The construction of meaning in the discourse of electronics: A systemic-functional approach*

La construcción del significado en el discurso de la electrónica: un discurso sistémico-funcional

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ABSTRACT

This paper is concerned with the lexico-grammatical resources the English language uses to construct meaning in engineering texts, particularly in those texts addressed to students where verbal and non-verbal language —i.e. mathematics, tables and graphs— combine. The initial hypothesis is that non-verbal representation texts can be analysed in the same way as any verbal text and that both verbal and non-verbal texts integrate in such a way that they constitute a powerful social-semiotic resource to create specific ways of meaning. Drawing on genre and on systemic theory, which views language as a meaning-making system rather than an expression-making one, several texts from the field of electronics have been analysed in the light of the three linguistic metafunctions proposed by Halliday (1978, 1985a), namely, ideational, interpersonal and textual.

KEY WORDS

Functional grammar. Semiotics. Technical writing. Discourse analysis

RESUMEN

Este artículo trata de los recursos léxico-gramaticales que la lengua inglesa utiliza para construir significado en los textos de ingeniería, particularmente en los textos para estudiantes en los que el lenguaje verbal y el no-verbal, esto es, matemática, tablas y gráficas, se combina. Se parte de la hipótesis de que estos textos se pueden analizar como los textos puramente verbales, y que, precisamente, la combinación del lenguaje verbal con el matemático y abstracto constituye un poderoso recurso soci-semiótico capaz de crear modos específicos de significado. Basándonos en la teoría sistémica se analizan varios textos del campo de electrónica recurriendo a las tres metafunciones propuestas por Halliday (1978, 1985a): experimental, inter-personal y textual.

PALABRAS CLAVE

Gramática sistémica. Semiótica. Escritura técnica. Análisis del discurso

1. Introduction

Most teaching material used in English for Science and Technology (EST) classes consists of texts which illustrate typical examples of scientific and technical genres. However, actual engineering texts are made up of a mixture of words, graphs and symbols, with words representing only a very small proportion of the text in some cases. Verbal texts are combined with mathematical expressions, quantitative graphs, information tables, abstract diagrams, and other visuals, which, in addition, are often directly integrated into a line of running verbal text, and into its syntax, thus extending grammatical resources in register-specific ways. In this sense, written technical texts are not meant to be read according to a unique implied sequence and represent a primitive form of *hypertext*. Lemke suggests that they are "semiotic *hybrids*, simultaneously and essentially verbal, mathematical, visual and actional-operational"; therefore, they are better defined as *multi-media genres* (Lemke, 1998: 87). How, then, is meaning achieved in these texts, and in which way can they be analysed?

With the purpose of answering these questions, this paper sets out to analyse some engineering texts from the field of electronics. In so doing we will resort to genre theory and more particularly on the functional approach to genre deployed by Halliday and Martin (1993). This theoretical framework may allow us to understand how readers make meaning by linking text and figure, sentence and equation and how knowledge is construed in the discourse of electronics.Our initial hypothesis is that *hybrid* texts may be analysed in a similar manner as any other technical text,and that,underlying mathematical expressions, graphs and figures, there is always an implicit grammar.

Because of its focus on text, the discussion will be further restricted to just a few examples, selected as representative of basic features of the discourse of university engineering students. The texts analysed are from engineering text-books from the field of electronics and provide a major model of discipline-specific discourse. They come from *Power Electronics*, by N. Mohan, T. M. Undeland and W.P Robbins.(1995 2nd ed. 800 pp) and *Digital Design*, by J.F.Wakerly (1994 2nd ed. 840 pp). The most outstanding feature of the books is the combining of verbal and non-verbal language, that is, text, mathematics and graphs[1].

2. Theoretical framework: a systemic interpretation of meaning

According to the functional model of language as first devised by Halliday, and canonised by Martin's "systemiotic approach" on genre (term used by Ventola 1988), it is the context of culture (genre) and the context of situation (register) that insert and actually shape the meanings of texts. To account for the integral relationship between the structure of language and the structure of social relations, systemicists accordingly interpret language as "*linguistic*

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— Title: *Power Electronics. Converters. Applications, and Design*. TK7881.15.M64 1995 621.317 · dc20— Author/s: Ned MOHAN, Tore M. UNDERLAND and William P. ROBBINS - Editor: John Wiley & Sons Inc.

behaviour potential or the range of options from which a person's language and the culture to which he belongs allow him to select the range of possible things that 'he can do' linguistically" (Berry 1976: 24).

This view of language allows us to describe language genres, both oral and written, as subsets within a language that limit the speakers' choices in certain socially prescribed ways. The structure potential of a genre is an abstract category which specifies the "total range of optional and obligatory elements and their order in such a way that we exhaust the possibilities of text structure" available for selection within a genre (Halliday and Hasan 1985: 64). Genres, thus, express a potential for meaning in themselves because the restricted range of linguistic features that they use differs from the full range of possibilities within a language. Hence this difference in *valeur* within a system, in Saussure's sense, creates a context for *meaning*.

