A Complete Guide to Data Sheets

By F. Raymond Dewey

Introduction

Communications is an important part of engineering and "communications" implies clarity and understanding. The paper (or electronic) data sheet is the important communications link between individuals or companies with diametrically different needs, i.e., between the seller and the buyer. To a potential customer, the data sheet is *the company*. Readers will not usually comment on minor errors, but spelling, grammatical, or technical errors are noted and missing or confusing specifications reflect directly on the credibility and expected performance of the company. The data sheet is often considered by the buyer as a legal document and the warrantee of product performance.

The data sheet may also be used within a single company between individuals with different viewpoints or backgrounds, i.e., between the manufactuer's product design and product marketing, or between the user's systems engineering and incoming inspection.

The data sheet should include all of the information needed by the user to design the product into his system and to determine the acceptable level of performance in that system. The meanings of any terms and symbols used must conform to established industry standards or be explained in the data sheet. Products intended to be handled by individuals trained in other fields may require additional or different information.

Importantly, is a particular data sheet understood to mean the same as it was intended? Described here are some of the components of data sheets with an emphasis on communication between the writer and the reader. It is meant as a tuturial for both the writer and the reader.

Features vs. Benefits

Readers often confuse data sheets with advertising. That may be because almost always the individuals responsible for generating the data sheets (usually Marketing Communications) are the same people who are responsible for the product's advertising. Data sheets and advertising actually serve very different purposes. Ads often use visual impact with vague marketing claims about benefits to attract prospects to inquire about a product or to reinforce a customer's awareness of a company. They get the engineer's attention, offer an improved gizmo or a solution to a problem, and then provide a means for obtaining the data sheet. The data sheet is then supposed to emphasize product features and inform rather than impress; it should be complete and able to stand on its own without further technical discussions. The data sheet is *not* advertising but, in fact, fills the gap between the advertisement and the personal sales call. Purchases from a data sheet are a direct result of need; impulse buying is rare; customers buy products, not data sheets. The data sheet *should* be written by the engineers who know the product best, but they would rather be designing new products.

One thing is certain, the user and/or buyer *must* have the data sheet in order to specify the component purchase. From several surveys, specifications are the fundamental reason for the data sheet. After specifications, price and availability are good to have, but those are difficult to firm up enough for the printed product data sheet. Advantages and benefits are least important (but that is not to say unimportant) in a data sheet, but are very important in an advertisement, further emphasizing the difference between the two.

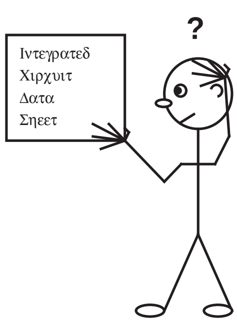
The Good, The Bad, and The Ugly or **Beware of Specsmanship**

A good data sheet allows the reader to accurately specify and purchase the exact product the reader needs without any other assistance. Even a barely acceptable data sheet should still allow the reader to make an intelligent decision as to whether or not the product should be further considered for a specific application. In general, data sheets are not read but are only referred to; engineers want/need hard facts about performance and specifications.

The material appearing here is from a series of articles by the author, which appeared in the September, October, and November, 1998 issues of Sensors magazine. Reprinted by permission.

“Specsmanship” is where Marketing or Manufacturing get out of control. The front-page headline states “Ten Ampere Output” but the specifications are only at 350 mA and the absolute maximum ratings are 500 mA continuous or 10 A for 1 ns with a 1% duty cycle. The text states “typically less than 1 μA leakage” but the specification allows as much as 100 μA. Would a device with 100 μA leakage really be acceptable? What else might be wrong with the device if less than 1 μA really is typical? Any claim not supported by the specifications should be suspect; a little specsmanship is expected, but too much may be intentionally misleading and border on dishonesty.

The product data sheet should be an agreement (compromise) of what is wanted or needed (as opposed to what is possible) between Marketing, Design Engineering, Manufacturing, and the customer … given the limits of cost, performance, and reliability. Marketing wants a data sheet (and a product) that will provide the answer for some large customer’s needs and also for all of the conceivable requirements of all possible customers. Part of the front page of a data sheet is typically Marketing’s. Here may be found background information, general descriptive matter, and vague adjectives like high, small, fast, and typical (see <u>Terms and Definitions</u>, below). Even the best ideas have to be sold, and the image conveyed may be more determined by the language used to describe it, not necessarily by the intrinsic worth of the idea. Design Engineering will go for something not quite so optimistic but still possibly falling into the realm of “pipe dream”. Manufacturing will only willingly agree to a specification that ensures 100% yield. Always in the background should be Quality Assurance and Reliability. They will try to keep the data sheet “honest” (nothing gets shipped unless it meets all of the published specifications).



IT LOOKS LIKE GREEK TO ME

Paraphrasing from the ISO/IEC Directives, Part 3, *Drafting and Presentation of International Standards*:

> “The objective of a [data sheet] is to define clear and unambiguous provisions in order to facilitate international trade and communication. To achieve this objective, the [data sheet] shall
> — be as complete as necessary
> — be consistent, clear and concise
> — be comprehensible to qualified persons who have not participated in its preparation.”

