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1. ANEP 31(Edition 2) Guide for the Use of STANAG 4222 is a NATO UNCLASSIFIED publication.

2. ANEP 31(Edition 2) is effective NATO-wide upon receipt.

3. ANEP 31(Edition 2) contains only factual information. Changes to this publication are not subject to ratification procedures and will be promulgated as necessary by AC/141 (IEG/5).

Chairman

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RECORD OF CHANGES

Change Date	Date Entered	Effective Date	By Whom Entered

FORWARD

1. This Allied Naval Engineering Publication (ANEP) is for use with STANAG 4222 covering a Standard Specification for Digital Representation and Encoding of Shipboard Data Parameters.

2. It was prepared by the NATO Industrial Advisory Group (NIAG) Sub-Group 45 on Improved Technologies and Techniques for Ships.

3. The tasking authority was the NATO Naval Armaments Group (NNAG) Information Exchange Group 5 (IEG/5) on Tactical Control and Data Handling.

4. In the event of any conflict between this ANEP and its subject STANAG, the STANAG shall take precedence.

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GUIDE TO THE USE OF STANAG 4222

1. INTRODUCTION

1.1 Scope and Application of STANAG 4222

STANAG 4222 applies to the shipboard environment and is intended for intra-ship digital data communications between devices, equipments, sub-systems, or systems which contain at least a modest data processing capability such as a micro-processor with firmware.

The objective of STANAG 4222 is to provide a means by which elements of data can be communicated between two or more parties and be readily interpreted and understood by all parties to have the same meaning. To achieve this objective, it specifies standard units of measure for physical parameters, measurement conventions for linear and vector quantities, and rules which standardize certain binary notations for the representation of numbers, discrete data, alpha-numeric data (including non-printing characters), and binary-coded-decimal numbers (including some algebraic characters). Each parameter listed in the standard has specified for it a unique decimal identifying code.

The Standard does not address the format, structure, or syntax of data messages, which should properly be the subject of other documentation, but provides a vocabulary of individual parameters, and specifies the way in which their quantitative attributes shall be represented in the naval intra-ship environment.

Transmission of data is not the direct concern of this standard, but the progress towards 8-bit byte transmission fields, and the near universal adoption of 8-bit multiples for the word lengths used in processing devices has determined the adoption of the 8-bit byte (octet) as the elemental formatting unit, giving considerable independence and flexibility of word length in the source process, destination process, and communication process, with minimal data packing inefficiencies.

1.2 Organization of this ANEP

This ANEP provides an overview of STANAG 4222 on the Digital Representation and Encoding of Shipboard Data Parameters in a less formal language than that used in the STANAG itself.

Chapter 2 discusses some of the international standards which have been used in preparation of the STANAG.

The reader interested in rationale for the chosen solutions to the representational problems raised is referred to Chapters 3 and 4.

For the reader primarily interested in application and implementation of STANAG 4222, attention is drawn to Chapters 5, 6, and 7.

Chapter 8 provides some recommendations on data element transmission.

2. APPLICABLE DOCUMENTS

STANAG 4222 draws heavily on relevant ISO standards, and also on other international and national standards. In some cases, because of the restricted scope of standards for the intra-ship environment relative to the wider scope of general standards, it has been possible to use sub-sets, or to be more specific in the standard where otherwise undesirable alternatives or ambiguities could arise. Documents referenced in STANAG 4222, together with related documents, are listed in Annex A.

3. STANDARD UNITS OF MEASURE

3.1 General

The International Systems of Units (SI) has been adopted generally for this standard since NATO navies either use many of them already, or have a policy of metrication which would, when implemented, make them compatible generally with the SI system. Meanwhile, there are examples of different units of measure being used for the same basic parameters, e.g., meter/kilometer/foot/ yard/data mile/geographical or nautical mile, and degrees + minutes + seconds/radians/mils/binary angular measure. Without appropriate common standards, equipments or sub-systems obtained from different sources, and which are required to communicate may well require, for each new partner, special-to-type software changes to accommodate different units of measure used in their respective processors. Implementation of the standard means that one design for the specified unit of measure has universal application. Note that the end users need have no knowledge of the units used between processors, any conversions which are necessary for them being made prior to presentation.

ISO 1000 specifies SI units and makes recommendations for the use of their multiples and certain other units. It categorizes units generally as 'base' or 'derived', the latter being an algebraic function of two or more base units. A third category of supplementary units comprises the radian and steradian which may be regarded either as base units or derived units.

STANAG 4222 does not explicitly make such a distinction, but groups parameters (called 'quantities' in ISO 1000) generally as in the ISO 31 series of specifications, and additionally lists 'Miscellaneous' parameters which are either dimensionless or do not conveniently fall into the aforementioned categories.

ISO 1000 indicates that the choice of the appropriate multiple (decimal multiple or sub-multiples) of an SI unit is governed by convenience. While any multiple or sub-multiple of a unit of measure in STANAG 4222 can be quantified to within the value of the smallest quantum of its binary representation, substitution of the unit by a multiple is not permitted. Thus, when a number is given in the context of a particular parameter there is no ambiguity with regard to the true value of that parameter, e.g., never in microseconds, or $1x2^{-20}$ seconds etc.

3.2 Units of Angular Measure

3.2.1 The ISO View

The SI unit for angular measure is given in ISO 1000 as the radian, and for solid angular measure, the steradian, but Annex A to that specification, with reference to "a table of decimal multiples and sub-multiples of SI units and some other units which may be used", states: "For a number of commonly used quantities examples of decimal multiples and sub-multiples of SI units, as well as some other units which may be used, are given in this annex." It is suggested that "the selection shown, while not intended to be restrictive, will none the less prove helpful in presenting quantities in an identical manner in similar contexts within the various sectors of technology...." Degrees, minutes and seconds are "recognized by the CIPM because of their practical importance or because of their use in specialized fields". Nevertheless, "Decimal subdivisions of degree are preferable to minute and second for most applications", and it is noted that the 'grade' or 'gon' ($\Pi \div 200$) may also be used.

3.2.2 The Naval Situation

As has been noted above, many different units of angular measure and their subdivisions are in use within NATO navies and the rationalization of them from the user point of view is outside the scope of this STANAG. However, for the transport of angular measure between intelligent devices which are capable of converting units of measure from that used in a particular application to that used for transportation and vice versa, it is desirable that a single unit be used universally. The choice lies between radian measure (and its multiples/sub-multiples) and circular measure (and its multiples/sub-multiples). A survey of the usage of angular measure on board ship shows readily that the latter predominates. Circular measure has been chosen therefore for the intra-ship applications covered by the STANAG. The unit chosen is one Full Circle of rotation (= 360°). Rules for the sub-division of Full Circle in a particular application are outside the scope of the STANAG, but the Full Circle in conjunction with the octet string (fixed point) representation is directly compatible with the binary angular measure (BAM) commonly used in weapons and fire control systems.

3.3 Units of Time

3.3.1 General

A clear distinction has to be made between two applications of time measurement. One is that of the measurement of the duration of a process, i.e., the time it takes to do something, like run 100 meters, or the time elapsed between two successive observations of a target by a radar. For this application the time unit 'second' is the only unit of measure allowed. The standard does not recognize decimal sub-multiples such as the microsecond. All values are represented as specified in the STANAG, wherein the notation (in this case representing the number of seconds) can give, for example, any value as $nx2^{m}$, $nx2^{16}$, $nx2^{8}$, $nx2^{-8}$, $nx2^{-16}$, $nx2^{-24}$ etc. where "n" is a binary number.

A common parameter in this category may be called a time stamp, time tag, or time of validity. Factors that influence the representation of this parameter include the word length of the processor (typically 32 bits or four octets), the time to process the value, the resolution of the value, and the range of the value. Either a four-byte octet string (fixed point) representation or a single precision real (floating point) representation satisfy the word length criterion. Processing the octet string (fixed point) representation is typically faster than processing of a real (floating point) representation. Assuming an octet string (fixed point) representation, a byte offset of -1 provides a resolution of approximately 0.0039 seconds (4 milliseconds), with a range of approximately 97 days. If the byte offset is -2, the resolution becomes approximately 0.000015 seconds (15 microseconds), but the range decreases to approximately 9 hours. Another alternative is to expand the time parameter representation to an eight-byte octet string. Using a byte offset of -4, this representation provides a resolution of approximately 0.2 nanoseconds and a range of approximately 69 years. The system designer must select the parameter representation (including range and resolution) that satisfies the requirements of the system and application under consideration.

The other application is that concerned with the ordinal date or time of day. Both are, of course, representations of elapsed time from implied reference points, but in general it can be said that the times involved are very much greater than in the former application, and that the two applications rarely, if ever, co-habit the same process.

3.3.2 Units for Ordinal Date

The field of application of ISO 2711 is stated to be "whenever representations or ordinal dates are used in the interchange of data among data systems. The ordinal date is commonly used in cases where machines are frequently utilized to carry out a systematic sorting in the order of succession of dates or to determine the number of days elapsed between two dates."

STANAG 4222 selects the ISO two digit representation specified in ISO 2711 for the 'year' on the basis that the century is implicit, but unambiguous in the intended applications.

The numerical calendar of ISO 2711 showing the numbering of the days of the year is reproduced in Table 1.

3.3.3 Units for the Time of Day

ISO 3307 states that 'it is designed to establish uniform time representations based upon the 24-hour time keeping system. It provides a means for representing local time of the day and Universal Time in digital form for the purpose of interchanging information among systems'. It also permits a variety of permutations of the units, hours, minutes, seconds, and their decimal fractions, recognizing that there must be an understanding between sender and recipient of time-representations as to the specific structure used. This is generally accomplished by adequate definition in format or record descriptions.