Considering language as social behaviour makes it possible for us to analyse the lexicon and grammar of a language as correlates of the social properties of a communication event in the culture where the language is spoken. The speaker's choice of one lexical or grammatical item over another limits the meaning potential of the text in specific ways, so that they can be understood by speakers of the same discourse community.

Halliday assumes that all languages express the potential for three kinds of meaning: ideational, or experiential meaning, interpersonal meaning and textual meaning. *Ideational meaning*, which is related to the field in the context of situation, refers to the way language represents our experience of the world —people, places, things and activities that make up our physical and psychological environment (*what is going on*. Halliday 1985a: 26). This meaning is realised in language through the grammar of transitivity system, the key elements being Processes (events or goings on in the world), Participants (people, places and things involved in processes) and Circumstances (places, time, manner, causes associated with processes).

Interpersonal meaning refers to the tenor of discourse (*who are taking part*). Language is described in terms of interactional properties. Through the interpersonal function "social groups are delimited, and the individual is identified and reinforced."

Finally, *textual meaning* for Halliday is expressed through those features of language by which it makes "links with itself and with features of the situation in which it is used". (1985a: 26) Textual theme and cohesion are among the grammatical features that express potential for meaning about the mode of discourse or the role assigned to language in a particular communication event (1985a: 26).

In this same line Lemke (1989, 1990, 1992, 1998) suggests that all meaning-making has become organised around three generalised semiotic functions which he terms presentational, orientational and organizational and which corrrespond to the three linguistic metafunctions of Halliday. This interpretation is central to genre theory.

These researchers (Halliday and Hasan, 1976, 1985; Hasan, 1984; Lemke, 1988, 1995) have also shown that ideational meaning contributes to organisational-textual ones through, for instance, cohesion and cohesive harmony and so do interpersonal-attitudinal ones. Likewise, textual/organisational meanings contribute to ideational ones by means of defining clauses, clause-complexes, rhetorical structure units and larger units of intertextual relationship, and in similar ways to the interpersonal and attitudinal texture of a text (Lemke, 1988; Mann and Thompson, 1986). Ideational choices of lexis, in turn, "contribute to the attitudinal stance of a text to its audience, to its content, and to other text-embodied viewpoints" (Lemke, 1998: 92). Following this line of reasoning, this paper will attempt to show to which extent mathematical expressions and graphs may contribute to the construction of meaning in electronic texts.

3. The discourse of electronics

3.1. Ideational meaning

Scientists use several lexico-grammatical resources in order to construct their field of knowledge, that is, their ideational domain. Electronics discourse is concerned with physical systems. In particular it is concerned with the quantitative behaviour of such systems. To facilitate understanding and analysis of such systems, several linguistic resources have been evolved. Meaning in these texts has been mostly achieved through what Martin (Halliday and Martin, 1993) terms *implication sequences*.

3.1.1. Verbal texts

Implication sequences are typically realised in language through cause and effect, condition, and time sequence patterns. The purpose of these texts is to describe a sequence of events which is particularly relevant to technology, such as the following example about the functioning of *dc motors* shows:

Text 1

In line frequency phase-controlled converters and single-quadrant step-down switch mode dc-dcconverters, the output current can become discontinuous at light loads on the motor. For a fixed control voltage *v control* or the delay angle @, the discontinuous current causes the output voltage to go up. This voltage rise causes the motor speed to increase at low values of *I*, as shown generically by Fig. 13-17. With a continuously flowing *i*, the drop in speed at higher torques is due to the voltage drop *RI* across the armature resistance; additional drop in speed occurs in the phase-controlled converter-driven motors due to commutation voltage drops across the ac-side inductance L, which approximately equal I in single-phase converters and in three-phase converters. These effects result in poor speed regulation under an open-loop operation.

Sources that produce these disturbances are very diverse. Overvoltages may be caused by sudden decreases in the system load, thus causing the utility voltage to go up. Undervoltages may be caused by overload conditions, by start of induction motors, or for many other reasons. Occasional large voltages spikes may be a result of switching in or out of power factor correction capacitors, power lines, or even such things as pump/compressor motors in the vecinity. Chopping of the voltage waveform may be caused by ac-to-dc line-frequency thyristor converters of the type discussed in Chapter 6 (Mohan et al 1995: 355).