Manufacturers can generate at least four basic types of product data sheets representing three progressions of confidence in (and information on) their new products and three levels of commitment to their specifications.

Four Types of Product Data Sheet – Three Levels of Commitment

The first product data sheet is “speculative” and is used to advise customers of proposed additions to a product line. These are most often labeled PRODUCT PREVIEW or DESIGN OBJECTIVE (some should probably be labeled PREMATURE). The minimal specifications given here are only target or goal and may change in almost any manner without notice. These rough data sheets are often only typed and photocopied. If a copy includes a coffee-cup stain or penciled-in notations, it was probably generated in Design Engineering. A speculative data sheet may be used for several months and often undergoes several updates (even weekly or monthly) as a result of marketing surveys, prospective customer feedback, and maybe even a few R & D samples that have been produced under ideal conditions through a pilot line. It is extremely unwise to design an application based on this data sheet, especially if samples are not yet available. In the worst case, the proposed product might never get beyond a market survey and never reach production.

After the first prototypes are generated, and if initial customer feedback is positive, “informative” product data sheets may be used to advise customers of the proposed addition to the product line in an ADVANCE INFORMATION DATA SHEET. A limited quantity of preproduction samples will often be available. This data sheet will contain more substantial information, including interfacing with the customer’s system, some specifications, and maybe even limited applications assistance. Specification details may still change without notice; any samples should meet all of the ADVANCE INFORMATION DATA SHEET specifications supplied with them; limits might be TBD (To Be Determined), wide open, or only typical values shown.

Sometimes a manufacturer will publish a PRELIMINARY INFORMATION DATA SHEET. This also is "preproduction" information while the manufacturer fishes for a significant customer. It may also be first production while the manufacturer attempts to reduce costs through device improvements. Most specification limits will be defined (and these should be tighter than the Advance Information data sheet) and many typical values may be included; minor changes will be expected as the significant customer defines *its* application (that's not necessarily the same as *your* application) or characteristics spreads become better controlled. The good part is that these products are *usually* safe to design in as the manufacturer has invested significantly in the product development, samples should be available in almost production quantities, and the device will almost always go into full production, even if only to the general-sale market.

Product Preview/Design Objective, Advance Information, and Preliminary Data are labels on data sheets to describe the product status. Interim and Limited Distribution or Restricted are used to describe the data sheet status rather than the product status.

In some cases, such as when a proprietary product becomes available for general sale, an INTERIM DATA SHEET might be released until complete characterization data and applications information can be added. Because the proprietary device was for one customer in a specific application, specification changes may sometimes occur to improve yields in general applications. Interim, or "temporary", implies that more complete specifications or applications information will be coming.

LIMITED DISTRIBUTION or RESTRICTED labels can be applied for any of several reasons, for example, legal restrictions by the original customer, production capacity limitations, a lower-cost version of an expensive popular product, or because a patent application is pending.

DEFINITIVE DATA is the "final" data sheet that defines the (hopefully) long-term, warranteed (see below) production limits. It usually includes some boilerplate to the effect that the manufacturer reserves the right to make "departures from the detail specifications to permit improvements in the design" (See also, Terms and Conditions, below). This is supposed to allow improvements in specifications and insignificant modifications that do not affect form, fit, or function in original applications. It should not permit specification degradation due to out-of-control manufacturing.

Very few data sheets are "complete". What users really want (some say need) is computer-readable information including schematic symbols, board layout patterns, circuit simulation, and thermal analysis. As devices get more complicated, the direct computer entry of design information will reduce the system design time and eliminate errors. See Electronic Data Sheets, below.

Is a Data Sheet a Guaranty or a Warranty?

"Guaranty" and "warranty" are not synonymous. A guaranty is a promise to answer for the obligations of another. No product data sheet can guarantee that a product will be installed and operated correctly by the user. However, whether express (written) or implied, a warranty is a promise that the product is suitable for the purposes stated — **UNDER THE CONDITIONS SPECIFIED**. An express warranty might be a promise to reimburse the user for any loss if the data warranteed proves untrue. While express warranties are rare, every data sheet is an implied warranty.

Although a written warranty does not by itself ensure reliability, it does indicate a minimum level of quality or performance. The penalties for not meeting the warranty provisions can become quite severe in terms of costs (including warranty costs built into the price of the product), liability, and public relations. Extended warranty periods should be based upon expected product performance (i.e., reliability) over time.

Revisions, and Other Nasty Thoughts

For whatever type of data sheet, it is always advisable to be using the latest information available (see also, Electronic Data Sheets, below). In the extreme, designing in an obsolete device is embarrassing for everyone and may result in *shortened careers*. Even the latest samples may be old production lots or obsolete product. As mentioned above, and even for the "final" definitive data sheet, there can be multiple revisions of a data sheet. To everyone's benefit, preproduction data sheets are usually conspicuously dated and carry a legend such as **"Subject To Change Without Notice"**. Unfortunately, the age of definitive data sheets is not always so obvious (check the copyright date and manufacturer's publication control codes). In other words — always check with the manufacturer for the latest available information before "freezing" a design or releasing it to production.

