CISPR EMI Measurements

Background

"CISPR" is the Comite International Special des Perturbations Radioelectriques, or *Special International Committee for RadioFrequency Interference*, which operates under the auspices of the International Electrotechnical Commission (IEC). Its objective, since its founding, in 1934, has been to facilitate international trade by promoting international agreement on radio interference limits.

Although the CISPR is a voluntary organization whose documents have no legal basis, its functioning is extremely important because its measurements and recommended limits have been adopted as the basis for growing number of national regulations throughout the world.

Origin of CISPR Requirements

When the CISPR began functioning, more then 40 years ago, the only service needing protection was audio broadcasting. Thus, it was logical to prescribe a measurement system which produced a reading for a given level of interference, which was proportional to the subjective annoyance effect in the listener to the radio broadcast being affected.

CISPR Detection for 150 kHz to 30 MHz

In the 1930's it was recognized that an EMI meter incorporating a quasi-peak type detector most closely tracked the degree of listener annoyance. However, various factors, including World War II, intervened to delay, until 1953, agreement on specificiations for a CISPR EMI meter. Table I summarizes the characteristics specified for the frequency range 150 kHz to 30MHz.

An instrument possessing the characteristics shown in Table I will respond to a variation in the repetition rate of impulses of a fixed level in the manner shown by the curve labelled "CISPR" in Figure 1. The other curves in Figure 1 show the response of other types of detectors commonly employed in interference analyzers. Note that the x-axis represents impulse repetition rate, in Hertz, and that the y-axis is amplitude (typically front-panel meter) response relative to response of a true-peak-responding detector calibrated in terms of the rms level of a cw signal of matching peak amplitude.

Table I-Characteristics of CISPR
EMI meter for 150 kHz to 30 MHz (Nominal)

Bandwidth at (-6dB)	9 kHz
Electrical Charge Time Constant of QP Voltmeter	1 millisecond
Electrical Discharge Time Constant of QP Voltmeter	160 milliseconds
Mechanical Time Constant of Critically-Damped Meter	160 milliseconds
Pre-detection Overload Factor (min.)	30 dB
Post-detection Overload Factor (min.)	12 dB

A *peak* detector is that type specified for measurement in conformance with Military Standards 461 and 462. As commonly employed in "scanning-receiver" type of interference analyzers oriented toward MIL-Std testing, the peak detector operates, in conjunction with associated "dwell" and "dump" circuits, to produce accurate readings of most types of interference as the receiver scans through sectors of the frequency domain. Although ideal for detection of isolated, or low-repetition-rate impulses which might cause sophisticated military systems to malfunction, the peak detector is not responsive to changes in impulse repetition rate. Correspondingly, it provides no indication of relative annoyance effect, since it provides equal readings for given impulse levels, whether the repetition rate is 1 Hz or 1000 Hz.

The curve designated "ANSI", in Figure 1, refers to response of instrumentation specified by Publication C63.2 of the American National Standards Institute (ANSI). The specified detector is of the quasi-peak type and differs principally from the CISPR requirement in that the electrical discharge time constant is 600 milliseconds, instead of 160 milliseconds. However, a proposed revision of the ANSI requirements, currently being circulated for comments prior to approval, brings the primary ANSI quasi-peak requirements into complete accord with those of the CISPR.

