Design through collaboration

DSL AMPIC

Design Specification

Product No. : 1253-000
Document No. : 106-062
Issue : 1.1
Date : 27/11/2014
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4 Record of Amendments

DATE	ISSUE	DETAILS (Include changed section numbers and implications)
23-Oct-2012	1.0	Initial Release
27-Nov-2014	1.1	Renamed to AMPIC Updated to latest document style Changed to TIVA™ Cortex®-M4 processor (7.1, 10.2, 11.2.1) 4-20mA Tx/Rx descriptions swapped (8.7, 8.8) Reduced to 4 analogue inputs (8.9, 9, 10.1.6) All SPI devices on single bus (8.15.2) Removed prototyping area (8.15.4) Added connector diagrams to represent correct orientation (10) Added prototype test plan (12.1) Updated customer approval wording (12.3)

5 Approvals

Commercial Approval:
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Engineering Approval:
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DSL

Client Approval[1]:
Rory Dear
Technical Sales Manager
DSL

[1] The client acknowledges that it is impractical to define the entire product, to manufacturing detail, within this document.
In signing the approval section of this document, the client confirms that this document defines all those aspects of the design which are of significance to them.
The client agrees that any unspecified items (which by implication are not of significance to them) are now the sole responsibility of DSL.
The client acknowledges that “client instigated” changes to those unspecified items could have implications on previously advised timescales and/or cost.

6 Document Organisation

Section 7, Problem Presentation
This section outlines DSL requirements for the system and a brief explanation of how it fits into their application.
Section 8, System Environment
This section describes the environment within which the system must operate. It describes all related entities, with their requisite data and events. The behaviour of the entities, either individually or globally, is described here. Also all entity relationships can be found in this section.
Section 9, Delimitation of inputs/outputs
This section shows all of the inputs and outputs for the system to be designed, the entities these go to and whether they are continuous or momentary.
Section 10, Functional Specification
This section describes, in detail, every function that the system must perform. This includes the precision of data and variables that each function uses, operating conditions, accuracy performances, special operating modes and predetermined methods.
Section 11, Technological Specifications
This section describes all constraints, such as cost, mechanical or environmental, for the system.
Section 12, Test and Certification Plan
This section provides a précis of the tests plan(s) to be created for the system. Also the customer certification obligations are outlined in this section.
Section 13, Documentation
This section outlines all required documentation, throughout the design phase.

6.1 Terminology

The **system** described, within this document, is that which shall be designed from it.
The **application** considered in this document shall be the closed system, having no useful relation with the outside for the problem to be solved, formed by the system to be designed and the objects related to it.
The **environment** is all application objects, excluding the system to be designed. Objects in the environment are called **entities**. An object has a dynamic behaviour and has its own independence. It is necessarily a functional reality, but not necessarily physical.

6.2 Terms, Definitions and Acronyms

Term	Definition
ADC	Analogue to Digital Converter
API	Application Programming Interface: An interface implemented by a software program to enable interaction with other software.
CAN	Controller Area Network is a standard vehicular bus which allows microcontrollers and devices to communicate without a host computer.
COM	The original, yet still common, name of the serial port interface on IBM PC-compatible computers.
Component side	The component side of a PCB is, conventionally, the upper side on which the components are mounted.
DAC	Digital to Analogue Converter
ECR	Engineering Change Request
EEPROM	Electrically Erasable Programmable Read-Only Memory.
GPIO	General Purpose Input/Output.
GPS	Global Positioning System is a global navigation satellite system that provides location and time information where there is an unobstructed line of sight to four or more GPS satellites.
GSM/GPRS	Global System for Mobile communications / General packet radio switching is a packet switching mobile data service standardised as part of the phase 2+ update to the second-generation GSM standard.
JTAG	Joint Test Action Group (JTAG) is the common name for the IEEE 1149.1 Standard Test Access Port and Boundary-Scan Architecture. It is used for testing printed circuit boards using boundary scan.
kS/s	Kilo Samples per second
LAN	Local Area Network
MAC	Medium Access Controller
MB	Megabyte
MS/s	Mega Samples per second
OS	Operating system
OTG	See USB OTG
PCB	Printed Circuit Board
PWM	Pulse-width modulation
QEI	Quadrature encoder interface
RAM	Random Access Memory.
RS232	A standard for serial binary single-ended data and control signals commonly used in computer serial ports.
RS422	A point-to-point or multi-drop serial data transmission standard using balanced or differential signalling.
RS485	A point-to-point or multi-drop serial data transmission standard using balanced or differential signalling.
RTC	Real-Time-Clock
RTOS	Real-Time Operating System.
SPI	Serial Peripheral Interface Bus
SRAM	Static Random Access Memory.
Solder side	The solder side of a PCB is, conventionally, the lower side where through-hole components were soldered from.
SWD	Serial Wire Debug is a 2-pin low pin count and high-performance alternative to JTAG which is compatible with all ARM processors.
TTL	Transistor-Transistor Logic is a class of digital circuits where both the logic gating function and the amplifying function are performed by transistors.
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus.
USB OTG	USB On-The-Go allows a USB device to act as either a host or a peripheral, with the mode selected by the cabling utilised.