Intellectual Property — Trademarks and Copyrights

The data sheet is a physical thing embodying the often intangible words and thoughts (intellectual property) of a company. The company has paid for the words and lays claim to its ownership with trademark (™), registered trademark (®), and copyright (©) notices. It is important to properly use trademarks and registrations in publications.

™ A trademark is a special adjective, mark, or design that is used to identify the source of a product. It cannot be a generic or common name for the product, but is used to modify the generic or common name. Failure to claim ownership (not affixing the ™), or only casual defense against infringement, may result in losing exclusive rights to the trademark. The trademark should be identified by the superscript the first time it is used in a publication, capitalized or enclosed in quotation marks.

® indicates a trademark that has been registered with the US Department of Commerce, Patent and Trademark Office. The adjective, mark, or design must always be used EXACTLY as registered so far as typography permits (DABiC not DABIC, SuperServo not Super-Servo or Super Servo).

A trade name is the name under which a company carries out its business. "Allegro™" is both trademarked (an adjective, as in Allegro integrated circuit) and a trade name.

© A copyright is legal protection for original works of authorship. It usually applies only to the arrangement of the words and graphic symbols, not to the words or symbols themselves, or to the thought, or to the general ideas expressed.

Trademarks and registered trademarks are vigorously defended by a company as being valuable property. A data sheet copyright, however, may be treated very differently. It is usually *desirable* to have copies made (i.e., from the internet) and widely distributed to possible customers. However, the copyrighted data sheet must not be modified to appear to refer to the product of someone else.

Terms and Conditions

Terms and conditions, or T & C, is the "boilerplate" that is attached to almost every formal document, e.g., the data sheet, request for quote (RFQ), the quote, hopefully the purchase order, and the back of this document. T & C most often cover things like indemnification (liability for damages), late delivery, infringement of patents, and acceptance of goods. Often, the first formal document is the data sheet. Its included terms and conditions are usually something like

This document contains information on a product under development. (Company) reserves the right to change or discontinue this product without notice.

or

(Company) reserves the right to make, from time to time, such departures from the detail specifications as may be required to permit improvements in the design of its products. Components made under military approvals will be in accordance with the approval requirements.

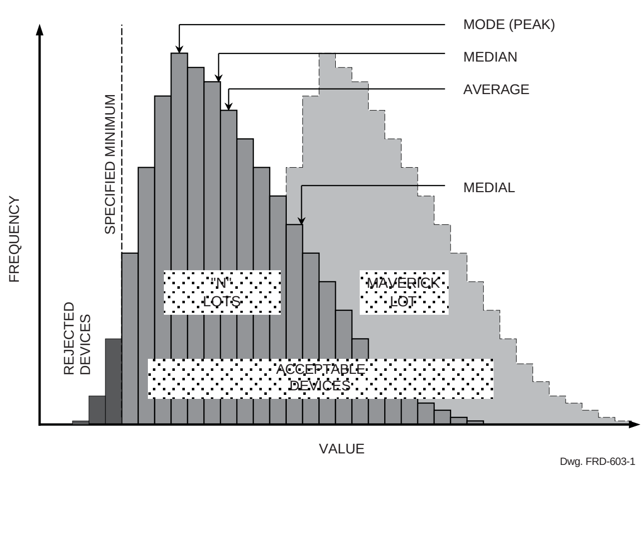
The information included herein is believed to be accurate and reliable. However, (Company) assumes no responsibility for its use; nor for any infringements of patents or other rights of third parties which may result from its use.

The acceptance of the data sheet (i.e., a purchase order with no new terms or conditions) is an acceptance of these included terms and conditions.

Terms and Definitions (you think that I know you understand what I said …)

Wild claims about typical or nominal performance (sometimes called "FEATURES") are meaningless unless they are backed up by useful limits. In an ideal normal distribution, the values for average, mean, medial, median, and mode are equivalent. Typical and nominal are not mathematical terms. They are defined as "any value *representative* of the entire group", but are often used to mean the mode (or peak) of the distribution. Conversely, except for with an ideal normal distribution that is centered between the limits, the average of the limits (medial value) might be a typical value but is not necessarily the same as the peak of the distribution. The real world is rarely ideal — device specifications are often compromises (for example, transistor beta and breakdown voltage are inversely related) and the specification limits might eliminate one or both tails, resulting in a lop-sided, skewed distribution as in the following figure. Worse, to the component manufacturer, "average" can apply to the entire population of acceptable or shippable parts (including all binouts). From the data sheet, the buyer will infer that "average" applies only to those devices shipped against the data sheet.

Typical values and typical characteristics curves are only given for circuit or system baseline design information and are usually at the nominal operating voltage and at room temperature. Although indicative of the distribution peak or median for a large number of production lots ("N"), typical values should not be expected for any particular device or single production lot. Even a multitude of fancy typical characteristic curves are useful only to indicate the general *shape* of a characteristic against the specified variable. A maverick lot (or outlier product) is not a normal lot, but may still be well within acceptable limits. System performance absolutely *must* allow for these maverick lots and any device performing within the specified limits.