Such freedom of choice for the representation of the time of day in the field of application of STANAG 4222 is neither necessary nor desirable, and one particular structure given in ISO 3307 has been adopted, namely hours, minutes, seconds, and fractions of a second, (normally to one hundredths of a second when a decimal representation is used).

4. MEASUREMENT CONVENTIONS

4.1 The ISO View

ISO 1503 on *Geometrical Orientation and Direction of Movements* provides the basis for the conventions specified in the STANAG for expressing the orientation/direction of vector quantities. The ISO document states under "Scope and Field of Application", that it:

- "establishes and defines directional terms in stationary circumstances (geometrical orientation);
- defines directions of movement and gives rules for establishing them;
- gives rules for the coordination of directions of movements of control elements to the intentional changes in technical objects". (This last item is outside the scope of the STANAG.)

ISO 1503 defines the directions in terms of a conventional Cartesian system of three mutually perpendicular axes, designated X, Y, and Z respectively to form a right-hand system as shown in Figure 1(a), and which is in accord with accepted mathematical/scientific practice. Further, this practice shows that angular measurements in the three intersecting planes P_{xy}, P_{yz}, and P_{zx} are measured from the positive X, Y and Z axes respectively, the positive angular directions being implicit, and as shown in Figure 1(b).

4.2 The Naval Situation

Standard computer algorithms exist for the manipulation of vector quantities expressed according to the conventions referred to above. Nevertheless, some naval engineering conventions are not in accord with them. For example, 'true bearing angle' is measured from North through East. Given that it is measured in a P_{xy} plane, the scientific notation would cause positive X-axis to be assigned to North, and from the bearing angle measurement direction given, the positive Y-axis be assigned to East (see Figure 1(b)). From the scientific right-hand convention, it follows that the positive Z-axis points in a downwards direction. If the perfectly valid and self-consistent left-hand convention were adopted, then the positive Z-axis would point in an upwards direction. Note, however, that the left-hand convention is not generally used. Unfortunately, an engineering convention has become established which reverses the allocation of the X and Y axes (possibly influenced by graphical representations wherein 'X' is usually assigned to the horizontal axis, and 'Y' to the axis perpendicular to it). The resultant coordinate system is mathematically viable provided that it is adequately defined, but in the P_{xy} plane at least it prescribes an angular measurement direction in conflict with that of either a right-hand, or left-hand convention (i.e., it goes from 'Y' through 'X').

Turning now to relative bearing angle measurement, this is conventionally measured from the 'forward' direction through 'starboard'. Given that it is measured in a plane designated P_{xy}, by the same arguments 'forward' would be in the positive 'X' direction, starboard would be in the positive 'Z' downwards. Again, system designers have chosen generally to reverse the X, Y assignments with a similar effect.

4.3 Rationale for the Adopted Conventions

The allocation of designatory letters to the coordinates, and the adoption of one rule or another within the data handling processes is not of concern to the user, provided that he is able to see, use, and generally communicate data using his conventions. The standardization of his conventions are outside the scope of STANAG 4222. He will usually refer to distances along the Z-axis, for example, as 'height' or 'depth', not as positive/negative. The allocation of sign is a task within the data processing function. It is here where errors are most likely to occur without careful specification control, and unnecessary proliferation of specifications could be generated in the absence of standardization.

Another important area where the absence of agreed and consistent measurement conventions can cause problems must be familiar to most system designers. It is that of ship's attitude. Whether, for example, a roll angle contributes in a positive sense or a negative sense to a given deck-place referenced elevation angle, clearly depends upon whether 'starboard-up' or 'starboard-down' is designated positive. The system designer has to reconcile the *de facto* conventions of the user, and those of the component parts of the system by means of proper coordinate transforms providing a common frame of reference. Again, this common frame of reference, or reference coordinate system may, in the absence of a standard, be quite arbitrary, provided that the user can continue to use his own conventions. The mathematical manipulations within the data handling process are transparent in this regard. The arbitrary nature of this reference once again is a potential source of errors and unnecessary proliferation of designs.

Faced with mathematical inconsistencies within coordinate systems being used in naval equipment, and inconsistencies between nations, it has proven impossible to select one of them upon which to standardize with any clear and general benefit. Figure 2 provides illustrations of the impossibility of reconciling 'user' convention with a mathematically consistent coordinate system. STANAG 4222, specifies the International Organization for

Standardization recognized set of conventions, as given in ISO 1503 and illustrated in Figure 1, for the representation of vector quantities within the data processing function, and for communication between data processing functions.

Figure 3(b) shows how this is applied to a ship referenced coordinate system. One typical set of 'user' coordinates is given in Figure 3(a) for comparison purposes, and to illustrate the relatively simple mapping required from one to the other.

5. DATA PARAMETER REPRESENTATION

5.1 General

STANAG 4222 defines representations for three main classes of data, i.e., numbers, discrete data, and alphanumeric data, and for certain sub-classes within them. The adoption of the 8-bit byte format element has already been touched upon, and it also influences the representations specified as will be described.

5.2 The Number Representation Systems

Two classes of numbers are addressed. One class is for numbers which, in a given application, have a possible range of values such that the radix point can be placed at an agreed, fixed position. The majority of numerical values which have to be transferred between data processing functions on board ship fall into this class. The defined octet string (fixed point) notation is recommended. The other class is for numbers whose range and resolution make octet string (fixed point) representation impractical. For these numbers a real (floating point) notation is defined.

It is worth stressing at this point, that the binary coded decimal representation, and the numerical part of the alphanumeric representation are notations for the representation of decimal digits, and not of decimal numbers *per se*. Some examples are:

Example	BCD String	Meaning
(1)	83342	83342 in the decimal numeration system
(2)	83342	833.42 in the decimal numeration system (the decimal point implied by agreed convention)
(3)	83342	0.000083342, reasons as for (2) above
(4)	83342	The 342nd day of the year 1983 (two numbers in the decimal numeration system)

5.3 Possible Octet String (Fixed Point) Representations

An algebraic number may be represented in three possible ways in the binary numeration system:

a. Representation of the absolute value and the sign;

b. Representation by the diminished complement (one's complement); or,

c. Representation by the radix complement (two's complement).

The representation of a positive number is identical in two cases; i.e., the sign bit is in the MSB position and is represented by the digit 0, and the number is represented by the absolute value in the pure binary system.

The representation of a negative number using the absolute value and the sign is accomplished by representing the negative sign with 1 in the MSB position, and the number is represented by the absolute value. This representation requires special sign processing, and different algorithms are necessary for addition and for subtraction.

Use of the one's complement representation requires that computation algorithms recognize two different binary representations of the number "zero" (either all zeros or all ones).

The two's complement representation is most commonly used because it simplifies addition and subtraction operations. In addition, the representation of the number zero is unique.

Examples of the three possible representations are presented in Annex B.

5.4 Adopted Octet String (Fixed Point) Representation

For the specified octet string (fixed point) representation, the pure binary numeration system is adopted, using two's complement for the representation of negative numbers.

The specified octet string (fixed point) representation of any number is based on an imaginary string of 8-bit bytes, the least significant bit of one of these having a weight of unity, (Figure 4(a)). This byte is called the 'reference byte', and the others extend in both directions to infinity, to provide bits with weights of binary multiples, or sub-multiples of unity. A byte or group of consecutive bytes is selected to contain the binary bits representing the possible values of a variable, based on its maximum value, and the required value of the least significant digit. Examples are given in Figure 4(b).

The number of bytes in the group and the positional relationship between them and the reference byte may be known *a priori*, for example by agreed convention. The value of the number represented is, therefore, precisely quantified.

There is no limitation on the number of bytes, or the offset value which may be specified.

In the majority of cases, it is to be expected that the binary number will not completely fill the required number of bytes. In the case of unused bits of lesser weight than the required least significant digit, clearly their values are of no consequence and may be set according to convenience. In the case of unused bits of greater weight than the required least significant digit, different rules apply. To simplify the negative number recognition processes, the sign position is always that of the 'most significant bit' of the most significant byte used. The combination of rules for the position of the least significant bit of a given number, and that of integral consecutive bytes, implies that in many cases there will be unused bit positions between that occupied by the sign identifier and the rest of the number. In order to preserve the two's complement notation, these otherwise unused bit positions must be filled with the same binary digit as that of the sign identifier. Examples of the use of these packing bits are shown in Figure 5.

It should be noted that the use of variable point, as defined by ISO is not recognized by STANAG 4222, other than in the alphanumeric and binary coded decimal representations which have the facility for coding 'decimal point' (comma).

The representation of integers, which is the most commonly encountered form of octet string (fixed point) representation in the decimal notation is catered for in the standard by the simple expedient of setting the byte offset to 'zero', thus making the least significant bit (LSB) of the least significant byte equal to 'one'. It is noted that integer values are the positive and negative whole numbers, including zero (as a single value).

5.5 Real (Floating Point) Representation

The representation of data by real (floating point) numbers is specified to be in conformance with the International Electrotechnical Commission (IEC) Standard, Publication 559, *Binary Floating-Point Arithmetic for Microprocessor Systems*. As its title implies, the objective of that standard is to define ways for new systems to perform binary floating-point arithmetic, whereas STANAG 4222 in concerned solely with the floating-point number representation itself. A floating-point number is characterized by a sign, a signed exponent, and a mantissa. Its numerical value, if any, is the signed product of its mantissa and the number two raised to the power of its exponent. In fact, the signed exponent is replaced by a biased exponent which is the sum of the signed exponent and a constant (bias) chosen to make the range of the biased exponent non-negative.

Two basic formats, and two extended formats are specified in the IEC document. The two basic formats are: single precision with a sign bit, an 8-bit exponent, and a 23-bit fractional mantissa; and, double precision with a sign bit, an 11-bit exponent, and a 52-bit fractional mantissa. STANAG 4222 recognizes only the two basic formats which are illustrated in Figure 6.

