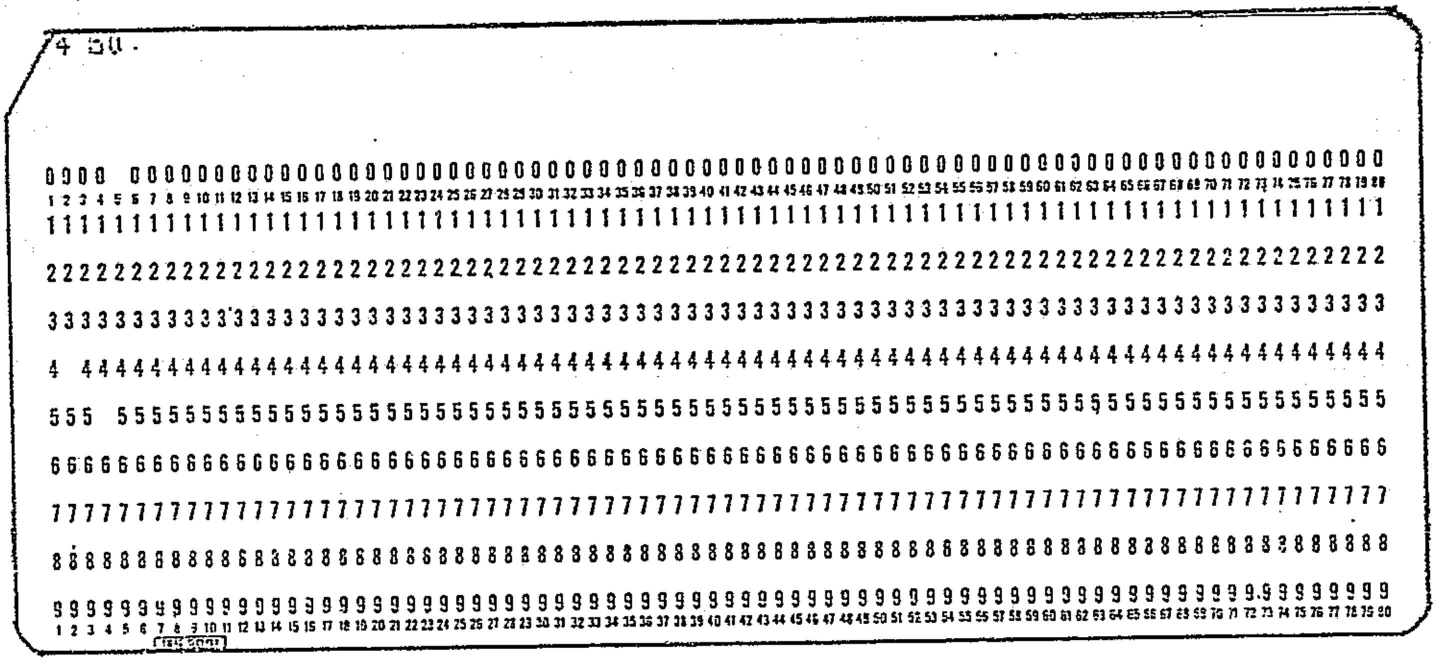

Figure 44. Example: Wire Table Size Card

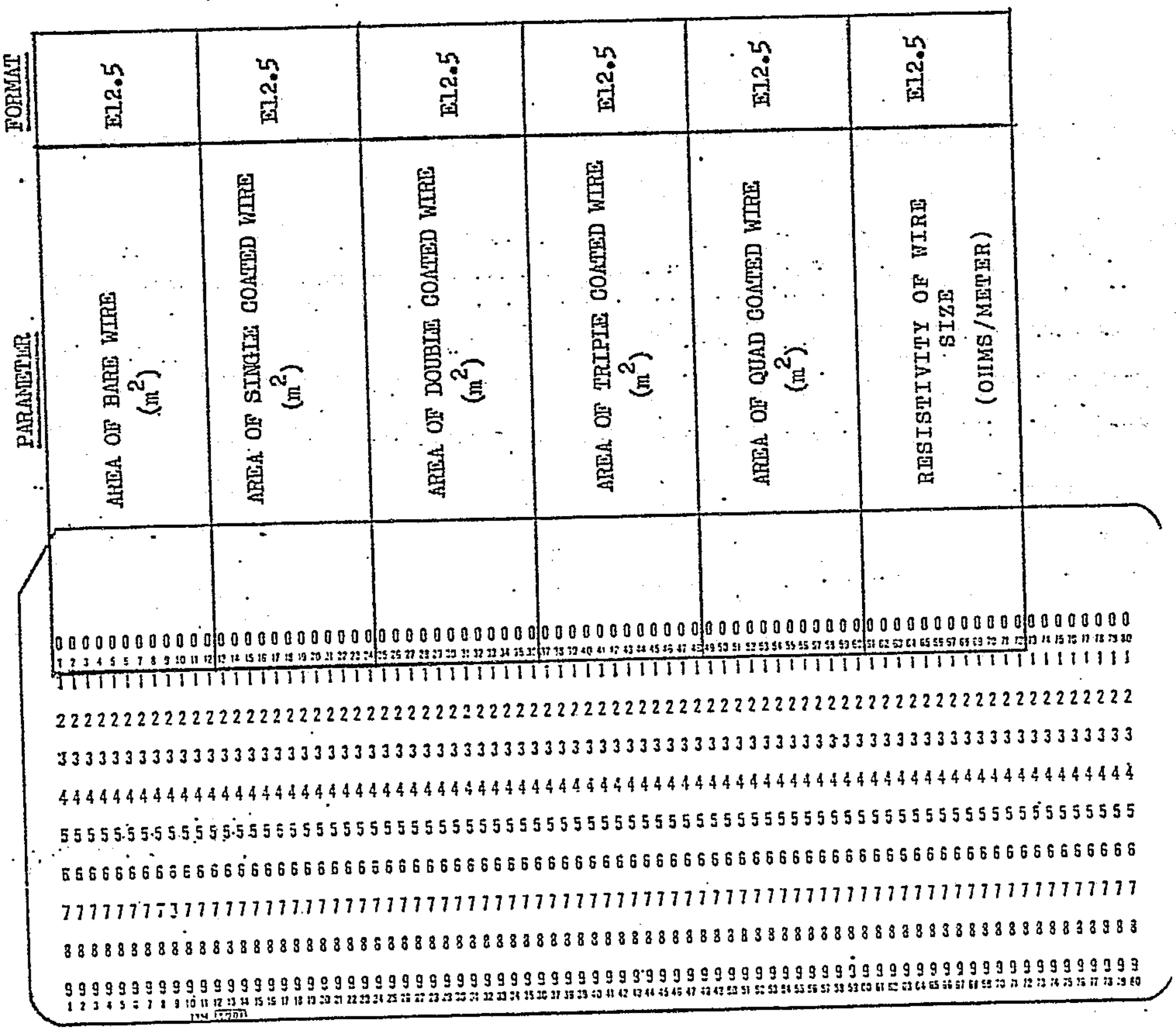

Figure 45. Wire Data Card

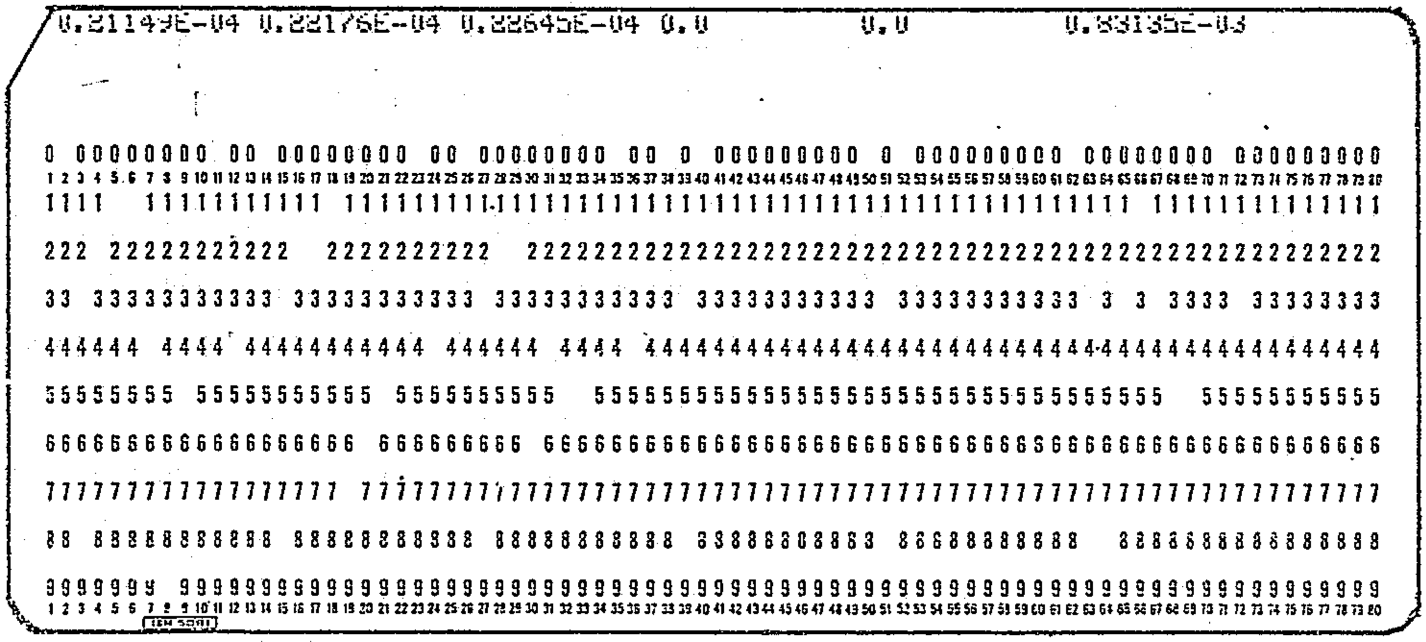

Figure 46. Example: Wire Data Card

PROGRAM INSTALLATION INSTRUCTIONS

Programs DC1DC and DC2DC described in this user's manual are written in FORTRAN IV and have been used on an IBM 370 model 165 operating under the control of the IBM Operating System Multiprogramming with a Variable number of Tasks (OS MVT). The two programs DC1DC and DC2DC are separate, stand-alone programs, each with its own separate identical data base. Program DC1DC consists of approximately 1050 statements, while program DC2DC consists of approximately 1075 statements. The data base, consisting of magnetic core loss, permeability and dimensional data, occupies approximately 