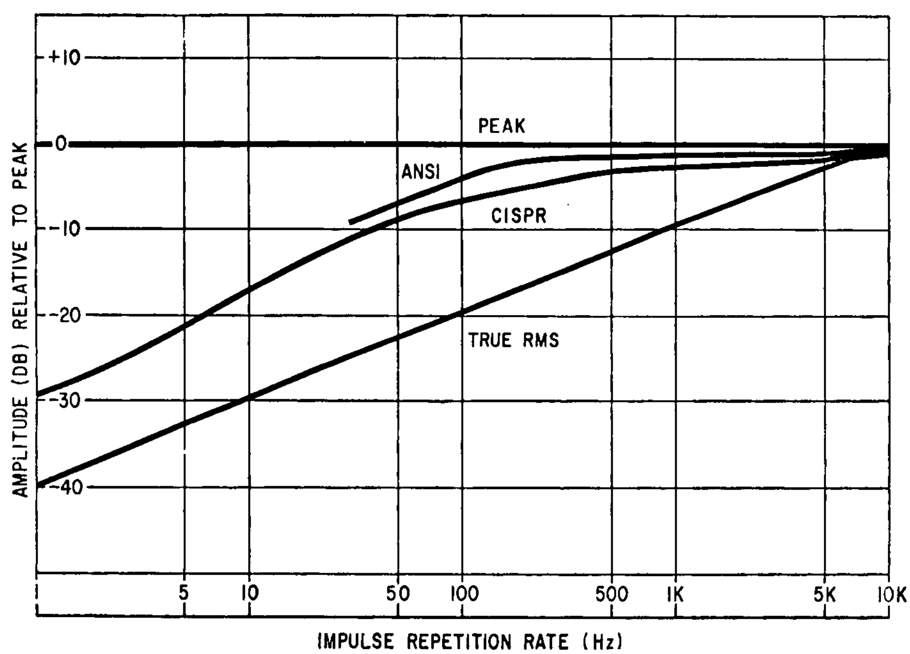

Figure 1- Relative Response of Various Detectors to Impulse Conditioned by CISPR Publication 1 Bandwidth (9kHz @-6dB)

Table II-CISPR EMI Meter Characteristics (nominal)

CISPR Publication: Frequency Range:	#3 (10-150kHz)	#1 (150kHz-30MHz)	#2 (25-300MHz)	#4 (300-1000MHz)
Bandwidth at (-6dB)	200Hz	9kHz	120kHz	
Electric Charge Time Constant of QP Voltmeter	45MS	1MS	1MS	
Electrical Discharge Time Constant of QP Voltmeter	500MS	160MS	550MS	
Mechanical Time Constant of Critically-Damped Meter	160MS	160MS	100MS	
Pre-detection Overload Factor (min.)	24dB	30dB	43.5dB	
Post-detection Overload Factor (min.)	12dB	12dB	6dB	

CISPR Detection for Other Frequency Ranges

Successful results obtained with applicatins of the CISPR Publication 1 characteristics (150 kHz-30 MHz) led to extension of similar instrument requirements to the range of 25-300MHz (Publication 2), 300-1000MHz (Publication 4) and 10-150kHz (Publication 3). Principal requirements of instrumentation specified for these additional ranges are shown in Table II; also included, to facilitate comparison, is the data for the Publication 1 range. A listing of all current CISPR Publications is appended at the end of this discussion.

Relationship with Other Requirements

West Germany-The VDE

VDE is the Verband Deutscher Elektroteckniker, or *Association of German Electrical Engineers*. As noted by Herbert Mertel, in his article on the VDE in this publication, the VDE may be compared to our IEEE combined with our Underwriters Laboratories, with a direct link to West German legislation. The VDE participates in CISPR and its requirements on instrumentation for EMI emissions testing include those of the CISPR. CISPR limits are specified as basic, but are relaxed by 14dB for industrial application (G limit) and tightened by 20 to 32dB for remote areas (K limit).

The SAE and CISPR

SAE J551d is the current (late 1976) issue of a standard published by the Society of Automotive Engineers (SAE), entitled *"Measurement of Electromagnetic Radiation From Motor Vehicles (20 to 1000MHz)"*. The procedures and limits in this Standard evolved from tests at Anderson, Indiana, in 1957, conducted to quantify the effects of impulsive radiated interference from motor vehicles on the performance of television sets. Although primary emphasis in the J551 series of standards has been on measurement of impulsive interference by peak detection, J551a and later editions also include provision for measurement by the CISPR quasi-peak method.

When CISPR quasi-peak detection is used, the allowable limit for radiated interference is 20dB lower than that applied for peak detection. Why 20dB? This is an important question, especially to U.S. automobile manufacturers, since the 20dB equivalency had been confirmed empirically by numerous comparison tests, and since reducing this number to 12dB, as recommended by a Swedish representative to CISPR in March 1975, would effectively tighten the limit by 8dB, on peak detector testing of all vehicles produced for export.