As noted above, the STANAG defines only the representation and format of binary floating-point numbers. It does not address other aspects of the notation. For guidance to the users of binary floating-point arithmetic, the wider scope of IEC Publication 559 is reproduced below:

"This standard specifies:

a. floating point number formats;

b. the results for add, subtract, multiply, divide, square root, remainder and compare;

c. conversions between integers and floating point numbers;

d. conversions between different floating point formats;

e. conversions between basic format (see Sub-clause 4.1) floating-point numbers and decimal strings; and,

f. floating-point exceptions and their handling, including non-numbers (NaNs)."

"This standard does not specify:

a. integer representation;

b. the interpretation of the signs and the fraction field of non-numbers (NaNs);

c. binary - decimal conversions to and from extended formats; and,

d. formats of decimal strings."

IEC 559:1989 has been compared to and found virtually identical to ANSI/IEEE Std 754-1985, *IEEE Standard for Binary Floating-Point Arithmetic*. The two standards have grammatical differences, but are identical in technical content.

5.6 Alphanumeric Representation

STANAG 4222 specifies a character set for use in the representation of data parameters to be exchanged between processing devices of shipboard tactical control and data handling systems. The set includes control characters, letters, digits, punctuation signs, and other symbols which are collectively, if somewhat loosely, called 'alphanumeric characters'. The standard also specifies the coded representations of each character, and defines the graphical representations for the control characters of the set.

STANAG 4222 (Edition 2) specifies use of the ISO/IEC 4873:1991(E) 8-bit code, which is derived from and compatible with the 7-bit code character set specified in ISO/IEC 646. The 8-bit code provides greater capability for future users of STANAG 4222. ISO 4873 offers options for selection from three different Levels and Versions. For a given implementation, the specific options to be used must be selected and specified. The following tables summarize the Elements and Levels defined in ISO 4873. A Version is a coded character set which provides the means to uniquely identify the elements of the 8-bit code that are to be invoked in a particular implementation; e.g., 'ESC 02/01 F' identifies the C0 Set, 'ESC 02/08 04/02' identifies the G0 Set.

The characters and their coding specified in STANAG 4222 are identical to the ASCII 7-bit Code set. They differ from STANAG 5036 Ed. 2, *Parameters and Practices for the Use of the NATO 7-Bit Code* only in the use of the 'number' character for code reference 2/3 instead of the 'pound Sterling' character. The use of the 'number' character for code reference 2/3 also conforms with the International Reference Version ISO 646 and ITA No. 5 in Recommendation V.2 of the CCITT Orange Book for the 7-bit Code. The ASCII Code has been chosen as the most used and internationally recognized set in data processing applications.

ELEMENTS OF THE ISO 4873 8-BIT CODE		
ELEMENT	**DESCRIPTION**	**COMMENTS**
C0 Set	A set of up to 30 control characters represented by bit combinations 00/00 to 01/15, except 00/14 and 00/15 which are normally unused	00/14 and 00/15 are available to represent S0 and S1 (which achieves compatibility with STANAG 4222 (Edition 1)
SPACE	A graphic character represented by bit combination 02/00	SPACE, G0, and DELETE correspond to the 96-symbol Printing Subset of the 7-bit code specified in STANAG 4222 (Edition 1)
G0 Set	A set of 94 graphic characters represented by bit combinations 02/01 to 07/14	
DELETE	a character represented by bit combination 07/15	
C1 Set	A set of up to 32 control characters represented by bit combinations 08/00 to 09/15	
G1 Set	A set of up to 96 graphic characters represented by bit combinations 10/00 to 15/15	
G2 Set	A set of up to 96 graphic characters	
G3 Set	A set of up to 96 graphic characters	

LEVELS OF THE ISO 4873 8-BIT CODE		
LEVEL	**COMPRISED OF**	**COMMENTS**
1	C0, SPACE, G0, DELETE, C1, G1	C1 and G1 may be empty. If C1 and G1 are empty and 00/14 and 00/15 are used to represent S0 and S1, Level 1 is identical to STANAG 4222 (Edition 1)
2	Level 1 + G2 and G3	C1 and G1 shall not be empty
3	Level 2 + LS1R, LS2R, LS3R	G1 shall not be empty; either, but not both, G2 and G3 may be empty; C1 shall not be empty

STANAG 5036 Ed. 2 "does not preclude the use of other codes or alphabets in limited or specialized systems not required to be interoperable with NATO. Neither does this standard (5036) necessarily apply to central processors". Nevertheless, STANAG 4222 is entirely code compatible with STANAG 5036. Should a telegraphic data receiver, to STANAG 5036 specifications, receive data from a STANAG 4222 compatible system it will print the 'pound Sterling' character instead of the international 'number' character. However, the appearance of a substituted 'pound Sterling' character should present no problems to NATO since there should be little danger of interpreting it as having currency significance). Conversely, should a 5036 compatible telegraphic data transmitter be used to input data to a 4222 compatible data processing system, the 'pound Sterling' character must be used for the 'number' character.

There is no restriction imposed by the STANAG on the number of bytes/characters which may comprise an alphanumeric data element.

5.7 Binary Coded Decimal Representation

It is recognized that there exist, and will continue to exist on board ship for considerable time, relatively simple devices for the input and display of generally small numbers of digits for which the full 7-bit alphanumeric code would be uneconomical. For these applications, a 4-bit code derived from the 7-bit code is specified. It is based on ISO/R963, *Guide for the Definition of 4-bit Character Sets Derived from the ISO 7-bit Coded Character Set for Information Processing and Interchange.*

The codes for the digits 0-9 correspond with those occupying bit combinations 03/01 to 03/09 in the 7-bit code. There are six other codes which are unassigned in the ISO standard, but the latter does make provision for a user to select any combination of the non-numeric characters from the 7-bit code for inclusion in positions 10-15 of the 4-bit set, and gives rules for their allocation to the codes available. It is considered that in the more restricted NATO naval shipboard environment, such freedom of choice for these characters is unnecessary and undesirable. A set of six non-numeric characters of wide application are specified in STANAG 4222 and codes assigned to them in accordance with the rules given in ISO/R963.

Figure 7 gives examples of packing BCD data into the 8-bit byte format. Note that there is no restriction imposed by the STANAG on the number of bytes/characters which may comprise a BCD data element.

5.8 Discrete Representation

5.8.1 General

Discrete data are given many names, e.g., flag bits, semaphores, status bits, etc. One thing they have in common is their implementation dependency. For this reason it is not possible to specify the representation, except in general terms.

5.8.2 Boolean (Single Bit Discrete) Representation

A Booelean discrete in STANAG 4222 refers to a statement which can, at any one time, have one of two states, 'true' or 'false'. A Boolean value must always have assigned to it a label which makes a statement, e.g., 'POWER ON'. A bit code of '1' indicates that the statement if 'true' and a code of '0' indicates that the statement is 'false'. Labelling a Boolean value 'POWER' is meaningless in this context.

5.8.3 Enumerated (Multi Bit Discrete) Representation

In some applications a higher integrity is required than that which can be provided by a single bit. This can be provided by employing two or more bits, each having a defined significance. Using two bits, and taking the 'POWER ON' example, one bit can be labelled with the statement 'POWER ON' and the other with the statement 'POWER OFF'. The truth table will then look like this:

STATEMENT LABEL	POWER ON	POWER OFF
EQUIPMENT STATUS	b1	b2
POWER ON	1	0
UNDEFINED/INVALID	1	1
UNDEFINED/INVALID	0	0
POWER OFF	0	1

Note: All states must be labelled, even if 'undefined' or 'invalid'.

Enumerated (multi bit discrete) data refers to a uniquely coded set of values, each of which represents one of several possible statements. For example, with reference to a radio transmitter, these statements might be:

- POWER OFF
- POWER ON : STAND-BY
- POWER ON : HOT STAND-BY
- POWER ON : QUARTER POWER (RF)
- POWER ON : HALF POWER (RF)
- POWER ON : FULL POWER (RF)

As with Boolean (single bit discrete) values, each possible value must be labelled, even if the state is 'undefined' or 'invalid'. Coding of Enumerated (multi bit discrete) data is very system dependent and no attempt is made in the standard to specify this.

5.8.4 Discrete Data Elements

There is no restriction imposed by STANAG 4222 on the number of bytes/discretes which may comprise a discrete data element.

5.8.5 Guidelines

While it is felt that no overriding rules can be stated for the packing of discrete data, some guidelines for a code of practice can serve a useful purpose. In any application, there will almost certainly be a conflict of interest between the data user and the data handler, but provided that user requirements can be adequately met, the implementation of a consistent set of rules for the formatting of the data can only be of positive value. The design authority must be the judge of what comprises an optimum solution for any given implementation.

Nevertheless the following guidelines are recommended for adoption wherever viable:

- the significance of unused bit positions should be unambiguously stated in appropriate documentation.

- bits which collectively provide a uniquely coded statement, (i.e., an Enumerated [multi bit discrete] set of values) should be contiguous.

- unless unacceptable penalties are imposed by so doing, the allocation of codes to Enumerated [multi bit discrete] statements should follow a logical series.

- discrete data parameters should be justified to the LSB position of the discrete data element.

- discrete data parameters should not overlap byte boundaries unless it is an Enumerated [multi bit discrete] discrete of more that 8-bits.

5.8.6 Unsigned Integers

An unsigned integer is defined as one or more consecutive octets, the value of which is an unsigned, pure binary number. An unsigned integer shall be represented as a Bit String. An unsigned integer one octet in length represents the range of integers from 0 to 255. An unsigned integer two octets in length represents the range of integers from 0 to 65 535.

