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Superseding ARP935A

Control Plan/Technical Construction File

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE AE-4 Electromagnetic Environmental Effects (E3) Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

1. SCOPE:

This document contains a "sample" Control Plan with explanations as to the intended content of various sections. It also can serve as a sample technical construction file as specified by the European EMC Directive.

2. REFERENCES:

DID DI-EMCS-80199A, 11 Jan. 1993, Electromagnetic Interference Control Procedures

MIL-STD-461D, 11 Jan. 1993, Requirements For The Control Of Electromagnetic Interference Emissions And Susceptibility

89/336/EEC, 3 May 1989, Council Directive regarding Electromagnetic Compatibility

3. RATIONALE/BACKGROUND:

An EMC Control Plan has been a significant requirement of EMC programs. It has also been the source of much debate since its purpose has been less than well defined. The SAE AE-4 Committee has put together this ARP to define and clarify the contents of the plan.

A Control Plan should be prepared early in the program. It has three main functions. 1) The requirements should be identified and listed. Much misunderstanding occurs because there is not a common understanding of what the exact requirements are. This document provides the manufacturer the opportunity to define the requirements as they understand them. 2) The proposed design approaches are identified. This provides the manufacturer the opportunity to explain what design considerations are being investigated and used on the program that will allow the equipment to comply with the EMC requirements. 3) The analysis of the design is presented to justify that the approaches being used are adequate to meet the program requirements.

3. (Continued):

The control plan needs to be submitted early enough that the customer can review the document and determine 1) if the requirements are understood, 2) if appropriate and logical considerations are being planned in the design, and 3) if proper analyses are being used to be able to clearly demonstrate that the equipment will satisfy the EMC requirements. Reality dictates that some time will elapse before the design really gets underway and EMC engineers really get involved. Thus, a two part submittal is recommended. The first submittal should clearly cover item 1 as listed above with summary coverage of items 2 and 3. The second submittal should more completely cover items 2 and 3 as described above.

Updated Control Plans are often specified. An "as built" document may be useful for the future in understanding the EMC characteristics of an equipment. Likewise, intermediate versions may be useful to see if the design ideas still make sense later in the program, and to see if the analysis still shows compliance with the requirements. But this is actually an expanded function of the original control plan and more rightly should be called out as a separate project status report document. This function is normally handled as part of project or design reviews.

Many items for the commercial European market don't fit exactly in the definitions or requirements of existing specifications. In this case the manufacturer prepares a "technical construction file" (TCF). This outline can be used as the basis for a TCF. The contents of the file are officially, but briefly defined in Article 10.2 of the EMC Directive and can be related to the paragraphs of this document as:

3.0) The equipment is described.
4.0) The explanation or rationale for the applicable requirements is presented.
5.0) The design and considerations used to provide compliance with the applicable directives.
6.0) The analysis, in this case, will usually consist of actual test results.

The AE-4 committee has reviewed documentation about TCF's and generic TCF's in the preparation of this ARP. Thus, ARP935A represents a good starting point, but may need tailoring after review by a specific competent body. The EMC Directive requires that the technical construction file be submitted to a competent body for evaluation and concurrence. Based on their background and experience, they may require that the content and format be adjusted.

With this philosophy in mind, an outline and discussion of contents of a control plan are as shown in Appendix A.

APPENDIX A
STANDARD CONTROL PLAN

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ABSTRACT

The EMC Control Plan delineates the MIL-STD-461 EMC requirements applicable to the XXX equipment. Techniques for interference control in the design and construction of the equipment are defined along with an analysis which demonstrates the predicted degree of compliance to the requirements.

The emphasis is to evaluate and define the requirements as they are to apply to a specific project. Then a discussion of possible design techniques to achieve compliance will be included. This must be developed in conjunction with the project considering cost and other design constraints. Part of the objective is to convey to the customer the assurance that adequate design considerations are being included up front. Since this is early in the design process, predictions may be used merely to identify areas where future design considerations may be required.

A.1 SCOPE:

This document contains the electromagnetic compatibility interference and susceptibility performance requirements and design approaches used for the EUT to comply with these requirements. The mechanical and electrical designs are outlined, and an interference control program is delineated that will be followed throughout the course of the equipment design phase to assure compliance with the listed requirements. An EMC analysis is included illustrating the predicted results expected from these design approaches. Actual test data, where available, verifying the results is also included as part of the analysis.

The scope should explain the purpose and content of the plan. It can also list details about the contract and statement of work as applicable.