As discussed above, the CISPR quasi-peak detector is responsive to the repetition rate of impulses in a precisely-prescribed fashion. Figure 2 shows this characteristic for the 25-1000MHz range of CISPR Publications 2 and 4. If we assume an 8-cylinder engine running at the test speed of 1500 rpm, the rate at which it is assumed to produce pulses is 100 Hz. Figure 2 shows that the reduction in amplitude response, relative to peak, for this rate is 12dB, corresponding to the Swedish members recommendation. However, the implicit assumption that all engine firing pulses are of equal amplitude is not supported by experimental evidence. The actual situation appears to indicate that only two of the cylinders usually dominate, producing an effective repetition rate of approximately 25Hz, and supporting the established value of 20 dB for limit relaxation when using quasi-peak.

Instrumentation

Susceptibility measurements are not required by any of the CISPR Publications. Thus, instrumentation needs, at present, are confined to those required for emission testing.

Because of the unique requirements imposed for CISPR testing, interference analyzers designed primarily for MIL-Std-type testing are usually not suitable for measurements in accord with CISPR requirements. Similarly, EMI meter specifically oriented toward the CISPR requirements are usually not adequate to perform MIL-Std-type measurements. However at least one manufacturer, the Electro-Metrics Division of Penril, markets an adaptor (the CMM-25) to convert its MIL-Std-oriented EMC-25 to CISPR requirements. Following is a brief analysis of the principal differences between instrumentation for MIL-Std testing, as compared to that needed for CISPR testing.

Linearity and Metering Range

To achieve the amplitude-vs-repetition rate characteristics required by the CISPR Publications, it is essential that linearity be preserved prior to detection. In addition, a specified relatively high overload factor must be maintained, both pre- and post-detector. Because of the MIL-Std emphasis on scanning receivers and X-Y plotting, the typical interference analyzer designed for MIL-Std tests boasts peak detection accompanied by "logging". It is not unusual for a MIL-Std-type interference analyzer to have an instantaneous dynamic range of more than 60dB for front-panel metering, X-Y plotting, and spectrum display.