5.9 Ordinal Date Representation

An ordinal date comprises two units of measure, the year and the day, but they are considered to be collectively a single parameter and are therefore accommodated in the same data element of a specified number of bytes. While a pure binary octet string (fixed point) notation is recommended for each of the two parameter components, other representations may be used provided that they conform to the rules of STANAG 4222.

The pure binary representation requires 9 bits for the day value (0-366), and 7-bits for the year value (0-99). The day value clearly must cross a byte boundary to accommodate its most significant bit. The remainder of the byte containing that MSB could, in principle, accommodate the year value, but this would invalidate entirely the sign bit convention of STANAG 4222 for octet string (fixed point) representation. Further, two separate parameter values cohabiting the same byte would make for untidy processing. Accordingly, the day value is allocated two bytes with the unused bits at the MSB end given the value 'zero' corresponding to the octet string (fixed point) rule specified. One byte is allocated to the year value and its MSB position is also set to 'zero' for the same reason.

Binary coded decimal, and alphanumeric representations of the ordinal date are handled precisely according to the rules given for BCD and alphanumeric representations in general. Each decimal digit is treated as such, and not as part of a number. The meaning of the sequence of decimal digits is known *a priori*, in this case by the formatting rules of STANAG 4222. In the BCD representation, the binary codes for the five decimal digits occupy contiguous half-bytes in ascending significance. The sixth unused half-byte is allocated the code for the 'SPACE' character. In the alphanumeric representation, the binary codes for the five decimal digits occupy contiguous whole bytes in ascending significance, the unused bit in each byte being set to 'zero'.

5.10 Time of Day Representation

Time of day is treated in STANAG 4222 in a similar way to that for ordinal date. Although there are three units of measure, the hour, the minute, and the second, they are considered to be collectively a single parameter and are therefore accommodated in the same data element of a specified number of bytes. While a pure binary octet string (fixed point) notation is recommended for each of the parameter components, other representations may be used provided that they confirm to the rules of STANAG 4222. Values of different units of measure are not allowed to cohabit the same byte in the pure binary octet string (fixed point) notation, and unused MSB positions in each are given the value 'zero'. In this notation, an additional byte is used to give binary sub-multiples down to 1/256. The total number of bytes for the 'binary' time of day representation is thus four.

In the BCD representation, fractional seconds are represented to two decimal places, giving eight half, or four whole, bytes exactly in the data element.

The alphanumeric representation is similar to that of BCD in that it comprises a string of eight characters giving tens and units of hours, tens and units of seconds, and tenths and hundredths of a second packed according to the general rules for alphanumeric data given in STANAG 4222. This representation can clearly be extended to the explicit statement of Universal or Zulu time. In some implementations, whether a time is 'local' or 'Zulu' will be known implicitly, by context. In others, 'local' and 'Zulu' time may cohabit the same process without adequate context to differentiate between them. In these circumstances, if it is 'Universal' or 'Zulu', the character 'Z' may be added after the least significant numerical character of the time, (ISO 3307). The resultant alphanumeric string will be treated as any other, according to the STANAG 4222 general rules for alphanumeric data.

6. METHODOLOGY FOR PARAMETER REPRESENTATION AND DATA ELEMENT FORMATTING

STANAG 4222 is intended to provide the tools for the system design/integration engineer to easily develop data parameter representations and formats for intraship digital communication. This chapter illustrates, by way of step by step examples, how this development may be achieved.

6.1 Identify and Define Parameters

The system design/integration engineer typically will prepare a comprehensive list of the information to be exchanged within the shipboard data handling system. Assume, for purposes of this example, that one set of information to be transmitted between processing devices by means of the data handling system consists of the following parameters:

Target Identification Number
Target Range
Target Bearing
Time Tag

Referring to appropriate tactical documents, the system design/integration engineer should define each of these parameters. Assume the following definitions:

Identification Number (Target) - The reference number given to the target.

Range (Target) - The distance from a reference point to a target or other object.

Bearing (Target) - The angle between a reference line and the line from a reference point to a target or other object. Bearing is measured in the horizontal plane, clockwise positive.

Time Tag - The instant at which the associated data are valid.

Note that the definitions of range and bearing are generalized. It is recommended that generalized definitions be stated together with a list of applicable parameter modifiers for each parameter, e.g., True or Relative could be the modifiers for the parameter Bearing. The system design/integration engineer must further define the reference point (e.g., own ship), and must determine whether true bearing (using the north-south line as the reference line) or relative bearing (using the ship's longitudinal axis as the reference line) is to be transmitted.

6.2 Determine Data Parameter Characteristics for the Application

The system design/integration engineer must determine the required maximum value and resolution to describe the numerical value of the data parameters. For example, the parameter maximum value and resolution might be specified as follows:

Parameter	Maximum Value	Resolution
Identification Number	4000	1
Range	250 Nautical Miles	10 feet
Bearing	360 degrees	0.25 degrees
Time Tag	30 days	10.0 milliseconds

6.3 Determine Standard Data Parameter Characteristics

From Table 1 of STANAG 4222, which identifies the quantities used to represent data parameters, we find the following characteristics for the parameters under consideration:

Parameter	Quantity	Unit of Measure	LSB of Reference Byte
Identification Number	Integer	(dimensionless)	1
Range	Linear Measure	meter	1 m
Bearing	Angular Measure	Full Circle	1 FC
Time Tag	Time	second	1 s

Since the maximum value and resolution of the parameters under consideration are not specified in the standard units of measure, it is necessary to convert these values to standard units. The following conversion factors apply in this example:

Feet x 0.3048	=	meter
Nautical Miles x 1852	=	meter
Degrees ÷ 360	=	Full Circle
Days x 86400	=	second
millisecond	=	second

When these conversion factors are applied, the specified maximum value and resolution of the parameters expressed in the standard units of measure become:

Parameter	Maximum Value	Resolution
Identification Number	4000	1
Range	463 000 m	3.048 m
Bearing	1 FC	0.000694 FC
Time Tag	2 592 000 s	0.01 s

6.4 Determine Appropriate Representation

The system design/integration engineer should select the appropriate representation for each of the data elements. The four parameters under consideration in this example can easily be represented using the octet string (fixed point) representation.

6.5 Format Data Elements

The octet string (fixed point) data parameter representation implements the reference byte and byte offset to define the format of data elements.

Table 2 of STANAG 4222 provides a list of the bit values of bytes for a sequence of bytes which includes the reference byte. Knowing the range of values to be represented (i.e., the maximum value and the resolution), the position and number of bytes required to represent the data parameter can be determined easily and without ambiguity.

For the Target Identification Number in this example, the resolution is 1, which is the value of the least significant bit (LSB) of the reference byte. Therefore, the least significant byte will be the reference byte. Since byte offset is defined as a signed integer indicating the position of the least significant byte of a data element relative to the reference byte, the byte offset for the Target Identification Number data element will be ZERO. The maximum value of this parameter, 4000, lies within the range of values for the byte identified as the first more significant byte in Table 2 of STANAG 4222. Therefore, the Target Identification Number parameter can be represented by a data element consisting of two bytes, with a byte offset equal to ZERO.

For the Target Range Parameter, the required resolution is 3.048 meters. Use of the reference byte as the least significant byte provides a resolution of 1 meter. Therefore, the byte offset will be ZERO. The maximum value for Target Range is 463 000 meters. Examination of Table 2 of STANAG 4222 shows that the byte identified as the second more significant byte satisfies this requirement. The Target Range data element will therefore consist of three bytes with a byte offset of ZERO.

The Target Bearing parameter in this example has a required resolution of 0.000694 FC. Since the reference byte has an LSB = 1 FC, lesser significant bytes must be examined in order to satisfy the resolution requirement. The first less significant byte has an LSB = 0.003 FC, which does not satisfy the requirement. The second less significant byte has an LSB = 0.000015 FC, which does satisfy the resolution requirement. Therefore, this will be the least significant byte of the data element, and the data element will have a byte offset of -2. The maximum value required for the Target Bearing parameter is 1 FC, however, this can be redefined as a requirement to represent ±0.5 FC within the required resolution. The maximum value requirement can be satisfied by using the first less significant byte. Therefore, the Target Bearing data element consists of two bytes and has a byte offset equal to -2.

In this example, the Time Tag parameter has a resolution of 0.01 s, which requires use of the first less significant byte, resulting in a byte offset equal to -1. The maximum value of this parameter is 2 592 000 s, which requires use of the second more significant byte. Therefore, the Time Tag data element will consist of four bytes with a byte offset of -1.

Table 2 of this ANEP, derived from Table 2 of STANAG 4222, illustrates the required range of values of the parameters considered and how the number of bytes and byte offset required to format the data elements are determined.

It is noted that STANAG 4222 specifies that bit positions between the most significant bit (MSB) of the parameter absolute value and the MSB of the most significant byte shall be equal in value to the sign bit. Furthermore, STANAG 4222 states that otherwise unused bit positions between the LSB of the parameter absolute value and the LSB of the least significant byte are undefined. Figure 8 illustrates the format of the parameters used in this example when the above rules are applied.

6.6 Alternative Data Parameter Representations

Other data parameters can be represented by following the basic procedures outlined in 6.1 through 6.5. The system design/integration engineer may find it necessary to use the alternative representation formats (real [floating point], alphanumeric, binary coded decimal, Boolean [single bit discrete], or Enumerated [multi bit discrete]) for certain parameters. For example, the trigonometric function, tangent, may be best represented using double precision real (floating point) format. If alphabetic information is to be encoded and transmitted between processing devices, alphanumeric format is appropriate. An application in which BCD format might be considered appropriate is the transmission of clock time (e.g., hour and minute). Discrete format may be specified for identification, classification, or status information. In these cases, the rules presented in STANAG 4222 must be followed.