Typical values (where they are the mode or peak of the distribution) are the starting point for a complex system design. Because "typical" is the value around which most devices should perform, ideal system performance should be the "typical" when all of the components in the system are at or near "typical". As every good circuit designer knows, system performance will be determined by the worst-case component performance and the allowable component specifcation limits must be reviewed against the desired system performance to achieve a reliable design.

LIMITS (the most important part of a data sheet) are those values that are warranteed under the specific test conditions shown. They are also the "legal" definition for determining acceptable devices. These are the tests that the manufacturer should perform in production and the only qualification or inspection tests that the user may perform on receipt. A common misconception is where a test condition is a range (usually operating voltage range or operating temperature range) implying warranteed performance at an infinite number of test points. This is of course an unacceptable test condition for manufacturing. The manufacturer will probably do these tests only at a worst-case condition or will use a generally accepted correlation to predict performance over the specified range.

It should be emphasized here that the rules for rounding numbers do not apply to limits. If the specified maximum is 5.0, a measured value of 5.001 may not be rounded down and is a reject! Because of test tolerances at both the manufacturer and at the user, the manufacturer will often "guard band" tests. For example, for a specified maximum of 5.0, a manufacturer's internal, production test limit might be 4.8 to allow for production and customer measurement errors of ±2%. Guard bands should prevent an actual value of 5.09 (reject) from being read as 4.99 (ok to ship) or an actual value of 4.91 (ok to receive) from being read as 5.01 (reject).

ABSOLUTE MAXIMUM (allowable) RATINGS are limiting values of permitted operation and should *never* be exceeded under the worst possible conditions initially, or throughout life. If exceeded, by even the smallest amount, **instantaneous catastrophic** failure can occur. Even if the device continues to operate satisfactorily, its life may be considerably shortened. Operation *at* an absolute maximum rating is permitted (although not desirable – even a short test is believed by some to cause incipient failure) but operation at two or more limits (i.e., output current and ambient temperature) almost always means that some other limit has been exceeded (in this instance, probably package power dissipation). In certain integrated circuits that include an internal thermal shutdown, fault conditions will generate higher than permitted (steady state) temperatures and activate device thermal shutdown circuitry. These fault conditions can be tolerated for short periods of time, but will affect life and should be avoided. Except for a maximum output voltage rating (often done as a leakage current test), production testing of the absolute maximum ratings is not usually performed.

“WARRANTEED” BY DESIGN, TESTED TO A LOT SAMPLE PLAN, or NOT TESTED IN PRODUCTION are terms usually applied only to the difficult-to-measure characteristics. Common examples are temperature dependencies and some dynamic (ac) tests. Warranteed by design is a “real” specification. Even though only a few devices might be tested, all devices are warranteed to the specification. A common practice now is for the manufacturer to rescreen the production lot or perform 100% test of a lot if even one device fails the sample testing. However, compare this against Unspecified Specifications, below.

RECOMMENDED OPERATING CONDITIONS may be given for optimum device performance but, other than functionality, does not promise any specific performance limits. Operation outside of these values is permitted (but within the absolute maximum ratings) often without any implied level of performance.

A single specification has dual purposes. From one viewpoint, it specifies the limits of acceptable *device* performance. From the other direction, it defines the worst-case operating conditions for acceptable *system* performance. See When Is A Minimum A Maximum? below. Designing an application based on sample performance or data sheet typical data can result in system failures (parametric or catastrophic) when production devices are used that do not meet the initial data spread but are still within the specified limits. The only solutions then are either an expensive system redesign or a more expensive custom specification (binout) for the critical parameter required.

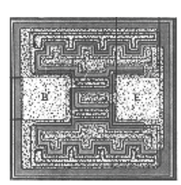
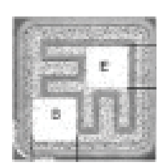
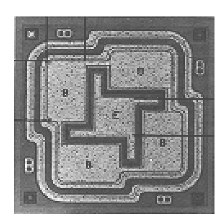
One of the advantages of English is that there are a multitude of synonyms for most words. Unfortunately, the thought-to-be subtle differences can make a major difference to the reader. Exact synonyms are rare. Of special importance are the differences in meanings between the following (non-synonymous) verbs:

Verb	Meaning
shall	a requirement
must	essential to successful achievement
should	a recommendation
may	permissive
can	able or possible to
will	a promise or expectation

Unspecified Specifications

Unfortunately, some data sheets *give* (as opposed to *specify*) an operating temperature range and then specify all of the parameters at room temperature only. What is the user getting???? Only functionality over the temperature range — without any implied warrantee of level of performance, which may be very marginal! For example, actual diode leakage current or transistor saturation voltage at high temperatures may be many times greater than the 25 °C limit — without any limit even implied. Conversely, for semiconductors at low temperatures, the user might only get survivability (very different from functionality). If the application requires wide-temperature operation, forget this kind of data sheet but work very closely with the manufacturer so that you get the device needed at an affordable price.