A.2 REFERENCES:

A.2.1 Applicable Documents:

A234567	System Specification for the XXX Equipment
MIL-STD-461D	Requirements For The Control Of Electromagnetic Interference Emissions and Susceptibility, 11 January 1993
MIL-STD-462D	Measurement of Electromagnetic Interference Characteristics, 11 January 1993
EN50081-1-2	Electromagnetic Compatibility - Generic Emission Standard, 1992
EN50082-1-2	Electromagnetic Compatibility - Generic Immunity Standard, 1995

With so many commercial and governmental documents existing, adequate references should be included to provide the justification and rationale for a reviewer's understanding.

A.2.2 List of Acronyms:

EMC - Electromagnetic Compatibility
EMI - Electromagnetic Interference
EUT - Equipment under test
GFE - Government Furnished Equipment
GOE - Ground Operational Equipment
PWB - Printed Wiring Board
QA - Quality Assurance
rms - Root mean square
TCF - Technical Construction File

A.3 DESCRIPTION OF EQUIPMENT:

A.3.1 Equipment Identification:

Information such as general equipment functions, special installation requirements, and references to instruction manuals, drawings, photographs, quality procedures, etc. should be available.

A.3.2 Technical Description, Function:

Sufficient description and theory of operation should be included to allow a customer reviewer to understand how EMI interacts with the equipment functions.

A.3.3 EMI Characteristics:

The XXX contains three MC68332 microprocessors operating at a clock frequency of 8 MHz. The microprocessors may be run at 16 MHz but for power conservation the present design calls for 8 MHz. A 16 MHz clock is used to drive the time-of-day function. Other clock speeds will be generated by dividing down the main clock. These speeds include a 512 kHz data clock and a 15 kHz keyboard clock. The power supply will use a 350 kHz switching DC-DC converter. Because of the relatively high clock speeds and their rise times, the enclosure, cables, power filters, and cable connectors will have a vital role in determining the EMC performance.

Sufficient information should be included about the normal operation so that a reviewer can understand the applicable requirements and categories for this equipment. Any available parameters such as logic rise times, amplitudes of rf signals and signal routing should be included.

There often may be more subtle issues or risks, or over-riding large-scale issues or risks. These should be identified here and adequately addressed in the design, test, and analysis sections.

A.4 TECHNICAL REQUIREMENTS:

A.4.1 Applicable Requirements of the EMI Specification:

The EMC requirements are those called out in the customer specification NMQA-123 which is based on and modifies MIL-STD-461D. These requirements are outlined in Table 4.1-1.

Where unusual requirements exist, the pertinence to the EUT should be explained in terms a project engineer can understand.

If this TCF is being prepared for equipment to be marketed in Europe, the implication is that existing specifications aren't clearly applicable, or that they require some modification. This issue should clearly be discussed here. The final decision of the applicable specifications as determined in conjunction with a competent body should be documented here.

A.4.1.1 Conducted Emissions, DC Power Leads: The conducted emissions on the 28 V DC power leads will be tested to the requirements shown in Figure 4.1-2 through 4.1-4. The CE101 test will use 10 mF line stabilization capacitors (LSC) from 30 Hz to 50 kHz. The CE102 test will use 50 µH line impedance stabilization networks (LISN) from 10 kHz to 50 MHz.

NOTE: The wording is only for example since the use of the LSC/LISN and the specific test method is dependent on whether the latest version of MIL-STD-461 is specified, or if a commercial requirement is specified.)

A.4.1.2 Radiated Emission, RE102: The radiated electric field emissions will be tested to the narrowband and broadband requirements shown in Figures 4.1-6 and 4.1-7. (If MIL-STD-461D is used, the broadband would not apply.) The XXX is a hand-held unit in the field. Therefore, the XXX will be tested as a portable unit on a 1 m non-metallic test stand. The DC power will be supplied through LISN's bonded to the shield room floor. All other tests will use the copper bench with the EUT elevated above the copper ground plane by 5 cm.

A.4.1.3 Etc.: These should be stated as they apply to the particular unit being designed. At times the limits are published as a function of voltage, or current, or as a function of EUT operating frequency, etc. These should be included and the final limit or requirement calculated and defined. Also a plot of the curves should be included rather than referencing a curve from another document.

A.4.2 Power Quality:

Requirements similar to those in MIL-STD-704 can be included here. This includes voltage fluctuations, frequency and voltage transients.

A.4.3 Interpretations, Clarification of Requirements, Necessary Explanations:

Examples of the type of issues to be addressed here. The idea is to do things in a reasonable manner and also let the customer know what is being done.

Antennas differing from those called out in the specification.

Use of instruments not called out in the specification.

Areas where tests need to be modified for particular equipment.

Explanation that cable radiation is not included. (For those cases where the manufacturer is selling an equipment and installation is the responsibility of the user).