260 cards. The total core requirement to compile and produce an executable module, including arrays, is 250 K on the IBM system described above.

The programs read only from the card reader and write only to the line printer. The logical unit number for the card reader on the system for which the programs were developed is 1 (one); the line printer unit number is 3 (three). These input/output unit numbers must be adapted by appropriate job control language or the programs must be edited to conform to the conventions of the system on which the programs are to be installed.

The installer may wish to copy the data base cards to a disk or tape file and assign the corresponding logical unit number for the read operations associated with the data base. These data base reads occur only once during the program execution at the beginning of the program. The control cards which describe the design specifications and control operations must be read by the card reader.

APPENDIX

LIST OF SYMBOLS

The following symbols may appear on the program output:

SYMBOL	MEANING
AREA (or CORE AREA)	The cross-sectional area of the magnetic core (m^2).
AWG	Wire size given by AWG numbers. (Program DC1DC).
AWG PRI.	Wire Size of the primary winding (Program DC2DC).
AWG SEC.	Wire size of the secondary winding (Program DC2DC).
B MAX	The maximum allowable flux density, given in tesla.
B MIN	The minimum allowable flux density, given in tesla.
B RESIDUAL	The residual flux density of the core material, given in tesla.
CAP ESR	The effective series resistance of the capacitor (ohms).
CONV FREQ	The frequency of operation of the converter system (KHz).
CORE PATH LENGTH	The mean magnetic path length of the core (m).