7. PARAMETER IDENTIFIERS

7.1 General

The need for parameter identifiers is implementation dependent, hence their use is not mandatory in STANAG 4222. Two types of parameter identifier are recognized, the decimal identifier and a system dependent descriptor. If used, the first must conform to the allocation and/or rules given in the standard. The second is for free use by the system designer

7.2 Decimal Identifiers

Each group, and parameter within a group is assigned a unique decimal value for data processing purposes.

Decimal values are allocated to individual parameters and listed in Table 3. Otherwise unallocated values are available as spare parameter identifiers.

8. RECOMMENDATIONS ON DATA ELEMENT TRANSMISSION

8.1 General

Data element transmission is not properly in the province of STANAG 4222. Nevertheless, during the preparation of that document it was realized that there are some important aspects concerning the presentation of the data at a transmission interface which are germane to the objectives of the STANAG but are not currently covered elsewhere. The following paragraphs provide recommendations which will aid in achieving compatibility and interoperability between operating devices. In the event of conflict with any other applicable STANAG, STANAG 4222 shall take precedence.

8.2 Data Word Length

It is recognized that the system design/integration engineer will specify the exchange of data elements between processing devices which are internally word organized, and the word lengths of these devices are not necessarily the same. The number of bytes in a data word should be determined at the system application level. The allocation of a data element over a sequence of words may be done without regard to word length limits.

8.3 Order of Transmission

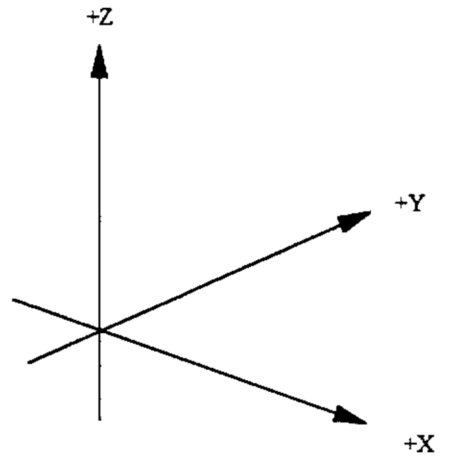
The least significant byte within each data element should be transmitted first. In the event that a data element requires more than one byte, the least significant byte should be followed by the more significant byte(s) in ascending numerical order.

In the event that a data element occupies two or more words, the word containing the least significant part of the data element should be transmitted first, followed by the word(s) containing the more significant part(s) of the data element.

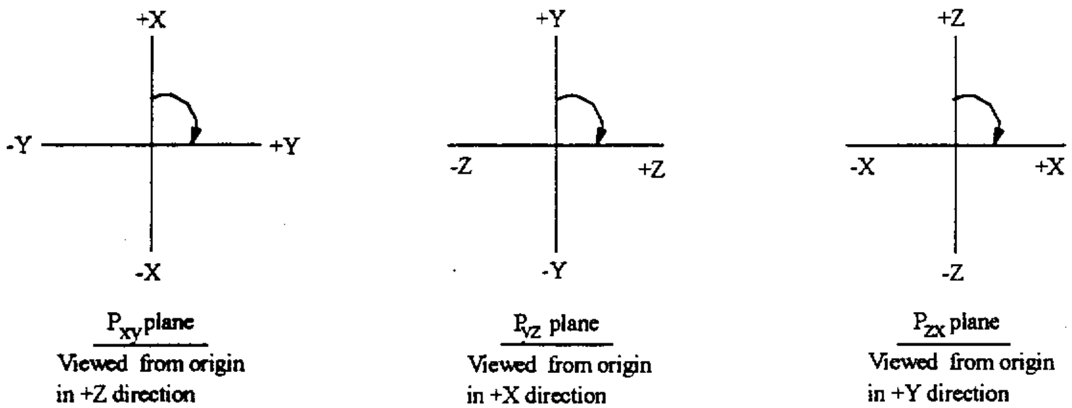
When serial transmission is used, the LSB of each byte should be transmitted first.

8.4 Validity

The system designer/integration engineer should determine whether or not validity bits are to be used. When specified, all validity bits should be places in a 'validity' byte (or bytes) starting from the LSB position. No other data should be included in the validity byte(s). The system design/integration engineer should establish the correlation between validity bits and data elements. A valid data element should be indicated by the corresponding validity bit set to 'zero'. No recommendation is made regarding unused bit positions.



(a) Coordinate system corresponds to the right-hand rule convention.

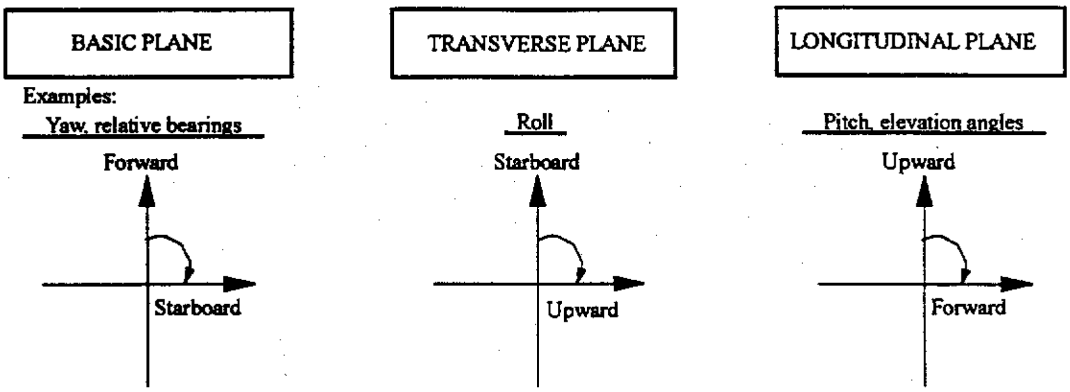


(b) The reference and direction of measurement of angles is similar in all three planes.

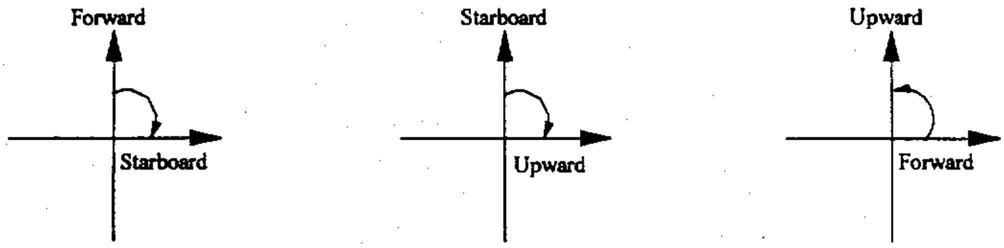
Note: Only the relative directions have significance in this figure. The orientation on the paper is arbitrary.

CONVENTIONS IN THE SCIENTIFIC NOTATION FOR
CARTESIAN COORDINATES

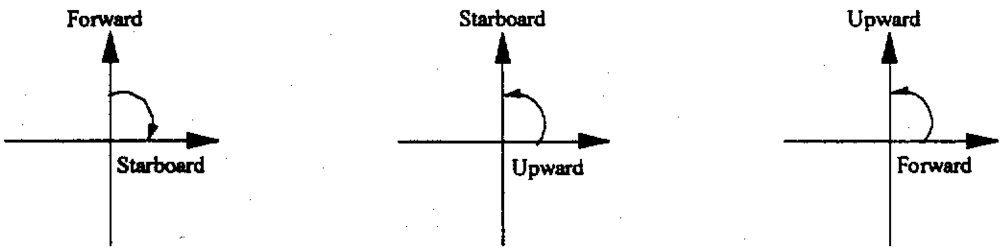
FIGURE 1



(a) A pure left hand rule which is compliant with Navy accepted basic plane convention, is compliant with some nations on convention in the transverse plane (roll), but measures angles in the longitudinal plane, e.g., 'elevation' downwards from the upwards axis.



(b) A set of coordinate conventions commonly used by Navies and which break the left-hand rule in the longitudinal plane.

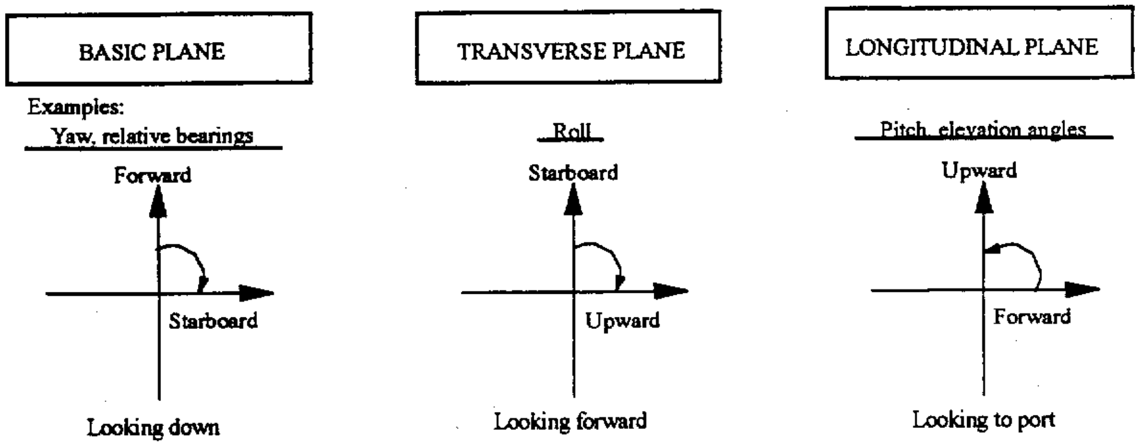


(c) A set of coordinate conventions also commonly used which break the left-hand rule in the transverse and longitudinal planes.