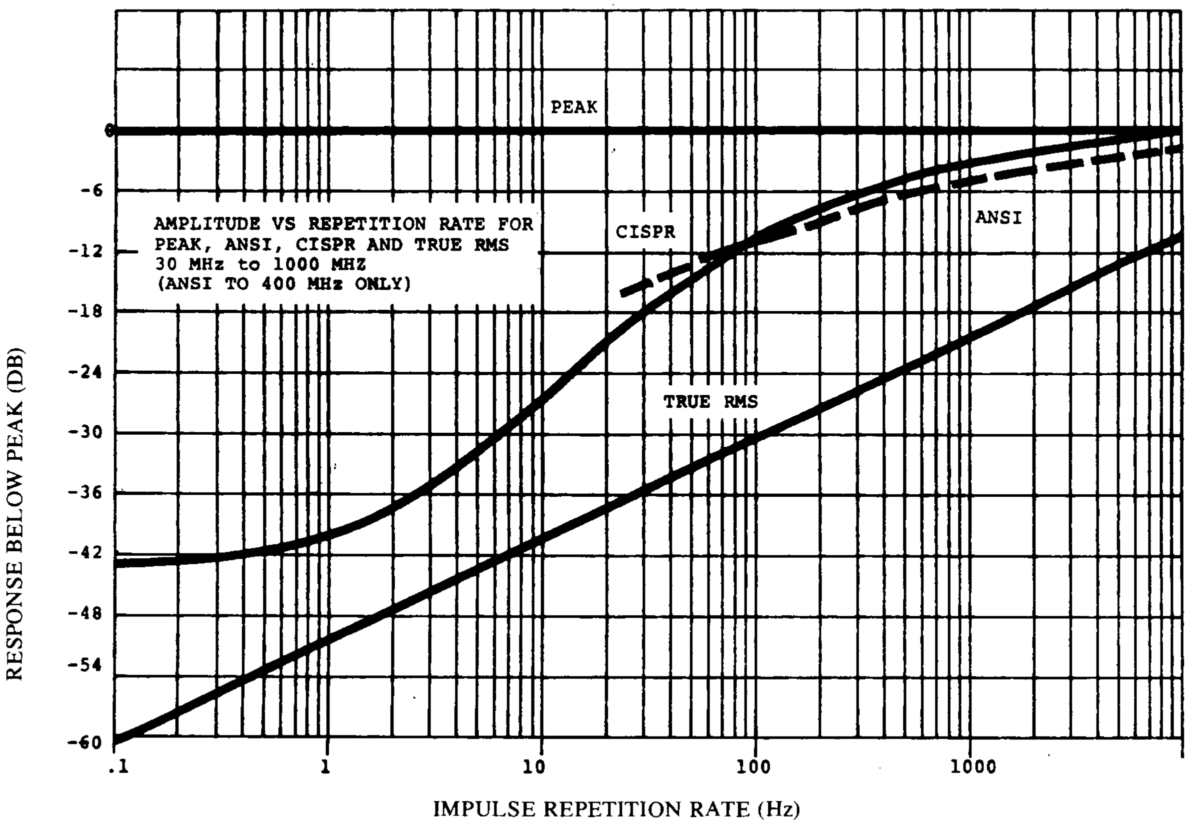

Figure 2- Relative Response of Various Detectors to Impulse Conditioned by CISPR Publication 2/4 Bandwidth (120kHz@-6dB)

In contrast, a CISPR-type EMI meter typically has a front-panel meter range of 10dB or less, as a consequence of the need to maintain linearity prior to the quasi-peak detection. The basic design problem in this regard can probably be appreciated by a brief consideration of the fact that the level of impulse required into the detector to produce a given meter reading, at a repetition rate of 5Hz, (in the Publication 1 range) is nearly 20dB greater than that impulse level required to produce the same reading when the repetition rate is 1000Hz. Add the 30dB pre-detector linear overload requirement for the Publication 1 range and the problem is even easier to appreciate.

It is not practical to X-Y plot the response of an orthodox CISPR EMI meter because of the restricted metering range and the need to observe the required constraints on the mechanical time constant of the front panel meter. However, at least one U.S. manufacturer provides an X-Y plotting capability based on post-detector logging, for use in initial assessment of specification compliance..

Bandwidth and Detector Constraints

For MIL-Std-type measurements, an EMI meter typically must have at leat two IF bandwidths, one relatively narrow for narrowband measurements, and one relatively wide for broadband measurements. Although the CISPR-mandated bandwidths shown in Table II are probably suitable for existing narrowband requirements, (assuming reasonable receiver front-end sensitivity) they are only one-tenth of bandwidths typically needed for currently-specified MIL-Std 461/2 broadband measurement requirements.

With regard to the detector itself, the MIL-Std requirement for peak detection typically requires a much faster charge time constant and a much slower discharge time constant than those specified for CISPR purposes. In addition, the MIL-Std preference for scanning receivers and X-Y plotting necessitates inclusion in the EMI meter of relatively sophisticated circuits which function, in association with the detector itself, to discharge rapidly, or "dump" the peak-charged level as soon as the associated X-Y plotter has time to register that amplitude.

Spectrum Analyzer Use

In view of the unique quasi-peak detector requirements mandated for true CISPR measurements, it is probably apparent that a spectrum analyzer is not well-suited to the CISPR measurement task. However, it has been shown that useful data can be obtained by reading the rms equivalent of the amplitude displayed by the spectrum analyzer and by:

a) subtracting from that level the factor appropriate to the impulsive repetition rate, as shown in Figures 1 and 2, provided that repetition rate is known, and by
b) correcting the reading by a factor which is 20 times the log of the ratio of the spectrum analyzer bandwidth @-6dB to the CISPR bandwidth @-6dB.

Since *a priori* knowledge of the repetition rate of noise usually cannot be assumed to be known with certitude, the Spectrum Analyzer is of only limited usefulness for CISPR measurements.

Pickup Devices

Conducted Measurements for frequencies between 10kHz and 30MHz, an *Artificial Mains Network* is used for measuring interference conducted out of a unit under test through its AC power cable. This type of Network, sometimes also called a *Line Impedance Stabilization Network*, provides a constant impedance at the sampling terminals and rejects interference entering on the power line itself. Since typical CISPR networks used for 150 kHz and higher frequencies have 150-ohm impedances, a 100-ohm series resistor and corresponding 9.5dB correction factor must be applied when using an Interference Analyzer with 50-ohm input impedance.

Radiated Measurements at frequencies up to 30MHz, conventional loop and rod antennas typically are used for measurement of magnetic and electric fields, respectively. Above 30MHz, broadband antennas, including biconicals and log conicals, may be used, provided their calibration can be referred to tuned dipoles.