Changes of limits because of modifications called out in the equipment specification.

Not measuring 400 Hz harmonics.

Conducted measurements taken on the center conductor of coaxial lines.

Rationale for excluding f_0 from RE102. This would include an analysis of the transmitter output power, the attenuation of the cable shield or load, the RE102 limit at f_0, and the physical location of the intentionally radiating antenna relative to the transmitter.

Rationale for excluding f_r from RS103. This would include a similar analysis as done for excluding f_0 from RE102.

Etc.

A.5 ENGINEERING PROGRAM:

A.5.1 Management Controls:

A.5.1.1 Lines of Authority: The EMC control program is managed by the XYZ project leader. It is his/her responsibility to coordinate all EMC efforts throughout the development, design, fabrication, and test phases. The EMC group acts as a service group providing support to all programs within the company. The EMC group has an engineer assigned to the program. He/she reports to the engineering project leader on matters concerning EMC. The EMC group provides the test facilities and additional technical assistance when needed.

Include an organization chart if available.

A.5.1.2 EMC Responsibilities: The responsible EMC engineer will perform the following tasks:

a. Establish design requirements and consideration necessary to comply with the EMC design goals.

b. Assist project design engineers in implementation of adequate EMC control methods in such areas as the power supply, internal shielding, enclosure shielding, and filtering.

c. Prepare the EMC Control Plan.

d. Prepare an EMC Test Procedure.

e. Perform preliminary tests on existing equipment to verify design approaches.

f. Perform formal EMC qualification testing.

g. Analyze and report EMC test results.

A.5.1.3 Milestone Chart:

A.5.1.4 Responsibilities Cconcerning Assoc., Sub., & GFE QA: Discuss the flowdown of requirements to any subcontractor and discuss handling of any major vendor items. Describe how the performance of subcontractors and vendors will be monitored. This includes the reviewing of vendor test procedures and reports.

A.5.1.5 Personnel Qualifications: The EMC engineer assigned to this program has had 8 years of experience in electromagnetic compatibility design and test operations. This experience will be used to assure that the EUT satisfies the specification requirements. There are 12 other experienced EMC engineers in the group with a total of over 180 years of experience that are available for consultation if there is a specific need.

A.5.1.6 Subcontractor Responsibilities:

A.5.1.7 Quality Program: The manufacturer's quality program should be documented. The customer or the market is relying on the fact that follow-on units will continue to perform as the one analyzed or tested. This section should provide that assurance.

A.5.2 Frequency Management:

This section of the plan shall describe the program to be employed that addresses:

How to minimize spectrum bandwidth
How to minimize receiver bandwidth
How to control oscillator frequencies and harmonics
How to maximize rise times of pulses

Include the rationale of design requirements that limit achieving the above goals.

A.5.3 Mechanical Design:

This section of the control plan shall describe the material and construction to be used to provide the inherent attenuation to electromagnetic emissions and susceptibilities while still meeting the contractual EMC requirements.

Types of metals and finishes
Compartments (module materials)
Circuit isolation
Filtering (circuits, response curves)
Front panel
Gasketing
Grounding
Bonding

A.5.4 Electrical/Electronic Design:

The plan shall describe the EMC control and suppression techniques which will be applied to all parts and circuitry, whether capable of generating undesired emanations or susceptible to the fields and voltages specified in the contract specification. The plan shall indicate, as a result of the program's design efforts, the following:

Choice of parts and control components
Bonding and grounding
Location of parts
Reasons for selection of pulse shapes
Circuit impedances
Power supply

A.5.5 Wiring:

This section of the control plan shall describe the electrical/electronic wiring design. This also is a good place to define inter-system cabling (external to Box XXX).

Length

Interconnect

Routing

Twisting

Filtering

a. General
b. Power lines
c. Signal lines

Shielding and termination

A.5.6 Follow-On Requirements:

Often EMC design integrity is affected by maintenance procedures. After either routine maintenance or repair, proper re-installation of gaskets, etc. is required for EMC reliability. What may be very logical to an EMC engineer may not be apparent to maintenance personnel.

Specific instructions and rework procedures should be identified and the approach documented here.

A.6 ANALYSIS:

A.6.1 Analysis Summary:

This section is titled analysis. It represents the documented rationale verifying compliance with the applicable requirements. For a MIL-SPEC program it will most likely contain analysis and prediction information since it typically is early in the design program. A number of modern analysis tools are becoming available for circuits, electromagnetic considerations, etc. These can be of great assistance in the design and prediction of results. Measured breadboard or experimental data will later be included. Whereas a technical construction file will be prepared much later in the product development cycle. Thus, the test results will most likely be required in this section.