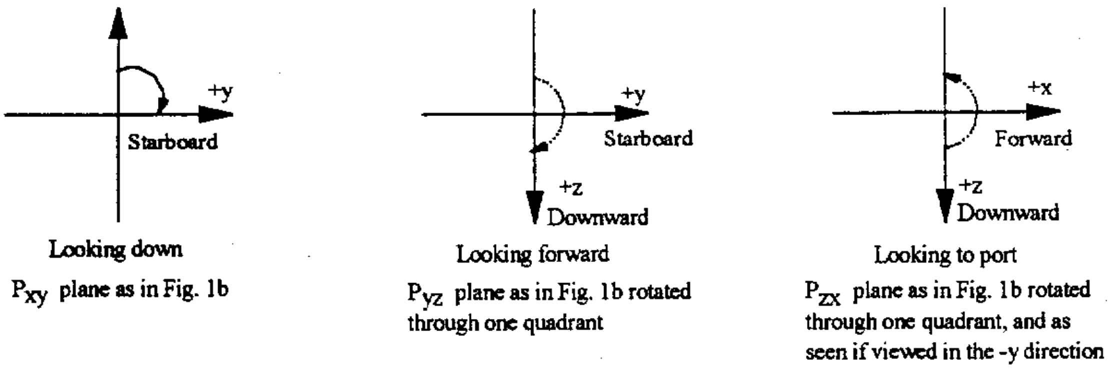
NOTE: Arrowheads indicate positive directions.

COMPARISON OF A LEFT-HAND RULE COORDINATE SYSTEM WITH TWO USER CONVENTIONAL SYSTEMS

FIGURE 2



(a) One set of coordinate conventions commonly used aboard ship. The same as Figure 2c with the transverse plane redrawn for illustrative convenience.



(b) The scientific notation used in STANAG 4222 redrawn for comparison with (a) above.

Although values in the upward direction have to be signed 'negative' within the data handling process, all other directions, both linear and angular, conform to a set of user conventions. The change of reference axis in the transverse and longitudinal planes requires only the addition of +/-FC.

4

A TYPICAL USER COORDINATE SYSTEM COMPARED WITH THE STANAG 4222 DEFINED SYSTEM

FIGURE 3

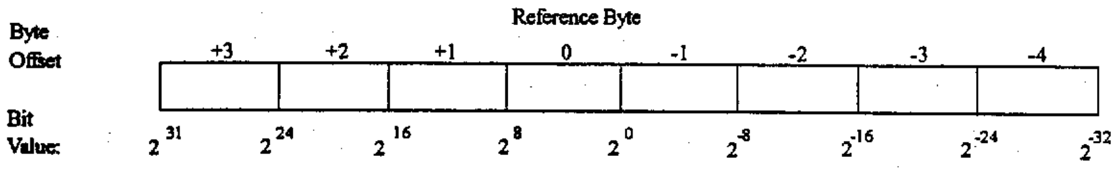
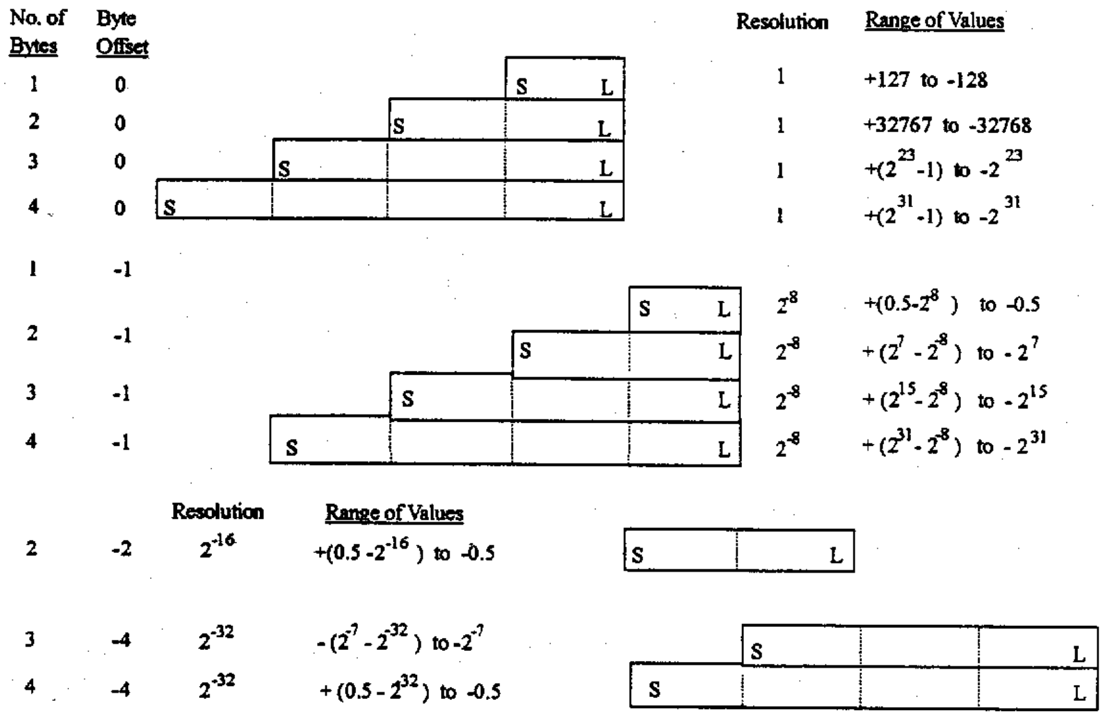


Figure 4(a) The reference byte and offset values



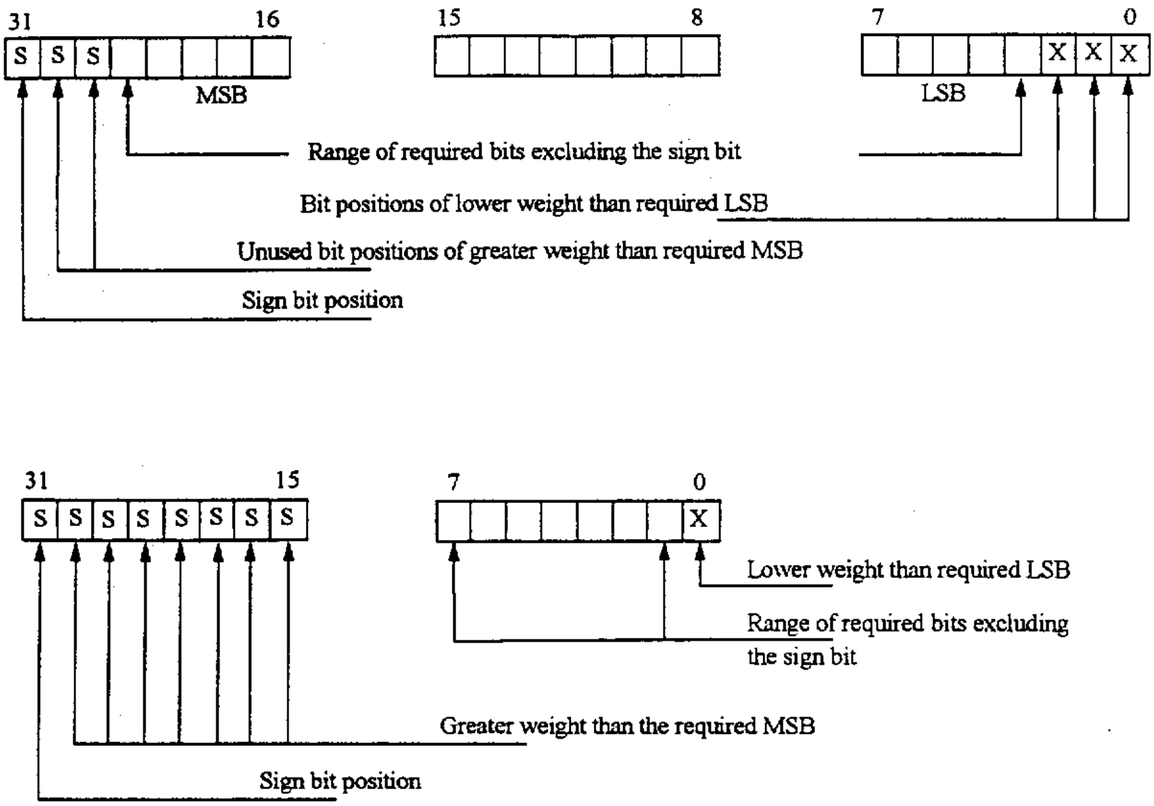
S = Implied Sign bit (value is '0' when represented number is '0' or positive, and '1' when it is negative.

L = Least significant bit. Its bit value = Resolution of the number.

Figure 4(b) Examples of byte offsets and numbers of bytes.

OCTET STRING (FIXED POINT) REPRESENTATION; THE BYTE SIGNIFICANCE

FIGURE 4



Examples illustrating the position of the implied sign (2's complement) bit and the required values to be assigned to unused bit positions.

Unused bit positions are filled at the MSB end with the 'sign' value, and at the LSB end with 'don't cares'.

OCTET STRING (FIXED POINT) REPRESENTATION: FORMAT OF MOST AND LEAST SIGNIFICANT BYTES

FIGURE 5

Single precision floating point data element. A 32-bit (4-byte) format having a 1-bit sign, an 8-bit exponent, and a 23-bit fraction.