Absorbing Clamp use of a special absorbing clamp is specified by CISPR in lieu of conventional radiated measurements, on small AC-powered appliances, in the frequency range above 30 MHz. Specification for use of the clamp is intended to simplify testing of this type of appliances and is based on recognition of the fact that interference from such a device, whose physical size typically is small in comparison with wavelengths involved, is conducted or radiated primarily by its power cord. The absorbing clamp consists of an array of ferrite toroid cores, some of which are used as a transformer to couple the inteference current in the AC cord to the interference analyzer, while the rest are used for damping external interference and line reflections.

CISPR Publications

English translations of the following documents may be obtained from the Sales Dept. of the American National Standards Institute, 1430 Broadway, New York, N.Y., 10018

CISPR 1 (1972)	**Specification for radio interference measuring apparatus for the frequency range of 0.15 MHz to 30 MHz, 68 p.**
CISPR 1A (1975)	**First supplement to CISPR Publication 1 (1972)**
CISPR-2 (1975)	**Specification for radio interference measuring apparatus for the frequency range 25 MHz to 300 MHz, 38 p.**
CISPR-3 (1975)	**Specification for Radio Interference Measuring Apparatus for the Frequency Range 10kHz-150 kHz.**
CISPR-4 (1967)	**Measuring set specification for the frequency range 300 MHz to 1000 MHz, 37p.**
CISPR-4A (1975)	**First supplement to CISPR Publication 4 (1967), 37p.**
CISPR 5 (1967)	**Radio interference measuring apparatus having detectors other than quasi-peak, 30p.**
CISPR-7 (1969)	**Recommendations of the CISPR, 73p. - Amendment No. 1 (1973)**
CISPR-7A (1973)	**First supplement to CISPR Publication 4 (1969)**
CISPR-7B (1975)	**Second supplement to Publication-7 (1969)**
CISPR-8 (1969)	**Reports and Study Questions of the CISPR, 61 p. Amendment No. 1 (1975)**
CISPR-8A (1973)	**First supplement to CISPR Publication 8 (1969)**
CISPR-8B (1975)	**Second Supplement to Publication 8, 67p.**
CISPR-9 (1967)	**CISPR Limits of radio interference and report of national limits, 76 p. (New draft copy in committee review)**
CISPR-10 (1976)	**Organization, rules and procedures of the CISPR, 30 p.**
CISPR 11 (1975)	**Limits and methods of measurement of radio interference characteristics of industrial, scientific, and medical (ISM) radio frequency equipment (excluding surgical diathermy apparatus), 33 p.**
CISPR 12 (1975)	**Limits and methods of measurement of radio interference characteristics of ignition systems of motor vehicles and other devices, 38 p.**
CISPR 13 (1975)	**Limits and methods of measurement of radio interference characteristics of sound and television receivers, 41 p.**
CISPR 14 (1975)	**Limits and methods of measurement of radio interference characteristics of household electrical appliances, portable tools and similar electrical apparatus, 53 p.**
CISPR 15 (1975)	**Limits and methods of measurement of radio interference of fluorescent lamps and luminaires, 21 p.**

This article was prepared by William S. Lambdin, General Manager, Electro-Metrics, Amsterdam, N.Y.

The 1976 edition of *ITEM* presented considerable coverage of the proposed B revision to MIL-STD-461, "Electromagnetic Interference Characteristics, Requirements for Equipment." According to informed authorities, in December, 1975, the proposed revision was scheduled for release in the summer of 1976. Informed readers now realize that it was not released on schedule. In fact, the summer of 1976 was more of a hopeful target date, evolving from earlier target dates starting in 1973.

MIL-STD-461 represents the basic EMI control standard used in the United States. Although it is a military document used on government procurements, many industrial and professional societies use it for a model in formulating specialized standards. For instance, the forthcoming HEW/FDA EMI specification has been modeled after MIL-STD-461, except for differences in the limits. MIL-STD-461 and its cousin, MIL-STD-462, "Electromagnetic Interference Characteristics, Meausrement of" can be considered the United States' standard for the control and measurement of EMI. Its application is almost universal since it is used by the governments of many foregin nations in their military procurements.

In its present state, MIL-STD-461A has six modifying amendments or Notices to the basic document. Notice 1 includes an addition for GSA procurements and a modification for electric hand tools. Notice 2 was even less significant, simply stating that the tables in the Appendix of Notice 1 were not applicable for Air Force Procurements.