Just because “second source” products meet the same set of published limits does not make them identical. This is especially true of ac parasitics that can become very important at the application frequency but are inconsequential at normal test frequencies. The three npn transistor chips shown below are all marketed as 2N2222s and should meet the specified dc characteristics. They will even meet the specified minimum f_T and maximum C_{ob}, but it should be obvious from the photographs that they will not be identical in all applications. Even from a

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single manufacturer, what will happen to the system performance when an unspecified parasitic drifts because of manufacturing process variations?

When Is A Minimum A Maximum?

The content and format of a data sheet is sometimes confusing. From the manufacturer's point of view, a breakdown voltage is usually specified as a minimum value, indicating that all acceptable devices exceed this minimum value. On the other hand, data sheets are also used by system designers, who must be sure that all parts of the finished system work together. They interpret this *minimum* breakdown as the absolute *maximum* that may be applied to the device. Very few designers are confused by this, especially because most (none that I've seen) manufacturers do not specify typical breakdowns for fear (with justification) that the user will try to design around the higher number.

But what about — minimum set-up time or input pulse width is 30 ns min, 25 ns typ? This comes from the unfortunate mixture of specifying *system requirements* with *device parameters.* This specification must be interpreted as "Devices will function with a set-up time or input pulse width of at least 30 ns." Typically, this device will function with a set-up time or input pulse width of only 25 ns, but it's not warranteed so it's not a meaningful number. A similar situation exists with logic input levels where V_{IH} = 2 V min and V_{IL} = 0.8 V max. As described here, these are requirements rather than parameters.

Related to min/max is something called "algebraic" vs "absolute magnitude" conventions. Where zero has no special significance (just another number), the algebraic convention should always be used, i.e., -40 °C is *lower than* +25 °C. Where zero is the absence of something, the absolute magnitude convention is normally used in the U.S., i.e., -40 V is *greater than* +10 V, and zero is the least possible value; if a range of values includes both positive and negative values, both limiting values are maximums (the minimum is implicitly zero). Normally we switch back and forth with no problems. However, some data sheets (more often European) can cause confusion when the algebraic convention is not clearly stated and the specification limits (for a latching Hall-effect magnetic-sensor IC) are:

Operate Point = 15 mT Max
Release Point = -15 mT Min

Here, using the absolute magnitude convention, a device release point of -20 mT is acceptable but using the algebraic convention it is not. Only if a typical value is also given is this specification clear. To reduce (that doesn't mean eliminate) the possibility of confusion, where algebraic convention is being used, it should be noted (se the following Caveats).

Caveats

NOTES, CAUTIONS, WARNINGS, etc. are bits of text generally set off from the main body. Their meanings ar levels of importance are significantly different.

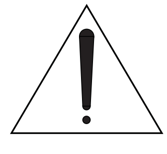
A NOTE (but see also NOTICE, below) is additional information or clarification that may be of interest to the reader. It should not include requirements or specifications.

The word ATTENTION is used to indicate important information that, if not observed, could result in damage a *component* or *system* as in "observe precautions for handling sensitive devices".

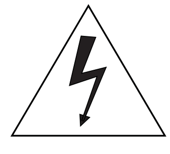
CAUTION messages are used to indicate procedures that, if not observed, could result in loss of data or dama to *equipment*.

WARNING messages are much more important; often in larger, heavier type, are boxed, and/or with colo (a yellow background is preferred). WARNING message are used to indicate potentially hazardous procedures tha if not followed correctly, could result in ***personal injury***.

Although generally not found in component data sheets except for the most extreme situations, **DANGE** indicates an imminently hazardous situation that, if not avoided, could result in ***death or serious injury***. DANGE messages would also use larger, heavier type, and/or be boxed, but here (if color is used) a red background is usually used.



This special exclamation mark ma be used with Attention, Caution, Warning, or Danger messages. It serves to emphasize the importanc of the message.



This lightning bolt symbol is often used with a Warning or Danger message to alert the reader to a special risk of electric shock.

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A NOTICE message should be used only to state a company policy (for example, "… are not intended for use in life-support applications without written consent.") or a legal requirement.

Standards

Standards are most often thought of as physical measurements (kilogram, meter, second, etc.) but are also procedures and "things" established by general consent as models or examples. Symbols, terms, and their definitions are also standardized to facilitate communication. Engineers, especially, like standards that provide for accuracy and repeatability.

Unfortunately, industry has not yet standardized data sheet contents, let alone data sheet formats. If industry did, it would be easy to compare similar devices from different vendors or even from a single vendor. But because test conditions reflect the major customer's operating conditions or the manufacturer's ideal operating point, similar devices do not necessarily use similar test conditions and often give very different specification limits. Sometimes the same device can have very different specifications for very different applications and will even have two different part numbers. This is best exemplified by audio power amplifier ICs that have later been specified as power operational amplifiers.