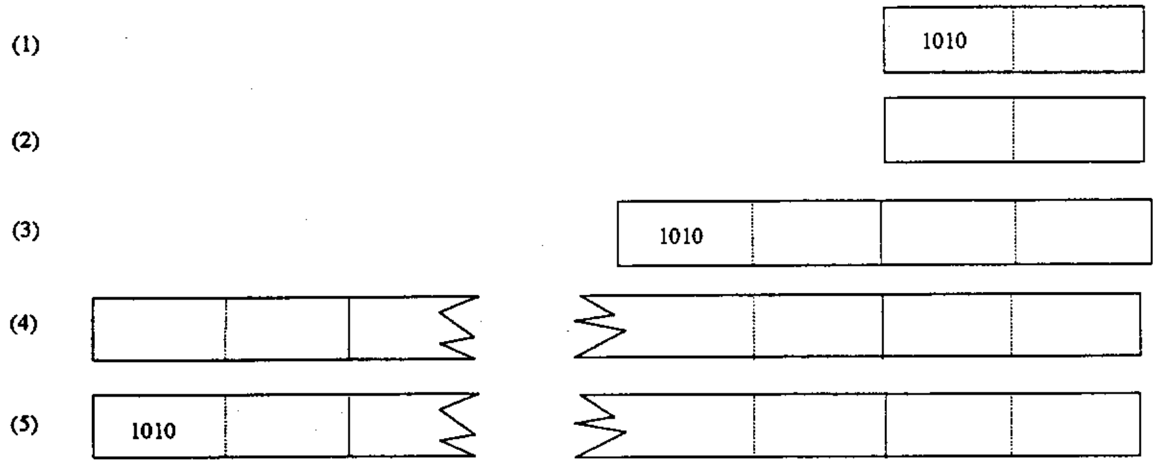
Double precision floating point data element. A 64-bit (8-byte) format having a 1-bit sign, an 11-bit exponent, and a 52-bit fraction.

These formats are derived from IEC Standard, Publication 559.

REAL (FLOATING POINT) REPRESENTATION FORMATS

FIGURE 6

EXAMPLES OF ALLOWED BINARY CODED DECIMAL DATA ELEMENTS



(1) Represents one decimal digit. The least significant half-byte is used for the decimal digit. The more significant half-byte is coded as a SPACE (1010). BCD data must be transmitted using an integral number of bytes.

(2) Represents two decimal digits. The values of two decimal digits can be coded within one byte.

(3) Represents three decimal digits following the rules outlined in (1) above.

(4) Represents the format of BCD data element with (2*N) (i.e., an even number) decimal digits where N is the number of bytes.

(5) Represents the format of a BCD data element with (2*N-1) (i.e., an odd number) decimal digits where N is the number of bytes..

BINARY CODED DECIMAL FORMAT

FIGURE 7

TARGET IDENTIFICATION NUMBER

Byte Offset 0
Resolution 1
Maximum Value 4095

s s s s v v v v	v v v v v v v v (LSB)

2048 … 1

TARGET RANGE

Byte Offset 0
Resolution 2 meters
Maximum Value 524 286 meters

s s s s s v v v	v v v v v v v v	v v v v v v v x

262 144 … 2

TARGET BEARING

Byte Offset -2
Resolution 0.000 4 Full Circle
Maximum Value 0.499 6 Full Circle

s v v v v v v v	v v v x x x x x

0.25 … 0.0004

TIME TAG

Byte Offset -1
Resolution 0.007 second
Maximum Value 4 194 303.993 second

s s v v v v v v	v v v v v v v v	v v v v v v v v	v v v v v v v x

2 097 152 … 0.007

S = SIGN
V = PARAMETER VALUE
X = UNDEFINED BIT

DATA ELEMENT FORMATS

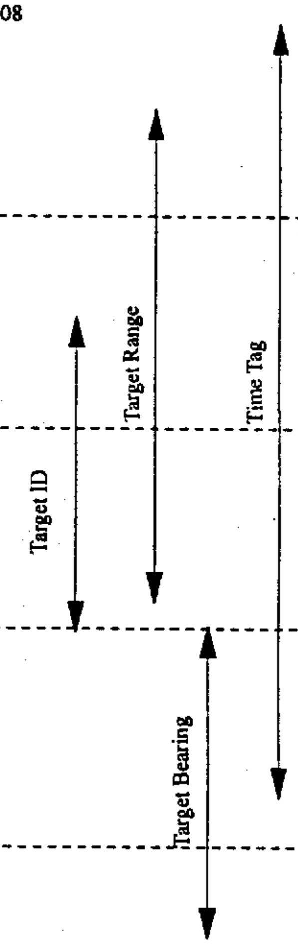
FIGURE 8

TABLE I. NUMERICAL CALENDAR

Day of Month	Day of Year											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
01	001	032	060	091	121	152	182	213	244	274	305	335
02	002	033	061	092	122	153	183	214	245	275	306	336
03	003	034	062	093	123	154	184	215	246	276	307	337
04	004	035	063	094	124	155	185	216	247	277	308	338
05	005	036	064	095	125	156	186	217	248	278	309	339
06	006	037	065	096	126	157	187	218	249	279	310	340
07	007	038	066	097	127	158	188	219	250	280	311	341
08	008	039	067	098	128	159	189	220	251	281	312	342
09	009	040	068	099	129	160	190	221	252	282	313	343
10	010	041	069	100	130	161	191	222	253	283	314	344
11	011	042	070	101	131	162	192	223	254	284	315	345
12	012	043	071	102	132	163	193	224	255	285	316	346
13	013	044	072	103	133	164	194	225	256	286	317	347
14	014	045	073	104	134	165	195	226	257	287	318	348
15	015	046	074	105	135	166	196	227	258	288	319	349
16	016	047	075	106	136	167	197	228	259	289	320	350
17	017	048	076	107	137	168	198	229	260	290	321	351
18	018	049	077	108	138	169	199	230	261	291	322	352
19	019	050	078	109	139	170	200	231	262	292	323	353
20	020	051	079	110	140	171	201	232	263	293	324	354
21	021	052	080	111	141	172	202	233	264	294	325	355
22	022	053	081	112	142	173	203	234	265	295	326	356
23	023	054	082	113	143	174	204	235	266	296	327	357
24	024	055	083	114	144	175	205	236	267	297	328	358
25	025	056	084	115	145	176	206	237	268	298	329	359
26	026	057	085	116	146	177	207	238	269	299	330	360
27	027	058	086	117	147	178	208	239	270	300	331	361
28	028	059	087	118	148	179	209	240	271	301	332	362
29	029		088	119	149	180	210	241	272	302	333	363
30	030		089	120	150	181	211	242	273	303	334	364
31	031		090		151		212	243		304		365

NOTE: In the leap year "1" has to be added in each case after February 28.

	BIT POSITION RELATIVE TO LSB OF REFERENCE BYTE	BIT VALUE
	23	8 388 608
SECOND MORE SIGNIFICANT BYTE (BYTE OFFSET = +2)		
	16	65 536
	15	32 768
FIRST MORE SIGNIFICANT BYTE (BYTE OFFSET = +1)		
	8	256
	7	128
REFERENCE BYTE (BYTE OFFSET = 0)		
	0	1
	-1	0.500
FIRST LESS SIGNIFICANT BYTE (BYTE OFFSET = -1)		
	-8	0.003 906+
	-9	0.001 953+
SECOND LESS SIGNIFICANT BYTE (BYTE OFFSET = -2)		
	-16	0.000 015+



DETERMINING NUMBER OF BYTES AND BYTE OFFSET

TABLE 2

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
0	— NOT USED —
1	ALTITUDE
2	DEPTH
3	DISTANCE
4	ELEVATION (relative to sea level)
5	— SPARE —
6	HEIGHT
7	LENGTH
8	RANGE
9	— SPARE —
10	— SPARE —
11	VISIBILITY
12	WIDTH
13	X-COORDINATE
14	Y-COORDINATE
15	Z-COORDINATE
16	— SPARE —
17	— SPARE —
18	— SPARE —
19	— SPARE —
20	— SPARE —
21	DISPLACEMENT
22	LIQUID VOLUME
23	VOLUME
24	— SPARE —
25	— SPARE —
26	— SPARE —
27	— SPARE —

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
28	RANGE RATE
29	SPEED
30	VELOCITY
31	VERTICAL RATE
32	WIND SPEED
33	HEAVE
34	SURGE
35	SWAY
36	DRIFT
37	--- SPARE ---
38	--- SPARE ---
39	--- SPARE ---
40	ALTITUDE
41	AZIMUTH
42	BEARING
43	COURSE
44	CROSS-LEVEL
45	DEVIATION
46	ELEVATION ANGLE
47	HEADING
48	LATITUDE
49	LEVEL
50	LONGITUDE
51	PITCH
52	ROLL
53	ROTATION
54	TRAIN
55	VARIATION

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
56	WIND DIRECTION
57	YAW
58	SET
59	--- SPARE ---
60	--- SPARE ---
61	--- SPARE ---
62	--- SPARE ---
63	--- SPARE ---
64	--- SPARE ---
65	AREA
66	--- SPARE ---
67	ANGULAR VELOCITY
68	THERMODYNAMICS
69	ELECTRICITY AND MAGNETISM
70	FORCE RELATED
71	ANGULAR MEASURE
72	MECHANICS
73	LIGHT
74	--- SPARE ---
75	--- SPARE ---
76	LINEAR MEASURE
77	TIME
78	LINEAR VELOCITY
79	ACOUSTICS
80	ENVIRONMENTAL
81	--- SPARE ---
82	LINEAR ACCELERATION
83	MASS RELATED

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
84	ANGULAR ACCELERATION
85	MISCELLANEOUS
86	VOLUME
87	FLOW
88	RADIATION
89	--- SPARE ---
90	--- SPARE ---
91	--- SPARE ---
92	--- SPARE ---
93	AZIMUTH RATE
94	BEARING RATE
95	ELEVATION RATE
96	HEADING RATE
97	PITCH RATE
98	ROLL RATE
99	ROTATION RATE
100	TRAIN RATE
101	YAW RATE
102	--- SPARE ---
103	--- SPARE ---
104	--- SPARE ---
105	--- SPARE ---
106	--- SPARE ---
107	INTERVAL
108	SYNCHRONIZATION
109	TIME TAG
110	ORDINAL DATE
111	TIME OF THE DAY