Notice 3 contained significant changes. For example, the conducted and radiated emission limits were relaxed, radiated emission limits were increased, and the subsystem compliance concept was introduced. Among many other changes, new paragraphs to cover production testing, armament and design guidance were added. Notice 3 is applicable for Air Force procurements only and represented the first real polarization of this joint service standard by a single agency.

The changes contained within Notice 4 are even more far reaching than Notice 3. In effect, this new 71 page document can stand alone without the basic standard or previous notices. Included among the changes are a new conducted transient emission requirement, subsystem definition and application, a list of equipment which are specifically exempt from the requirements, plus extensive matrix of equipment type procurements. Notice 4 represented the second major deviation from the joint services standard by a single agency.

In Notice 5, the revision was applicable only to mobile electric power (MEP) and superceded the requirements for MEP contained in Notice 3 and Notice 4. The sole purpose of Notice 6 was to provide clear figures which had not reproduced very well in Notice 5.

It is now anticipated that when the B version of MIL-STD-461 is finally released, it will be released simultaneously with the B version of MIL-STD-462. Readers should note, however, that the A designation for MIL-STD-462 will be skipped and not used.

The best informed sources are presently (January 1977) afraid to guess on a release date for the B version, but, hopefully, it will be some time during calendar 1977. This revision is significant and is pretty much the same as described in *ITEM '76*, except that the document has been reorganized for ease in use. The only technical change over the last year is expected to be an increase in transient susceptibility levels for Army procurements.

Copies of *ITEM '76* are in short supply. However, interested readers may obtain the free comprehensive eight-page "Requirement Tree," which thoroughly describes the B issue, by contacting Electro-Metrics, 100 Church St., Amsterdam, NY 12010.

EXCERPTS FROM PROPOSED MIL-STD-461B

TABLE 1

EQUIPMENT CLASSES – MISSION/INSTALLATION

CLASS A Equipments installed in critical areas of the following vehicles or installations	CLASS B Equipments which support Class A items used in critical areas	CLASS C Equipment not located in critical areas
A1 Aircraft (manned & unmanned) A2 Missiles A3 Ground Facilities (fixed) A4 Ground Facilities (mobile) A5 Submarines (all areas aboard submarines are considered critical areas) A6 Surface Ship, steel-hull, below deck A7 Surface Ship, steel-hull, above deck A8 Surface Ship, non-steel hull A9 Tracked & wheeled vehicles A10 Space systems including launch vehicles, space vehicles, ground systems and associated AGE	B1 AGE used on the flightline for checkout and launch of aircraft communications and other electronic support equipment such as flightlines, receiver sites and radio rooms B2 Trainers and simulators B3 Portable medical equipment for aeromedical airlift	Examples Shop maintenance and test equip. AGE Other similar equip. used in isolated areas

TABLE 2

TRANSIENT (SPIKE) SUSCEPTIBILITY REQUIREMENTS

SPIKE NUMBER	PEAK LEVEL	MAX DURATION	APPLICABLE CLASS		
			NAVY	AF	ARMY
1	100V	10μS	A1,2,9; B1,2,3; C	A1→4,9; B1→3; C	ALL
2	100V	0.15μS	A1→4,6→9; B1→3; C	A1→9; B1→3; C	
3	400V	5.0μS	A3→9	A5→9	

NOTES:
1. For Army only, Spike 1 plus others as specified
2. Aerospace (class A10) use Mil-Std-1541
3. See Table 2 class definitions

TABLE 3

RADIATED E-FIELD SUSCEPTIBILITY LEVELS FOR RS03

FREQUENCY RANGE	CLASS OF EQUIPMENT		
	A1→4; A7→10, B3	A5,A6, B2, C	B1
14 kHz – 30 mHz	10 V/M	1 V/M	5 V/M
30 mHz – 12.4 GHz	5 V/M	1 V/M	5 V/M
12.4 – 40 GHz	20 V/M	1 V/M	5 V/M

NOTES:
1. Requirements for class A5 ends at 1 GHz
2. 14 kHz – 50 kHz deleted for Army only
3. 50 kHz – 500 kHz level at 1 V/M for Army only
4. External on aircraft – 200 V/M, 14 kHz – 10 GHz
5. Navy operational environments, See MIL-HDBK–235
6. See Table 2 for class definitions