The main purpose of this text is not only to describe *how* a particular sequence of events occurs, but mainly *why* it occurs. For this reason, events are linked both as a sequence and as a set of cause and effect relationships. Cause and effect relationships between events are emphasised in this sequence. This is due to the fact that causal explanations deal with either abstract entities and properties or describe events which are not generally accessible to immediate observation or experience but which, nevertheless, have to be made explicit to our understanding. Knowing, for example, how an engine operates does not provide us with the resources for designing new engine-devices. We need to know which other factors are involved in the process and what will happen if these factors are altered: this implies using cause and effect relationships. This can be seen if we deconstruct the text into its generic constituents:

Effect	**Cause**
Overvoltages (*may be caused*)	by sudden decreases in the system load *This causes*
the utility voltage to go up.	
Undervoltages(*may be caused by*)	a) overload conditions b) start of induction motors c) other reasons
Occasional large voltages spikes (*may be a result of*)	switching in or out of power factor correction capacitors, power lines...
Chopping of the voltage waveform (*may be caused by*)	ac-to-dc line-frequency thyristor converters

The generic structure of this text consists of a short introduction which gives some background about the topic and it is followed by an explanatory sequence. The relationships of cause and effect are constructed here either between phases in the explanation sequence or within phases in the sequence. Table 1 shows the cause/effect phases in the text.

Table 1

	Cause	**Effect**
Phase 1	For a fixed control voltage *v control* or the delay angle @, the discontinuous current *causes*	the output voltage to go up
Phase 2	This voltage rise *causes*	the motor speed to increase at low values of *I*.
Phase 3		With a continuously flowing *i*, the drop in speed at higher torques *is due*
Phase 4		the voltage drop *RI* across the armature resistance;

The basic linguistic categories involved in the text are processes, mediums, agents, circumstances and results. Thus, the link between phases is achieved by means of circumstances of cause (*due to*) and processes of causation (*result in, causes*). Circumstances of cause build cause and effect relationships between the phases in the implication sequence whereas processes of causation build cause/effect relationships within phases. Along with these processes of causation which represent cause fairly explicitly there are also many processes which imply a causal relationship between things but are less easy to detect because the causality is not carried by a word or group of words but by the grammatical relationships between participants in a clause arranged in an actor-goal relationship.

The structure of each clause or clause complex is a simple relation, but the information is packed in nominalisations. Nominalisation is a significant feature of causal explanations. Halliday (1985b) has shown us how our meaning-making potential is enlarged when the verbal resources normally used for one function, such as nouns for things, are deployed for another, such as nouns for processes, which thereby become semiotically both in some ways thing-like, in others process-like, thus constituting a new semiotic hybrid reality, a phenomenon which he calls grammatical metaphor. As nominalisation turns an event into a noun, it allows us to represent an event as causing another event in a single clause, with the resulting compactness of information, which allows us to construct cause and effect relationships within a single phase in the explanation.

This sequence of steps in the nominalisation process, i.e. turning happenings into things which can be technicalised, plays also an important role in the creation of technical terms. Thus, *overvoltages* is a technical term whose meaning refers back to a previously defined process.

An extension of this is to have a technical nominal group compound with a Classifier^Thing structure, but where the classifier is a nominalisation representing the agent from the implication sequence. These complex nominal groups contribute to quantify and qualify the descriptions making them more accurate, such as the examples below show:

- *Occasional large voltages spikes* may be a result of switching in or out of *power factor correction capacitors*, power lines, or even such things as pump/compressor motors in the vicinity.
- Overvoltages may be caused by sudden decreases in the system load, thus causing the utility voltage to go up.
- *Undervoltages* may be caused by *overload conditions*, by start of induction motors, or for many other reasons.
- Chopping of the voltage waveform may be caused by ac-to-dc line-frequency thyristor converters.

In addition, nominalisation enables a choice in the textual organisation of the clause, where given information is presented in thematic position:

Thematic /Given/Agent	Rhematic/New/Goal
the discontinuous current causes	voltage to go up
This voltage rise causes	the output of the motor speed to increase

Thus, a chain-like effect is formed in which the given information in each sentence topic refers anaphorically to the new information in the last occurring comment.

3.1.2. Non-verbal texts: equations and graphs

In text 2 implication sequences are realised both through verbal and non verbal resources:

Text 2

Often in small dc motors, permanent magnets on the stator as shown in Fig. 13-1a produce a constant field flux *Ff*. In steady state, assuming a constant field flux Φf, Eqs. 13-2, 13-3, y 13-8 results in

$$T_{em} = k_T I_a \quad (13\text{-}10)$$

$$E_a = k_E \omega_m \quad (13\text{-}11)$$

$$V_t = E_a + R_a I_a \quad (13\text{-}12)$$

Where

$$k_T = k_t \Phi_f$$

and

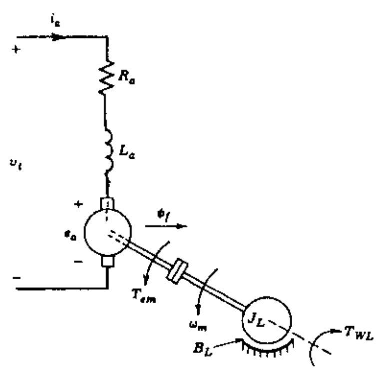
$$k_E = k_e \Phi_f$$

Equations 13-10 through 13-12 correspond to the equivalent circuit of Fig. 13-4a. [From the above equations, it is possible to obtain the steady-state speed *wm* as a function of T_{em} for a given Vt]:

$$\omega_m = \frac{1}{k_E}\left(V_t \pm \frac{R_a}{K_t} T_{em} \right) \quad (13\text{-}13)$$