7 Problem Presentation

7.1 Specification

DSL are increasingly receiving requests for custom designs that require ARM® processors, or for designs that require lower performance and power consumption than x86 based processors.

The low performance and consumption type of designs do not always need a full operating system, such as Microsoft® Windows®, Windows® Embedded Compact or Linux®, although they may require some real-time, deterministic, aspect.

There are, currently, three families of ARM® processors:

1. Cortex™-A series are application processors which have similar multimedia capabilities and overall performance comparable to the ICOP Vortex processors or Intel® processors used in other DSL distributed products.
2. Cortex™-R series have a similar performance to the mid-range Cortex-A processors but include hardware support for real-time operating systems with features such as deterministic interrupt performance.
3. Cortex™-M series have performance equivalent to the best microcontrollers, whilst being very energy efficient.

The Cortex™-M4 processors are general purpose, high performance, 32-bit, microcontroller type, processors with support for highly deterministic real-time applications.

Processors based on the ARM® Cortex™-M4 core are widely available, from manufacturers including NXP, Atmel, STMicro, Texas Instruments, Toshiba and Freescale.

Compilers with support for these processors are also widely available, from software houses including Keil, IAR systems, Mentor Graphics, Code Red, MikroElektronika and the processor manufacturers themselves.

It is proposed to create a sensor development kit, including an ARM® Cortex™-M4 based processor with a number of inputs, outputs and user interface hardware that are predicted to be required for sensor designs.

It is anticipated that clients could use this sensor development kit to fully develop and test a sensor design before requesting that DSL create a custom design for them.

Development kits, manufactured by the processor manufacturers, such as Texas Instruments, all seem to be targeted toward a particular application, so have limited scope to use as a basis for another sensor type.

The ‘best’ competitor development kit is manufactured by MikroElectronika.

This goes to the other extreme, whereby they have a baseboard with a plug in microcontroller module and plug in I/O modules.
This gives total flexibility but does not necessarily make the most of the built-in capabilities of the microcontroller, as each I/O module uses a serial connection. Also this does not, necessarily, give the lowest current consumption for each function.

The proposed system would provide each customer the opportunity to choose the interfaces he needs for his application, switch off the others and get as close as possible to what his own sensor design needs to be, functionally, without requiring software changes for the production version, and using the same amount power, so that they can size batteries if necessary.

7.2 *Brief analysis*

The proposed solution will be based on a Texas Instruments TIVA™ ARM® Cortex™-M4 processor.

These processors have a cost of approximately $3-$11, dependent upon the amount of included flash, RAM, peripherals and the maximum processor clock speed.

Texas Instruments has a comprehensive suite of royalty free software, supporting all of the peripheral interfaces, to speed development, as well as a number of example programs that can be used as a starting point for new designs.
The software, provided to drive each interface can be incorporated into your own software or is available in ROM to free storage.
Texas Instruments also supply a free real-time operating system, with no run-time fees, that can be used stand-alone or with their own compiler.

The Texas Instruments TIVA™ ARM® Cortex™-M4 microcontrollers are also supported by all of the major ARM® compilers.

The proposed solution would include a thermocouple[2] connection, an on-board temperature sensor, 4-20mA input, analogue inputs and GPIO, to provide the inputs for the sensor.
The GPIO connections will be organised in such a way that some can be configured for use as a PWM output.

A microSD connector will be included to provide potential data logging storage[3].

System connections will be delivered using 4-20mA outputs, CAN, USB OTG and Ethernet.