SYMBOL	MEANING
DSN MODE	The mode of operation of the converter at the design point in the PO-VI plane. A "1" implies continuous conduction, a "2" implies discontinuous conduction (Program DC1DC).
EFF	The efficiency of the converter (%).
EFF/MASS	The efficiency of the converter divided by the mass of the reactor element, (%/KG).
HEIGHT	The height of the magnetic core (m).
IA	The minimum value of reactor current over a cycle (amperes) (Program DC1DC).
IAP	The value in amperes that the primary current takes on at the beginning of the transistor on-time (Program DC2DC).
IAS	The value in amperes that the secondary current takes on at the beginning of the transistor on-time (Program DC2DC).
IB	The maximum value of reactor current over a cycle (amperes) (Program DC1DC).
IBP	The maximum value of primary current over a cycle (amperes) (Program DC2DC).
IBS	The maximum value of secondary current over a cycle (amperes)(Program DC2DC).

SYMBOL	MEANING
IB MAX	The maximum value that IB takes on over the design range of the converter. (Program DC1DC)
IBP MAX	The maximum value that IBP takes on over the design range of the converter. (Program DC2DC)
IBS MAX	The maximum value that IBS takes on over the design range of the converter. (Program DC2DC)
I COLL	Current in the collector of the transistor at which the saturation voltage was measured (amperes).
IC RMS	The RMS value of current in the capacitor (amperes).
IC RMS MAX	The maximum value that IC RMS takes on over the design range of the converter.
IND	The inductance of the single-winding reactor (mh) (Program DC1DC).
IP RMS	The RMS value of primary current (amperes) (Program DC2DC).
IS RMS	The RMS value of secondary current (amperes) (Program DC2DC).
IP RMS MAX	The maximum value that IP RMS takes on over the design range of the converter.

SYMBOL	MEANING
IS RMS MAX	The maximum value that IS RMS takes on over the design range of the converter (Program DC2DC).
IX AVE	The average value of the single-winding reactor current over a cycle (Program DC1DC).
IX RMS	The RMS value of the single-winding reactor current (Program DC1DC).
IX RMS MAX	The maximum value that IX RMS takes on over the design range of the converter (Program DC1DC).
MASS	The mass of the magnetic core (KG).
MAX CORES	The maximum allowable stack height.
MU	Relative Permeability
N	Number of turns of wire for the single-winding reactor (Program DC1DC).
NP	Number of primary turns for the two-winding reactor (Program DC2DC).
NS	Number of secondary turns for the two-winding reactor (Program DC2DC).
OP MODE	"1" if the converter operates in the continuous mmf mode over its entire design range. "2" otherwise.

SYMBOL	MEANING
PO	The output power (watts).
P OUT MIN	The minimum output power of the converter (watts).
P OUT MAX	The maximum output power of the converter (watts).
PRI. IND.	The inductance of the primary of the two-winding reactor (mh) (Program DC2DC).
PRI. WIRE LEN.	The length of wire used in the primary winding of the two-winding reactor (m) (Program DC2DC).
PRI. WIRE RES.	The resistance (ohms) of the primary winding of the two-winding reactor (Program DC2DC).
REACTOR AREA	The cross-sectional area of the magnetic material in the reactor (m^2).
REACTOR LENGTH/TURN	The length of wire per turn of the reactor, based on a 40% winding factor (m).
REACTOR MASS	The mass of the wound reactor (KG).
SEC. IND.	The inductance of the secondary of the two-winding reactor (mh) (Program DC2DC).

SYMBOL	MEANING
SEC. WIRE LEN.	The length of wire used in the secondary winding of the two-winding reactor (m) (Program DC2DC).
SEC. WIRE RES.	The resistance (ohms) of the secondary winding of the two-winding reactor (Program DC2DC).
STACK HEIGHT	The height in meters of the core stack.
T ON	The transistor on-time (μsec).
T OFF	The transistor off-time (μsec)
V DIODE	The diode forward drop (volts).
V IN	The input voltage (volts).
V IN MIN	The specified minimum input voltage (volts).
V IN MAX	The specified maximum input voltage (volts).
V OUT	The regulated converter output voltage (volts).
V SAT	The transistor saturation voltage (volts).
WIRE LENGTH	The length of wire used in the single-winding reactor (m) (Program DC1DC).

SYMBOL	MEANING
WIRE RESISTANCE	The resistance (ohms) of the wire used in the winding of the single-winding reactor (Program DC1DC).
WN. AREA	The area of the window of the core (m^2).

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