(Mohan et al.1995:380)

C- TA dc **motor** equivalent **circuit**.
(Fig. 13-4a)



In spite of the evident textual ellipsis of this hybrid text there is an implied grammar underlying mathematical expressions. Textual ellipsis is an important organising factor (Downing and Locke: 2002, 240-241) which acts as an important cohesive device in mathematical texts. Thus, we are able to analyse this text as if it were any verbal text provided we consider that

- any single term, such as *T, E, V* above is a nominal, unless it forms part of an expression.
- any equation *Eq*, can be considered a noun, unless it forms part of a sentence.
- any two such nouns *T* or *Eq*, related by a predicator (i.e. a sign of equality, inequality, proportion or transformation) can be considered a sentence.
- such sentences may be extended indefinitely by the addition of another predicator, a single term, *T* or/and equation, *Eq* and such sentences may act as a main clause, dependent clause or a noun.
- such sentences are related to other sentences throughout the text.

Following this line of reasoning, we might be able to interpret text 2 as an implicit sequence of cause and effect relationships which underlie the non-verbal realisations, i.e mathematical equations and their accompanying graphs (as shown in Mohan's Fig 13-2 and 13-4:.380). Thus, we are able to verbalise the previous mathematical equations as follows:

Cause	Effect
Tension (Eq....)	intensity (Eq....)
Intensity (Eq...)	magnetic flux(Eq...)
Magnetic flux (Eq....)	torque (Eq....)
Torque (Eq...)	~~speed (Eq...)~~

The generic structure of this text can be compared, therefore, to that of text 1. Cause and effect relationships are, in fact, a powerful resource of language to achieve meaning. In addition to mathematical expressions, scientific practice makes use of abstract graphs which only show conceptual relations, and not actual data. The textualisation here is only possible via mathematics.

Though graphs represent a higher abstraction from language, as Lemke has suggested (Lemke, 1998), mathematics is more powerful than visualisation, even though it is less intuitive, because it can represent patterns that cannot be visualised, and allow them to be compared, manipulated, combined, etc. This might be due to the fact that language is too analytical and tends to isolate the parts of a problem from one another and it is much poorer in resources "for formulating degree, quantity, gradation, continuous change, continuous co.variation, non integer ratios, varying proportionality, complex topological relations, or non-linear relationships" (Lemke 1998: 96). However, in the electronics domain, equations are better understood by means of graphs since graphs and visuals work better than words in the comprehension of a problem. They trigger the kind of intuitive thinking required in understanding theoretical science and they allow a problem to be grasped at once (Arnhein, 1969). As Kress and van Leeuwen (1990) argue, visuals do not simply accompany text in teaching materials: they actively organise and construe meaning and often play a more dominant role than written text itself.

The diagrams and graphs shown in figure (13-4) show the schematic representation of the equations mentioned above:

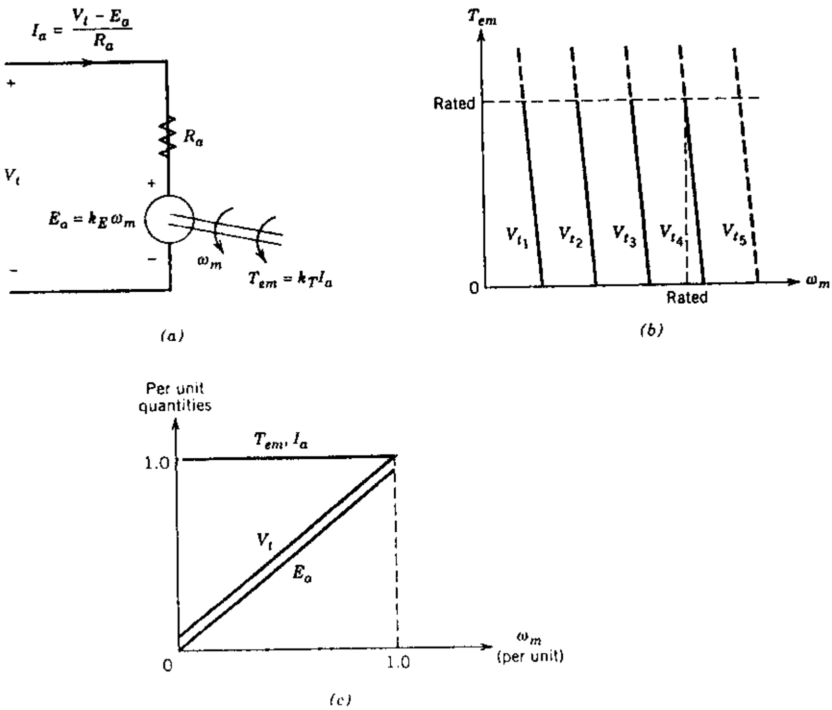


Figure 13-4. Permanent-magnet dc motor: *(a)* equivalent circuit: *(b)* torque-speed characteristics: $V_{t5} > V_{t4} > V_{t3} > V_{t2} > V_{t1}$ where V_{t4} is the rated voltege: *(c)* continuous torque-speed capability.

Figure 2. (Mohan, 1995: 380)

This abstract graph has a mathematical formulation, and that, in turn, is rooted in an extension of the semantics of natural language and its grammar. In addition, a graph can be read as verbal text since, provided the meaning of axes and of function lines is well established, graphics are subjected to certain conventions, such as the presentation of sequences from left to right and top to bottom of the page. Thus, letter (a) "equivalent circuit" in Fig. 13-4, is a visual representation of equation 1 in text 2, and can be read as a concrete case for stationary motors; letter (b) visualises the three physical magnitudes for each tension entry (i.e.Vt); and letter (c) can be read as a representation of the limit values in relation to torque.

Participants in the grammar are mathematical abstractions, predicators (sign of equality, inequality, proportion, axes, lines, drawings etc) and (elliptic) causative and relational processes. By means of these elliptic verbs each step is organised as a sequence of *Theme-Given-Agent* and *Rheme-New-Goal*, with the next step picking up the New of the previous step, and redeploying it as Theme.

This way, verbal text, mathematical expressions and graphs complement each other to create a strong and powerful sense of meaning.

3.2. *Textual/organisational meaning*

Lemke (1992:94) has claimed that "every meaning-making act constructs a system of organisational relations defining wholes and parts of those wholes, both in the semiotic space of the text and in the meaning-making act itself". Language creates words-in-phrases, phrases-in-clauses, chains of reference and cohesion, and large and subtler structures and textures of the verbal text (Halliday and Hasan, 1976, 1985; Lemke, 1988, 1995; Matthiessen, 1992). Graphs and mathematical expressions also participate in interactions that define parts and unite them into wholes. Text 3 is an example of how cohesion is achieved in electronics texts.

Text 3

As a particular case, an evolution or initial value problem is said to have a Langrangian structure if there is a functional

(u) = Eq

So that the system dynamic behaviour of the governing equations may be stated in the form...

The result obtained is then

Eq (L u) = 0

Where *u* denotes the problem state variables and *L* the Lagrangian functional. (source: students' handouts)

Cohesion in this text, as in the other texts examined, is mostly realised by means of (1) cohesion markers which, in the above example express consequence: *thus, so that, then*; (2) prepositions: *from, on, by*; (3) relatives: *this, where*; and (4) verbs.

Cohesion markers may in some cases be sparsely represented, but if one accepts that Eq, Eq, Eq....without even a comma between one Eq. and the next, can exist as a constituent of a sentence, one may claim that engineering texts do not contain a sentence which does not include at least one word, and that that one word is sufficient to establish a claim to be read as part of a sentence.

Prepositions and adverbs also act as cohesive links. The preposition *from*, for instance, indicates that the following equation is derived, not from the last quoted equation, but from another previously established equation which may be realised in any earlier part of the book.

The words *where* and *with* which invariably follow an Eq and precede one or more Eqs perform a similar function in the sentence.

A common form of verbal realisation which gives cohesion to the text is the use of some verbs. These verbs are seldom used with an agent: *is said, may be stated,* and they frequently refer to previous equations. The commonest realisation of verbs is the *-ing* form, which is used either absolutely, as in "subtracting, (we get...)" or with a circumstance of means: *by changing* Their function in the text is that of means. The *-ing* verb form acting as a subject is also frequently used and has a cohesive function:

- multiplying Eq 2.... gives Eq 3...

One important feature is the use of nominalisation (e.g. *addition, differentiation, rearrangement*), sometimes preceded by preposition (*On rearranging, ...we get*) which, again, performs a cohesive function:

- The subtraction of Eq 1... yields ...

Another significant feature of these texts is the use of processes in theme position. Most of them are mental processes —*observe, notice, assume, solve, evaluate*— which call for the reader's cognitive attention, and a set of verbs which ask the reader to perform an activity, in this case a mathematical activity, such as *divide, eliminate, equate, expand express, ignore, add, apply, assume*, etc, as the following examples show:

- We may thus write Eq....... In symbols and using Eq 2.... this becomes Eq.... or Eq.....
- By changing the order of integration we find the desired result, or Eq...
- We may summarise our findings as follows: at any time T Eq.... And Eq...