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[2] If a Maxim MAX31855 device was used, this provides a cold-junction compensated digital temperature output via SPI bus. This part is available for K, J, N, S, T, E and R-type thermocouples, allowing us to provide a connection for the most popular type in the development kit and support all of the other types for custom designs.
[3] This is not required for normal application storage.

One RS232 port and one RS422/RS485 port can be used as generic connections for system or sensor use.

An expansion port, including I2C, SPI and a TTL serial port, with hand-shaking lines, will also be provided.
Further connections, such as Bluetooth® and WiFi, can be added using AT modem modules from companies such as Multitech or U-blox on these interfaces.

The GPIO ports will connect to a 2-line character LCD, momentary push buttons and LEDs to provide a simple user interface, whilst inputs will be opto-isolated and outputs will have some change-over relays and some open collector outputs.

8 System Environment

Analysis of the problem shows that the following entities must be considered:

8.1 TIA-232-F compatible serial networks

This will network work at up to 115.2 KBaud. It will not support RTS, CTS, DCD, DTR, DSR and RI modem control lines. This is an alternate interface for connection to a host.

Entity data and event definition

All data and events passed both to and from the system, will meet those outlined in the *TIA-232-F* standard.

8.2 TIA/EIA-422-B compatible serial networks

Working at up to 115.2 KBaud, this is an alternate interface for connection to a host.

Entity data and event definition

All data and events passed both to and from the system, will meet those outlined in the *TIA/EIA-422-B* and *TIA-485-A* standards.

8.3 Ethernet LAN

This is an alternate interface for connection to a host.

Entity data and event definition

All data and events, passed both to and from the system, will meet the *IEEE 802.3, 2000 Edition (ISO/IEC 8802-3: 2000)* specification.

8.4 CAN Bus

This is an alternate interface for connection to a host.

Entity data and event definition

The protocol for this interface will conform to the *CAN protocol version 2.0 A/B* and the physical layer will meet *ISO 11898*.

8.5 USB device(s) and host(s)

This is a peripheral control interface. It may be used to connect other entities to the product or connect the product to a host.

Entity data and event definition

The events and data for this interface are described in the *Universal Serial Bus Revision 2.0 specification*.

8.6 Thermocouple

This allows the connection of an external, cold-junction compensated, temperature sensor. The standard build will allow the connection of a K type (Chromel-Alumel) thermocouple, whilst build options will allow the use of other thermocouple types.

Entity data and event definition

The data will in 14-bit digital format[4], with a resolution of 0.25°C. This will register temperatures from -270°C to 1375°C, with a K-Type thermocouple[5].
This will not generate an event or interrupt and will need to be polled.

8.7 4-20mA transmitter

This is an analogue current loop device, which controls the loop current to represent a single parameter. The application program will be responsible for the appropriate scaling.

8.8 4-20mA receiver and power supply.

This is an analogue current loop device which can interpret a single parameter transmitted from the system as a current correlated to the parameter. This can be used to connect external sensors. The input will be converted to an analogue voltage, which can be read by the application program. The application program will be responsible for any scaling necessary to convert this to the original sensor's units.

8.9 Analog Inputs

Four analog inputs will be provided for application use. The application program will be responsible for interpreting and scaling.

8.10 GPIO.

8.10.1 Isolated inputs

Eight isolated inputs will be provided for application use.

8.10.2 Open Drain Outputs

Six open drain outputs will be provided for application use.

8.10.3 Change-over relay outputs

Two change-over relays, with 240VAC switching capability, will be provided for application use.

[4] 12-bit unit and two bits for the fraction
[5] The temperature returned will be calculated using a linear relationship between the thermocouple voltage and temperature. This will require software correction to allow for any non-linearity in the thermocouple.

8.11 Temperature Sensor

The system will include a temperature sensor to read the approximate ambient temperature around the system.

Entity data and event definition

This will read temperatures of, at least, -40°C to 85°C.
This will have a resolution of 9 bits and an accuracy of ±2°C.
This will not generate an event or interrupt and will need to be polled.

8.12 microSD Card

This will provide optional local, flash based, storage to allow the application to perform any data logging function necessary.

Entity data and event definition

All data and events passed both to and from the system, will meet those outlined in the *SD Specifications Version 3.01 SPI Mode*.

8.13 Application program

This is the customer's software. It provides a unique service to the user making the system part of a larger whole.