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
112	— SPARE —
113	— SPARE —
114	— SPARE —
115	— SPARE —
116	— SPARE —
117	CARGO CAPACITY
118	FUEL CAPACITY (gravimetric)
119	MASS
120	PAYLOAD
121	WEIGHT
122	LINEAR DENSITY
123	SURFACE DENSITY
124	DENSITY
125	RELATIVE DENSITY (use Ratio)
126	— SPARE —
127	— SPARE —
128	— SPARE —
129	— SPARE —
130	— SPARE —
131	FORCE
132	THRUST
133	TORQUE
134	ATMOSPHERIC PRESSURE
135	FLUID PRESSURE (air, steam, liquid)
136	PRESSURE
137	STRESS
138	VACUUM
139	— SPARE —

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
140	--- SPARE ---
141	--- SPARE ---
142	--- SPARE ---
143	ENERGY or WORK
144	EQUIVALENT SHAFT POWER
145	FREQUENCY
146	POWER
147	ROTATIONAL FREQUENCY
148	--- SPARE ---
149	--- SPARE ---
150	--- SPARE ---
151	--- SPARE ---
152	--- SPARE ---
153	MASS FLOW
154	FLUID FLOW
155	DYNAMIC VISCOSITY
156	KINEMATIC VISCOSITY
157	--- SPARE ---
158	--- SPARE ---
159	--- SPARE ---
160	--- SPARE ---
161	--- SPARE ---
162	HEAT FLOW PER UNIT AREA
163	HEAT FLOW RATE
164	QUANTITY OF HEAT
165	TEMPERATURE
166	--- SPARE ---
167	--- SPARE ---

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
168	— SPARE —
169	— SPARE —
170	— SPARE —
171	CAPACITANCE
172	CONDUCTANCE
173	CONDUCTIVITY
174	CURRENT
175	CURRENT DENSITY
176	DISTORTION (use Ratio)
177	ELECTRIC FIELD STRENGTH
178	ELECTRICAL POTENTIAL
179	FREQUENCY
180	INDUCTANCE
181	MAGNETIC FIELD STRENGTH
182	MAGNETIC FLUX
183	MAGNETIC FLUX DENSITY
184	POWER
185	QUANTITY OF ELECTRICITY
186	RESISTANCE
187	— SPARE —
188	— SPARE —
189	— SPARE —
190	— SPARE —
191	— SPARE —
192	— SPARE —
193	ENERGETIC LUMINOUS FLUX
194	ILLUMINANCE
195	LUMINANCE

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
196	LUMINOUS FLUX
197	LUMINOUS INTENSITY
198	LUMINOUS POWER
199	LUMINOUS POWER LEVEL
200	QUANTITY OF LIGHT
201	WAVELENGTH
202	--- SPARE ---
203	--- SPARE ---
204	--- SPARE ---
205	--- SPARE ---
206	--- SPARE ---
207	--- SPARE ---
208	FREQUENCY
209	SOUND INTENSITY
210	SOUND POWER
211	SOUND PRESSURE (instantaneous)
212	SOUND POWER LEVEL
213	SOUND PRESSURE LEVEL
214	STATIC PRESSURE
215	VELOCITY OF SOUND
216	VOLUME VELOCITY
217	WAVELENGTH
218	--- SPARE ---
219	--- SPARE ---
220	--- SPARE ---
221	--- SPARE ---
222	--- SPARE ---
223	--- SPARE ---

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
224	ABSORBED DOSE
225	ABSORBED DOSE RATE
226	DOSE EQUIVALENT
227	EXPOSURE RATE
228	RADIATION EXPOSURE
229	--- SPARE ---
230	--- SPARE ---
231	--- SPARE ---
232	--- SPARE ---
233	--- SPARE ---
234	--- SPARE ---
235	ATMOSPHERIC PRESSURE
236	TEMPERATURE
237	--- SPARE ---
238	--- SPARE ---
239	--- SPARE ---
240	--- SPARE ---
241	--- SPARE ---
242	--- SPARE ---
243	CONSTANTS
244	CONVERSION FACTORS
245	MATHEMATICAL FUNCTIONS
246	RATIO
247	PERIODIC EVENT
248	INTEGER
249	--- SPARE ---
250	--- SPARE ---
251	--- SPARE ---

TABLE 3 - LISTING OF DECIMAL IDENTIFIERS	
DECIMAL IDENTIFIER	
252	— SPARE —
253	— SPARE —
254	— SPARE —
255	— SPARE —

ANNEX A

REFERENCED AND RELATED DOCUMENTS

RELATED DOCUMENTS

ISO 1000	SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units (Second Edition 1981-02-15)
ISO 31/0	General Introduction - General Principles Concerning Quantities, Units and Symbols (Second Edition 1981-07-01)
ISO 31/I	Quantities and Units of Space and Time
ISO 31/II	Quantities and Units of Periodic and Related Phenomena
ISO 31/III	Quantities and Units of Mechanics
ISO 31/IV	Quantities and Units of Heat
ISO 31/V	Quantities and Units of Electricity and Magnetism
ISO 31/6	Quantities and Units of Light and Related Electromagnetic Radiations
ISO 31/VII	Quantities and Units of Acoustics
ISO 31/10	Quantities and Units of Nuclear Reactions and Ionizing Radiations
ISO 1503	Geometrical Orientation and Directions of Movement
ISO 2711	Information Processing Interchange - Representation of Ordinal Dates
ISO 3307	Information Interchange - Representations of Time of the Day
ISO R963	Guide for Definition of 4-bit Characters Derived from the ISO 7-bit Coded Character Set for Information Processing Interchange
ISO/IEC 4873: 1991(E)	Information Technology - ISO 8-bit Code for Information Interchange - Structure and Rules for Implementation

RELATED DOCUMENTS

ISO/IEC 8824: 1990(E)	Abstract Syntax Notation One (ASN.1)
IEC 559:1989	Binary Floating Point Arithmetic for Microprocessor Systems
ANSI/IEEE 754-1985	IEEE Standard for Binary Floating-Point Arithmetic

ANNEX B

COMPARISON OF ALGEBRAIC NUMBER REPRESENTATIONS

IN THE

PURE BINARY NUMERATION SYSTEM

B-1 INTRODUCTION

To represent an algebraic number in the pure binary numeration system, three possibilities exist:

A. Representation by the absolute value and the sign

B. Representation by the diminished complement (one's complement)

C. Representation by the radix complement (two's complement)

In the three cases, if the total number of bits of a signed number is 'n', including the sign bit, the sign bit is in the MSB position.

B-2 REPRESENTATION OF A POSITIVE NUMBER

The representation of a positive number is identical in the three cases A, B, and C; i.e.,

- The plus sign is represented by the digit '0' (zero)
- The number is represented by the absolute value in the pure binary numeration system.

Example 1:

Positive Number in Decimal Numeration			Positive Number in Pure Binary Numeration	
			n = 5 bits	
+	7		0	0 1 1 1
Sign	Absolute Value in Decimal Numeration		Sign	Absolute Value in Pure Binary Numeration

B-3 REPRESENTATION OF A NEGATIVE NUMBER

B-3.1 Case A - Absolute Value and Sign

With Case A, the representation of a negative number is as follows:

- The minus sign is represented by the digit '1' (one)
- The number is represented by the absolute value in pure binary numeration.

Example 2:

Negative Number in Decimal Numeration			Negative Number in Pure Binary Numeration	
			n = 5 bits	
-	7		1	0 1 1 1
Sign	Absolute Value in Decimal Numeration		Sign	Absolute Value in Pure Binary Numeration

This representation requires special sign processing and it is necessary to use different algorithms for addition and for subtraction.

B-3.2 Case B - One's Complement

With Case B, a negative number is represented by the diminished (radix 2), or one's complement of the corresponding positive number. The mechanism is, from the positive number, to change the digits '0' to digits '1' and the digits '1' to digits '0'.

Example 3:

Positive Number in Decimal Numeration			Positive Number in Pure Binary Numeration	
			n = 5 bits	
+	7		0	0 1 1 1
Negative Number in Decimal Numeration			Negative Number in the Diminished (One's Complement) Numeration	
-	7		1	0 1 1 1
Sign	Absolute Value in Decimal Numeration		Sign	One's Complement Value

This representation introduces a small difficulty in computation algoritms which must recognize two different binary representations of the number 'zero', either all 'zeros' or all 'ones'.

B-3.3 Case C - Two's Complement

With Case C, a negative number is represented by the radix (2), or two's complement of the corresponding positive number. The mechanism is, from the positive number:

- to obtain the one's complement value (see paragraph 3.2)
- to add the absolute value '1' in pure binary numeration to the one's complement value.

Example 4:

Positive Number in Decimal Numeration			Positive Number in Pure Binary Numeration	
			n = 5 bits	
+	7		0	0 1 1 1
			One's Complement Value	
			1	1 0 0 0
			Absolute Value '1'	
			0	0 0 0 1
Negative Number in Decimal Numeration			Negative Number in the Radix (Two's) Complement	
-	7		1	1 0 0 1
Sign	Absolute Value in Decimal Numeration		Sign	Two's Complement Value

Example 5:

Positive Number in Decimal Numeration			Positive Number in Pure Binary Numeration	
			n = 5 bits	
+	0		0	0 0 0 0
			One's Complement Value	
			1	1 1 1 1
			Absolute Value '1'	
			0	0 0 0 1
Negative Number in Decimal Numeration			Negative Number in the Radix (Two's) Complement (Identical to the Positive Number)	
-	0		0	0 0 0 0
Sign	Absolute Value in Decimal Numeration		Sign	Two's Complement Value

This representation is the most used one because it simplifies addition and subtraction operations. In addition, the representation of the number 'zero' is unique.