Several resources are also used to achieve *cohesive harmony* (Hasan, 1984) throughout the texts. For example, the development of a complex equality or physical relation can be traced discontinuously over a stretch of several chapters. The segments are discontinuous, and equalities and relations are reintroduced throughout the book; some equalities involve a confluence of more than one other partially independent argument. Likewise, several devices are used in order to follow the line of the argument, such as (i) numbering the equations, (b) using some anaphoric and cataphoric lexical items:

- As we discussed in the introduction in Section 1
- As an example consider...
- In the previous sections...
- By looking at the devices conducting in Fig... we notice that there is.. This implies that..

- We discussed earlier that
- Similar to the discussion in Section 8-3-2-6...
- As noted above

and.(3) by means of anaphoric and cataphoric references:

- — This arrangement is usually referred to as the "standby power supply" as we discuss in the next section (Mohan et al.: 362)
- We will define the following constants. Since in general... is a reasonable approximation to replace—
- in the foregoing expression.

Textual ellipsis, as commented on earlier, is also an important factor in the organisation of these texts. Finally, comprehensive index and marginal notes throughout the text call attention to definitions and important topics, thus showing a strong interaction between writer and reader. All these examples show to what extent textual meaning also contributes to the creation of the interpersonal and attitudinal texture of the text.

3.3. Interpersonal meaning

So far we have been concerned to show how and to what extent electronics texts construct their field of knowledge; we will focus now in the types of reader/writer relationships realised through language, that is, in the *tenor*. This aspect of language has received scant attention in the analysis of scientific texts, since tenor in written technical language is more difficult to identify. It is normally assumed that scientific texts are "impersonal" in the sense that the focus is on the object rather than on the human agent, who generally is left outside. In fact, technical texts for students are purely expository. Persuasion can be assumed not to exist since the subject matter is a class or classes of systems to be studied. The presentation of an argument can be reduced to "I hereby inform you that this expression or value can be arrived at by the following line of reasoning". There is no way in which the student/ reader has to evaluate an argument. The only task required is that of identifying the value of a description or an argument and seeing what other segments in the text it relates to. as well as learning to produce other descriptions or arguments on demand. However, though this is generally so, we should not forget that language is essentially a shared communicative event and that this fact presupposes the existence of a human writer and a reader who to some extent share a world of personal experience transcending the mere necessities required to generalise about systems and classes of systems. This fact is manifested in the grammar in several ways.

Tenor is related to interpersonal meaning in systemic grammar and it is realised by mood in the lexico-grammar. It involves performing the following tasks (Halliday and Martin, 1993: 27): "giving the reader information, which he or she is expected to receive. Asking the reader for information which he or she is in fact not expected to possess, but will be all the more grateful to the author/s for providing; and asking the reader for services". These three functions are in fact completely fulfilled in the texts being analysed through the following lexico-grammatical procedures:

3.3.1. "we" in thematic position

This pronoun is chiefly used in both text-books, and there is no reason to think it could not have been omitted. The use of the agent *we*, in expository genders renders the text more specific and personal:

- ...we will develop equations that show the influence of various circuit parameters...
- We can write...Let us now integrate...
- Once we negate either input, the outputs return to complementary operation. However, if we negate both inputs simultaneously...
- Our knowledge of...
- Note that even though the "safe" next state for unused state is 000, *we didn´t* just put 0s in the corresponding map cells, as *we* were able to do in the D case. Instead, *we* still had to work with the application table

The reader's-writer interaction is particularly striking in *Digital design*. Thus, in the introduction we can see a photograph of the author with the caption *Hi, I´m John*... followed by these salutation words:

> Welcome to the world of digital design....We will give you the basic principles that you need to figure things out, and we'll give you lots of examples. Along with principles, we'll try to convey the flavour of real-world digital design by discussing current, practical considerations whenever possible. And I, the author, will keep on referring to myself as "we" in the hope that you'll be drawn in and feel that we're walking through the learning process together (1).

Contractions, which are seldom used in formal technical written language, contribute to rendering the text more friendly and familiar. Similarly, the use of the pronoun *we* in all these examples invites the assumption that both the writer and reader are included and that they both share a common experience.