8.13.1 Flash storage

In addition to the program storage, will be provided to store any relevant configuration parameters

8.13.2 NVRAM

NVRAM will be provided to allow the application program to record any run-time parameters that are required to be retained during power down situations. This will operate faster than the flash but will not be as fast as the normal program SRAM.

8.14 User

User interaction will be provided by the application program and can include the use of the following interface functions:

8.14.1 Momentary switch inputs

Four momentary switches will be provided for application use.

8.14.2 Character LCD

A two line character LCD, with a common 8-bit parallel interface, will be provided for application use.

8.14.3 LEDs

Two LEDs will be provided for application use.

8.15 Expansion

Expansion of the system for additional application requirements will be met with the following ports:

8.15.1 I^2C Port

This is a serial port which has a common connection to the on-board temperature sensor.

Entity data and event definition

All data and events passed both to and from the system, will meet those outlined in *the I^2C-Bus specification.*

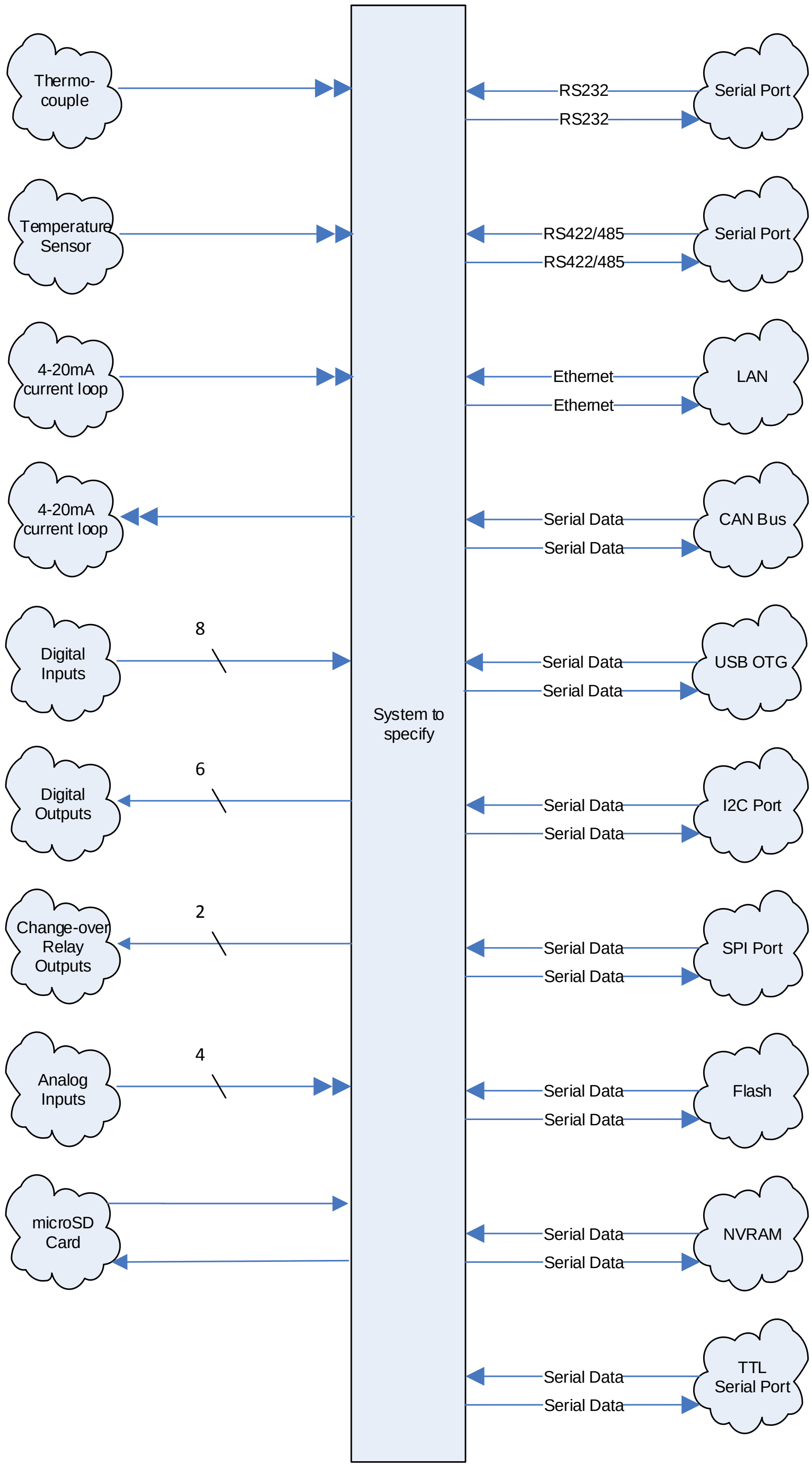
8.15.2 SPI Port

This is a serial port which has a common connection to the thermocouple, the 4-20mA input and the on-board storage devices.