The closest we are to standards is in the terms and definitions for the various tests performed (or not performed). A French technical writer can write "horlage" and not communicate anything to the English reader. However, the internationally agreed-upon "standardized" abbreviation CK is usually understood (horlage is the French word for clock). Whether a product data sheet is published in English, French, Cyrillic (Russian), or Kan-Ji (Chinese or Japanese), the technical symbols are always the same. The example shown below is nonsensical but the symbols I_{CEX}, $V_{CE(sat)}$, and $V_{CE(sus)}$ can make the (here meaningless) text less important.

ϑετπλϖξε	Λςφηκι	Ψσα	Σωε	ζδω	Γπυ
Φφδηιτεω	I_{CEX}	—	10	50	μA
Θξγφπυτσ	$V_{CE(sat)}$	—	0.5	0.7	V
βϑεωασθι	$V_{CE(sus)}$	40	50	—	V

International standards define the prefix k as the multiplier 10^3, 1 K as 1 kelvin (-273.15 °C), and 1 kB as 1000 bels [unlikely, but 10 000 dB] Unfortunately, industry uses 1 kb/s as 1000 bits per second and 1 kB/s as 1000 bytes per second. Further, in the specialized field of memory storage capacity, 1 Kb means 1024 bits and 1 KB means 1024 bytes, where "K" (not to be confused with "k") means 2^{10}. A "1 Kb memory" is often read as a "one kilobit memory" and *usually understood* to mean 1024 bits of storage capacity. Compounding the confusion, when used to describe storage capacities, "M" (mega) means 2^{20} and "G" (giga) means 2^{30}.

Terms, definitions (in English), and letter symbols for semiconductor devices are given in EIA/JEDEC Standard 77 (for discrete semiconductor devices), EIA/JEDEC Standard 99 (for ICs), and EIA/JEDEC Standard 100 (for microcomputers, microprocessors, and memories). When used correctly, the meaning of a symbol is precisely defined … i_c, i_C, I_c, I_C, $I_{C(AV)}$, I_{cm}, I_{CM}, $I_{C(PP)}$, $I_{C(RMS)}$, etc.

Language tends to change with time as new words are generated or slang creeps in. Some would say that this enriches the language. While new technical abbreviations or acronyms are always being generated (by marketing or ad agencies) their replacement of symbols can cause considerable confusion. For example, the abbreviation BV for breakdown voltage should not extend to BV_{CEO} for collector-emitter breakdown voltage as this symbol can/should be read as the quantity of flux density and collector-emitter voltage ($V_{(BR)CEO}$ is correct). Similarly, if R is the symbol for resistance, thermal resistance is symbolized as R_θ or R_{th}, not θ.

Graphic symbols for logic functions and schematics are defined in IEEE Standards 91 and 315, respectively. Where IEC standards are used, letter symbols for electrical technology are given in IEC 27 and for semiconductor devices and integrated circuits in IEC 148. Terms, definitions, and letter symbols for semiconductor devices are given in IEC 747 (for discrete devices), IEC 748 (for ICs), and IEC 824 (for microprocessors).

Although certainly not "standards", there are some excellent aids for the data sheet writer. These include the standards and publications style manuals of the Electronic Industries Association (EIA Engineering Publication EP-7) and the IEEE. These two style manuals generally agree (although the EIA style manual includes much additional information of use to the electronics technical writer). Both are in the process of being brought into conformance with ISO/IEC standards requirements (Directives, Part 3).

Electronic Data Sheets (the data sheet's been printed, now what?)

Because system design cycles are being drastically shortened while device functionality and complexity is increasing (Moore's "Law" gives a 2x change in integrated circuit functionality, speed, and cost every 1.8 years), the process of finding the proper components for a design absolutely must be made both easier and faster. The design-in process most often starts only with knowing that possible solutions exist (somewhere). On the horizon are several programs that promise easier access to "standardized" specifications and more up-to-date "electronic" data sheets.

The original electronic data sheet was nothing more than a scanned-in document on a floppy disk or a CD-ROM. Access to a specific data sheet was fast – *if* you knew the manufacturer *and* you knew the part number of the device you wanted information on. Many hundreds of pages could be reduced down to one thin CD-ROM (and this is still the most cost-effective way to store massive amounts of data).

Similarly, fax-based information-retrieval or fax-on-demand systems can provide an up-to-date scanned-in data sheet. Access to a specific data sheet is fast – again, *if* you know the manufacturer and you can identify the device you want information on.

The next step was to index device specifications for computer search and retrieval of appropriate part numbers. One of these early programs contained a single manufacturer's complete bipolar transistor product line on a single 360 KB (5-1/4") floppy. After several devices were selected, it was then up to the user to obtain the appropriate data sheets to make the final selection. Even with these limitations, almost all of the users preferred the floppy search over a paper search (note that the paper catalog was still required though) and thought it was easier and faster to use.

A single CD-ROM can contain up to 680 MB, or almost 8 000 data sheet pages, and also include a menu-driven search program. A CD-ROM from one source has information on more than 1.2 million ICs and discrete devices from several hundred manufacturers, complete manufacturer's addresses and telephone numbers, sales offices' and distributors' locations, and it's updated every 60 days. The recently standardized DVD disks will store up to 17 GB, or about 200 000 data sheet pages.