3.3.2. Use of second person pronoun

It is normally assumed that, as a rule, scientific and technical texts show no *appraisal* (appraisal is defined by Halliday as the *working relationship*) that is, there is no working relationship between readers and writers since there is *no contact* and status is unequal (expert writing for learner) and the text does not function to appraise students´ work. However, we find several examples in which appraisal is shown. This is most strongly marked by the pronoun *you* and verbs in the declarative mood, not simply in typical examples such as ... *you obtain, you have*...but in specific speech acts addressed directly to the reader as the following examples show:

- Don't try this yourself unless you're prepared to deal with the consequences!
- Still, you may be curious about how off the-shelf flip-flops and latches "do their thing"
- If you have the ability to use either expression form to realize a logic function...then in general you must work out both forms ...
- When you are trying to debug such a problem, the extra capacitance of an oscilloscope probe touched to the floating input is often...
- If you have been paying attention, you may have noticed...
- Enough to damp out the noise and make the problem go away. This can be especially baffling if you don't realize that the input is floating!

In this last example, the pronoun *you*, the exclamation mark, the evaluative language (*especially baffling*), the specific warning, all serve to invoke a writer deeply concerned with his readers' reactions. The interactional effect of these direct addresses is particularly strong when they are concerned with the student. For example, we read:

- That's too much work, even for students

3.3.3. Imperative mood

The imperative mood is a way of expressing social interactions. In the following examples the writer is *demanding services* (Halliday and Martin, 1993) from the readers. In this case mental services:

- *Prove* that a two's complement number can be multiplied by 2 by....
- *State* and prove correct a technique similar to......
- *Calculate* and *compare*...
- *Obtain* an expression for the Fourier components in the waveform...
- *Note* that even though the "safe" next state for unused state is 000

Negative polarity also appears in theme position, thus creating a strong feeling of interaction between writer and reader:

- *Don't try* this yourself unless you're prepared to deal with the consequences! (D.D p16)
- This can be especially baffling if you *don't realize* that the input is floating! (DD p107)

As electronics deals with systems and classes of systems, it is not surprising to find mental processes such as the above mentioned. There are verbs such as *imagine, suppose, assume, consider* etc., which share a common function in these texts clearly distinguishable from what they actually mean in everyday language. They act in scientific language as introductions to the establishment of the class of systems to be treated or as a nexus between arguments. However, their use in theme position seem to invite students to treat a statement as other than a fact.

3.3.4. Causal relations

Causal relations in general in English also incorporate interpersonal meanings as gradations of obligation, inclination and probability. Martin (1992: 194) interprets causal/conditional relations in English along interpersonal lines, as *modulating* and *modalising* relations of temporal successions between events.

In the semantic realm of causality, the two functions of language as representation and exchange are realised in the same causal scheme: whereas degrees of obligation, inclination and probability typically grade a speaker's intention, "they may also be applied to grade causal relations between events that involve neither speaker, nor listener" (Rose 1998:241). The lexis of cause in technical English includes a large, delicate range of possible expressions of these meanings. By means of this range of finely graded judgements, science writers negotiate their relationships with their peers, masters and apprentices (Hunston 1993, 1994). These interactional features can be appreciated in the following examples:

> *As* a simplification to gain better insight into the motor behaviour, the friction term, *which* is usually small, *will* be neglected by setting B =0 in Eq. 13-22. *Moreover*, considering just the motor without the load, J in Eq. 13-22 is *then* the motor inertia J. *Therefore*... (Mohan: 385)

The use of *Moreover* seems to imply here a shared experience between reader and writer.

Conditional relations showing degrees of obligation and probability typically occur in mathematical argumentation, as the following examples suggest:

- It *should* be noticed...emphasised...
- *If* a four-quadrant operation is needed....*then*
- *If* the speed does not have to reverse *but* braking is needed, *then* the...
- *If* we take the Laplace transform of these equations...

3.3.5. Questions and exclamations

As Martin (1992) points out *Vocatives, Modal adjunts, Comment adjunts, Finites* and *Wh-interrogative* elements also fulfil interpersonal functions: they are used to exchange roles in rhetorical interactions with addresses (statements, questions, offers, etc.) and to express the speaker's own angle of the matter, that is, accompanying degrees of modality (i.e.

probability and usuality) and modulation (i.e. inclination and obligation). Thereby, questions, whether or not they are used to announce a shift in the system, can clearly be assumed to interrogate the reader. There are many instances in the texts where the writer asks the reader. Sometimes they are rhetorical questions, since the reader is not expected to know the answer, but as a rule, the student/reader is asked to carry out an activity, in general a mental activity:

- As a function of n, how many "bad" boundaries are there in a mechanical encoding disc that uses an n-bit binary system?
- How many different 3-bit binary state encodings are possible for the traffic-light controller of table 2-12?
- ...How many fingers would you say the Martians had?

Likewise, exclamations invite the reader to share in the writers' surprise. The following examples clearly show this rhetorical technique. In addition, negative polarity in theme position also contributes to give a strong feeling of interaction between writer and reader:

- Don't try this yourself unless you're prepared to deal with the consequences!
- This can be especially baffling if you don't realize that the input is floating!