Figure 6.1.1 is a summary sheet indicating the results of the analyses for the various EMC requirements on the XXX equipment. The actual analyses and further information is provided in the following sections of this Control Plan.

A.6.2 Conducted Emissions, Interconnecting Leads, CE01, CE03:

Should include the detailed approach. List each potential leakage path versus each requirement, including the isolation elements.

Frequency components from intentional signals on the cables which exceed the CE01 and CE03 limits are exempt. This rationale is predicated upon determining by analysis over what portion of the frequency test spectrum any intentional signals (i.e., clocks and digital data) will exceed the specification limits. This portion is then exempted insofar as those emissions that are necessary to effect performance. Table 4.1-1 lists the control/signal leads that exist for the XXX.

The XXX has a wideband operational data rate capability between 1 Mb/s and 450 Mb/s. This is dependent on the system clock speed. For the test frequency range of interest (30 Hz to 50 MHz), the XXX shall be operated at the 1 Mb/s data rate to determine if any conducted emission levels are above the specification limit. The single ended clock amplitude level is 500 mV into 50 Ω for an expected current of 10 mA or 80 dBµA (or 80 dBµA/MHz). The 1 Mb/s clock has a pulse width of 0.5 µs, and nominal rise and fall times of 500 ps (regardless of clock speed). Thus, the spectral distribution breakpoints are 637 kHz (i.e., 1/{π x d}, where d is the pulse width), and 637 MHz (i.e., 1/{π x t_r}, where t_r is the rise/fall time).

For CE01, it is predicted that the intentional data energy content will not be detectable since the spectral distribution starts at 637 kHz. For CE04, the frequency components from the intentional signals are exempt from 500 kHz to 50 MHz as illustrated in Figure 4.1-5. (Test references are only meant to be typical since the spec may not be 461D, or may be an EN reference.)

The control and signal leads to be tested are as follows. The command and status cable bundle for the J2 connector shall be separated as follows.

J2 - 21,34,36,38,41,43,45,47,53
J2 - 22,35,37,39,42,44,46,48,54
J2 - 1,6,8,11,13,17,19,23,26,28,32,49,51
J2 - 2,7,9,12,14,18,20,24,27,29,33,50,52
J3 - PT Data Out (exempt where applicable)
J6 - PT Clk Out (exempt where applicable)
J8 - PT AVE SIM In
J9 - CT Data In (exempt where applicable)
J11 - CT Clk In (exempt where applicable)
J14 - SIM PT Clk In
J16 - SIM CT Data Out
J17 - SIM CT Clk Out

A.6.3 Conducted Emissions, Power Leads:

The frequency range over which the limit for specification applies is from 15 kHz to 50 MHz. Since the nominal switching frequency is 100 kHz, then the 100 kHz fundamental and all its harmonics through 50 MHz must be controlled. In addition to the converter switching frequency, the rectifier action will be responsible for the generation of odd and even harmonics of the 60 Hz line frequency. This may coupled through the transformer and appear on the input line as spectral lines of emission energy at 60 Hz harmonics.

The most consistent method of controlling these power line emissions is by filtering and compartmentalizing the input and output filters from the main AC to DC converter. The use of filter sections on the input power leads suppresses the noise while not adversely affecting the power supply efficiency.

The optimum design approach is to minimize or prevent EMI generation at the source rather than suppressing it after it has been generated. Generally, EMI increases as dV/dt increases, or abruptly changes. But for power switching circuits, a high dV/dt plus minimum DC resistance results in high efficiency. A balance is needed between these effects.

The under damped nature of efficient power circuitry results in EMI, due to oscillations, and ringing which occur during device switching. Device switching produces odd harmonics while the rectifiers and filters produce even harmonics. Thus, the following devices and techniques are utilized in preventing EMI at the source:

a. EMI bulkhead mounted suppression filters have attenuation versus frequency expressed in terms of a 50 Ω measurement system. Knowledge of the terminations at both ends of the filter is required for design optimization.

b. The input power line filter is designed to operate on a low impedance circuit and is placed line to line. The EMI bulkhead filter is installed on both the AC input and AC return.

c. Snubbers tailor the switching wave forms of semiconductor devices.

d. Ferrite beads are effective in low impedance switching circuits. When placed around conductors connected to power transistors, SCRs, and rectifiers, the beads reduce EMI above 1 MHz by eliminating parasitics oscillations.

e. Minimizing capacitance from circuits to ground reduces common mode EMI.

f. By-pass capacitors are an effective means to suppress differential mode EMI. The capacitors reduce external high frequency current flow by shunting the current path.

g. Multi-point grounding reduces EMI by reducing inductance.

h. Low pass filters on the dc lines control conducted EMI.