Although electronic data is easier and more accurate than retyping the specifications manually, as modern system design gets more complex, customers want more-complete product information in electronic form, rather than just an electronic version of the printed data sheet. The need for computer-aided design is becoming a requirement with some manufacturers already provide SPICE models for their devices. Especially when large amounts of data are being accessed, the speed at which the information can be down loaded is important. The "old" 14.4-baud modem can transfer data at a rate of about 1.8 kilobytes per second (7 kB/s coming) while a 12x CD-ROM can download up to 1800 kilobytes per second.

Unfortunately, the disks or CD-ROMs that are coming from the independent technical-information services are not "industry standard" and may even be intentionally incompatible with each other. In response to this problem, several semiconductor manufacturers have recently joined together, in a collaborative effort called the "Pinnacles Group", to develop a universal electronic data sheet format based on the Standard Generalized Markup Language (SGML) that is neither software-, hardware-, nor vendor-specific. Here, tags will be used to identify the purpose of the information rather than its appearance. Where present data sheets are only "human sensible", these proposed electronic data sheets will also be "computer sensible". If it works out, these electronic data sheets will reduce the costs of finding and using data sheets, enable efficient electronic communications, and promote designer/user concurrent engineering.

Another approach is to make complete information available on-line via a desktop computer and modem or wide-area network (internet). Software is available to make the information platform- and software-independent.

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The Information Superhighway

Electronic data sheets on the internet, or "information superhighway", can provide an up-to-the-minute capability with text documents located quickly via searches on key words. Engineers at small firms can now get service that they could never have received and the big OEMs get more up-to-date information faster than with a printed data sheet or applications note. However, the PC serial-port transfer limit is currently (subject to change without notice) about 115 kilobits per second. Most modems can compress data up to a 4-to-1 ratio, and the FCC currently prohibits modems from transferring data at a rate greater than 53 kilobits per second.

28.8 kb/s modem	3.6 kilobytes per second
56 kb/s modem	7 kilobytes per second
PC serial-port transfer	14.4 kilobytes per second
ISDN	16 kilobytes per second
T1	193 kilobytes per second
DBS (DirecPC®)	400 kilobytes per second
4x CD-ROM	614 kilobytes per second
DVD	1 108 kilobytes per second
12x CD-ROM	1 843 kilobytes per second

DirecPC is a registered trademark of Hughes Network Systems, Inc. for a satelite internet service.

The internet data sheets might sometimes include hypertext markup language (HTML) to tag paragraphs and headings, which does little in the search for parametric data but can provide links to other documents or other locations. HTML requires plain text consisting entirely of letters, numbers, and other common characters, without formatting (no 8-bit characters). Confusion will occur when complex symbols become gibberish, or do not print out.

Additionally, a variety of internet access software (web browsers: Microsoft Explorer® vs. Netscape Navigator®) means that unlike the precise control of a printed data sheet page layout, an internet page layout is a variable depending on the exact software used.

As originally typeset (printed with helvetica, symbol, and zapf chancery type faces):

> The *Company* POWERHALL® A5276SU is available with 1000 Å of metallization, a temperature stability of ±3%, an intrinsic voltage of 150 μV, and an extrinsic resistance of greater than 10^5 Ω over a temperature range of -40 °C to +150 °C. For example, $ß \approx 3.3 \cdot 10^{-3} \eta V_{(BR)CEO}/\Delta T_J$.