3.3.6. Evaluative language

As has already been commented on, modal adjunts, mood, and comment adjunts also fulfil interpersonal functions. Words such as *important, mainly, highly, negligeable, surprisingly, especially*, which frequently appear in the texts examined, express the writers own opinion on the matter which the reader is invited to share. Even the focusing adjunt *only*, (see Quirk 1985: 210) in sentences of the type *it can only be done...* may imply "from somebody's point of view". Similar semantics can be applied to *still* and *once again* in the following sentences:

- *Still*. This subsection describes the J-K synthesis process "just for fun"
- so J-K flip-flops *still* didn't save us anything
- *Once again* a tedious and error-prone process

In sentence (1) above the comment "*just for fun*" has also a relevant interactive function, as well as the informal use of the short form of the verb *to do* and the pronoun *us*, which includes writer and reader. In sentence (3) the nominal *tedious and error-prone process* gives also the writer's point of view of the matter.

Likewise, describers are used to express the writer's opinion and to invite the reader to share it:

- Another *interesting* feature of ABEL is...
- Floating CMOS inputs are often the cause of *mysterious* circuit behaviour
- The excitation equations obtained from this map are *somewhat* simple than before
- *Obviously*, it takes *quite a bit of patience and care* to fill in the entire excitation table (a job best left to a computer) (Digital Design:.496)
- *Interestingly*, the three loops give rise to...
- We'll readdress *this curious* difference later.

Use of importance markers such as *too*, following a mental process in theme position (i.e. imperative) also implies a share experience between writer and reader:

- Notice, *too*, that the formula....

The same semantics can be applied to non-defining relative clauses. The use of *which* followed by qualifiers is particularly striking in sentences such as:

- In an improperly constructed *(ambiguous)* state diagram, the next state for some input combinations may be unspecified, *which is generally undesirable*, while multiple next states may be specified by others, *which is just plain wrong* (Wakerly: 550).

3.3.7. Appeal to shared knowledge of the world

There are many instances in which the writer makes specific reference to entities assumed unique and known to both writer and reader and to laymen who have no knowledge of the discipline being discussed. This is a typical procedure in science and technology. Complex systems and equations are frequently explained by analogy. As an example of this, the earth, the sun and the moon are frequently used in mechanics as specific and familiar examples of celestial bodies, or simply bodies following certain stated paths. Chemical equations are compared to a recipe. Coloured balls, playing cards, examination results and other familiar items are used in statistics instead of simply labelled objects and set of numbers. Thus, it is common to find references to events outside the field:

- The design of LFSR counters is based on the theory of *finite fields*, which was developed by French mathematician Ëvariste Galois (1811-1832) shortly before he was killed in a duel with a political opponent (Wakerly: 626).

This reference to the outside world is also typical in the language of problems:

- The first expedition to Mars found only the ruins of a civilisation. From the artifacts and pictures, the explorers deduced that the creatures who produced this civilisation were four-legged beings with a tentacle that branched out at the end with a number of "grasping "fingers"... (Mohan et al.: 70)

4. Concluding remarks

This paper has been concerned with the analysis of some engineering texts from the field of electronics, whose most striking feature is the combination of verbal and non verbal language, particularly mathematical expressions, quantitative graphs, information tables and abstract diagrams. The purpose of the analysis was to show how these hybrid texts are combined so as to make meaning and in which way they can be analysed. The application of systemic functional theory of language to the analysis of these texts shows that mathematics and graphs can be analysed as any other verbal text since there is always an implied grammar and written conventions in the reading of tables and graphs, mathematics and formula which underlie the mere visual representation of the language of physical systems, thus extending grammatical resources in register-specific way.

It has also shown the systemic premise that linguistic features have "generic" potential to convey meanings about the real world experiences and relationships between them (ideational function); about relationships between authors and readers (interpersonal function), and about relationships among parts of a text, a text and a context, and a text and other texts (textual function). Particularly, the analysis of these texts shows that ideational meaning contributes to organisational-textual ones through cohesion and other rhetorical devices and so do interpersonal-attitudinal ones. Likewise, textual/organisational meanings contribute to ideational ones by means of defining clauses, implication sequences, clause-complexes, nominalisations, textual ellipsis, and larger units of intertextual relationship, which, in turn, contributes to the interpersonal and attitudinal texture of a text (Lemke, 1988; Mann and Thompson, 1986). Choices in the lexico-grammar of the ideational domain also contribute to the attitudinal and interpersonal stance of the electronics texts as well as to its content and organisation. In addition, the graphs, equations and abstract diagrams complement and add meaning to the mathematical language. They all together form a semantic whole where every part in the system sustains one another, thus creating new orders of meaning. A corollary of this is that this type of texts are better treated as integrated, multi/semiotic genres, thus confirming Lemke's thesis, which estates that separating in any textual analysis these multiple channels of communication would signify to neglect the fundamental unity of communicative meaning-making.

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