This same document might be printed (courier type face) from the internet as:

```
The Company POWERHALLr A5276SU is available with 1000
A of metallization, a temperature stability of +3%,
an intrinsic voltage of 150 mV, and an extrinsic
resistance of greater than 105 z over a temperature
range of -40 *C to +150 *C.  For example, s x 3.3
10-3hV(BR)CEO/jTJ.
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However, once a possible "hit" is found, pricing, samples, technical support, and the printed data sheet can be received within a few days. The standard internet connection does not easily replace the data sheet with its many drawings, graphs, or photographs, but can greatly improve customer service and responsiveness. Printed data sheets can be marked up, taken to meetings, and compared side-by-side for alternative or competitive devices.

Electronic data sheets (CD-ROM, DVD, or Internet) will eliminate much of the publishing time lag and help to ensure that the latest information (and possibly including price and availability) is used by the systems designer in contrast to the printed data sheet, which is often obsolete the minute it is printed (or even before). In whatever form, electronic data sheets will promote designer/user concurrent engineering.

A Personal Comment

You don't have to be nuts to work here — but it sure helps. The data sheet writer must be willing and constitutionally able to spend hours writing, polishing, and rewriting sometimes only a very few lines of text. The ability to produce a 12-page data sheet in readable prose on exact schedule should be of less value than a willingness to rewrite a line of text several times in order to achieve precisely the honest, informative (but not necessarily too informative), and technically accurate message that engineering, sales, marketing, quality control, and the customer want to have. However, misquoting Thomas A. Edison, "there comes a time to shoot the [writer] and get down to [publishing]."

Conclusion

Except for standard symbols, terms and their definitions, and the always confusing language, there is no such thing as a "right" or "wrong" data sheet style, only more-effective (usefullness and practicality) and less-effective ones. The most effective style is not the one that follows some preferred textbook approach nor does it have to "dazzle" the reader, but rather, the style that the reader is most attuned to and conveys the most information. What the reader wants are answers to specific questions or problems; to the extent that the data sheet gives him these answers quickly, easily, and reliably, its effectivenesss is assured.

Everything regarding printed data sheets applies equally to electronic data sheets. In whatever format, the data sheet will remain the important communications link between engineers, and often part of the legal contract between seller and buyer — but only if it is clear, complete, and understood by the reader the same way it was intended by the writer.

> "If language is not correct, then what is said is not what is meant; if what is said is not what is meant, then what ought to be done remains undone; if this remains undone, morals and art deteriorate; if morals and art deteriorate, justice will go astray; if justice goes astray, the people will stand about in helpless confusion. Hence there must be no arbitrariness in what is said."
>
> Confucius

Contrary to popular opinion, many engineers are capable of writing good data sheets. However, a little knowledge can be worse than none, as in a recent new product release for a fully compensated amplifier where the proof reader changed "100 mHz response" to "100 MHz response". Unfortunately, in this case, seismic amplifiers really do need to operate down to 0.1 Hz!

Allegro Data Sheet Boundaries

1. The data sheet needs to convey an accurate and honest picture of Allegro's technical leadership and expertise – the data sheet is a subliminal communicator of corporate image and intent.

2. The technical level of Allegro data sheets must assume a level of technical comprehension and experience on the part of the designer/user – Hall-effect data sheets assume a different electro-mechanical competency.

3. The data sheet should be viewed primarily as an "engineering" document with promotional statements limited to the descriptive front-page text.

4. All abbreviations, terms, symbols, and schematic symbols must conform to national and international standards, which is especially important where the readers' primary language is not English or where the reader is not an electrical engineer.

5. The data sheet must be grammatically correct.

6. The data sheet should follow a format that makes sense and appeals to the broadest cross-section of readers.

7. The data sheet should provide key fundamental determinants immediately up front – an order of specifications based on importance and convenience to design must be established thereafter.

8a. The data sheet should provide the designer with sufficient and realistic technical and applications information so as to facilitate the product's design into the suggested application, or

8b. The data sheet should provide sufficient technical information to allow the reader a comparison leading to the replacement of a competitive device.

9. The electrical characteristics of the data sheet serve a dual function of both design information and purchasing information and must agree with Allegro's internal manufacturing specifications.

10. Applications nuances known by applications engineering, through ongoing customer contact, should be incorporated into data sheets on a continuing basis.

Basic References

The principles described here apply to product data sheets in general. There are also several industry consensus standards and publications that can aid in the generation and use of data sheets for electronic devices and, specifically, for semiconductor devices:

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IEC/ISO Directives, Part 3, **Drafting and Presentation of International Standards**.

ANSI/IEEE Std 100, **IEEE Dictionary of Electrical and Electronics Terms**.

ANSI/IEEE Std 260.1, **Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)**.

ANSI/IEEE/ASTM SI 10, **Standard for Use of the International System of Units (SI): The Modern Metric System.**

ANSI/IEEE Std 280, **Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering**.

ANSI X3.50, **Representations for U.S. Customary, SI, and Other Units to be Used in Systems with Limited Character Sets**.

ANSI Y1.1, **Abbreviations for Use on Drawings and in Text**.

ANSI Y10.20, **Mathematic Signs and Symbols for use in Physical Sciences and Technology**, and supplement.

EIA EP-7, **Style Manual for Standards and Publications of EIA and JEDEC**.

JEDEC Std. No. 46, **Guidelines for User Notification of Product/Process Changes by Semiconductor Suppliers**.

JEDEC Std. No. 77, **Terms, Definitions, and Letter Symbols for Discrete Semiconductor and Optoelectronic Devices**.

JEDEC Std. No. 99, **Glossary of Microelectronic Terms, Definitions, and Symbols**, and supplement.

JEDEC Std. No. 100, **Terms, Definitions, and Letter Symbols for Microcomputers and Memory Integrated Circuits**.

JEDEC Pub. No. 103, **Suggested Data Sheet Classifications and Disclaimers**.

JEDEC Pub. No. 104, **Reference Guide to Letter Symbols for Semiconductor Devices**.

JEDEC Pub. No. 120, **Index of Terms Defined in JEDEC Publications**.

Raymond Dewey, the author of this paper, is a retired Technical Information Coordinator for the Communications Department of Allegro MicroSystems, LLC (previously Sprague Semiconductor Group). In this capacity he was responsible for the generation of the company's product data sheets. Mr. Dewey was also the chairman of the EIA/JEDEC JC-10 Committee on Semiconductor Terms and Definitions. The opinions expressed here are his and do not necessarily represent those of Allegro MicroSystems or EIA/JEDEC.

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