8.15.3 TTL Serial Port

This is a UART serial port, with modem control lines and TTL signal levels.
This will network work at up to 115.2 KBaud. It will support RTS, CTS, DCD, DTR, DSR and RI modem control lines, where possible, to permit the use of AT modem modules, where required.

9 Delimitation of inputs/outputs



10 Functional Specification

10.1 Power Supply

This function will accept a regulated 5V DC input and generate any additional supplies necessary for the application.

This will allow a customer to power the development board, using either a laboratory power supply or an ICOP desktop power supply.
This may not reflect the power supply requirements of the end application.
Any additional power supply regulation, protection or battery switching and charging circuits will need to be prototyped separately and incorporated into a product designed from the sensor development kit.

Methods

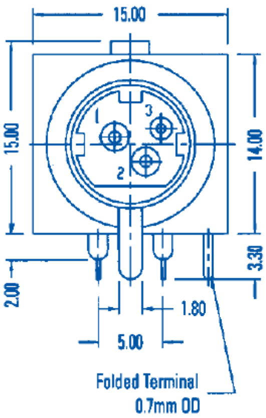
This device will be provided with a, vertically mounted, 2-way screw terminal and a Kycon KPJX-3S connector in parallel.

The pin-out of the terminal connector will be as follows:

1	5V IN
2	0V IN

The pin-out of the Kycon connector will be as follows:

1	5V IN
2	0V IN
3	N/C



10.2 Microcontroller

This function will provide the storage for the OS and application code and execute both.
This will require connections to the following interfaces:

- 3 off asynchronous serial ports for communications with:
    - TIA-232-F compatible peripheral devices
    - TIA-422-B or TIA-485-A compatible peripheral devices
    - Expansion devices, with handshaking lines
- SPI port for communication with:
    - microSD Card
    - Flash, for application configuration storage
    - NVRAM, for non-volatile application variable storage
    - Thermocouple
    - 4-20mA outputs
    - Expansion devices
- I2C-Bus for communication with:
    - Temperature sensor
    - Expansion devices
- Can-Bus interface
- Ethernet LAN controller
- USB OTG controller for communication with USB hosts and devices
- Analogue to digital converters[6] for 4-20mA input(s) and general application use
- General purpose input/output[7] (GPIO) for:
    - LCD character display
    - Push button inputs
    - LED outputs
    - General application use
- JTAG interface (for debug support and application programming)

Use of specific components

This should use a Texas Instruments TIVA™ ARM® Cortex™-M4 Microcontroller.

10.2.1 SRAM

This function will provide temporary data storage for the application program, running on the Microcontroller.

Methods

The Texas Instruments TIVA™ ARM® Cortex™-M4 Microcontroller family include devices with between 12KB and 256KB of SRAM.

[6] Support for analogue comparators should be provided where possible
[7] Support for QEI and PWM should be provided where possible

10.2.2 Flash

This function will provide program storage for the application.

Methods

The Texas Instruments TIVA™ ARM® Cortex™-M4 Microcontroller family include devices with between 32KB and 1024KB of flash.

These devices can also include TIVAware™ software in ROM, which provides royalty-free functions for controlling the microprocessor's peripherals, reducing the application flash requirements.

10.3 TIA-232-F compatible serial network

This function will provide the TIA-232-F compatible transceiver.

No handshaking lines will be implemented.

Methods

This device will be provided with a, vertically mounted, 3-way screw terminal.

The pin-out of this connector will be as follows:

1	RxD
2	GND
3	TxD

Electrical interface specifications

The TIA-232-F pins must include ±15kV (Human body model) ESD protection.

The electrical characteristics for the TIA-232-F send/receive function must meet the *TIA-232-F standard*.

Temporal Specifications (Timing constraints)

The data packets for the TIA-232-F send/receive function must meet the *TIA-232-F standard*.

10.4 TIA-422-B/TIA-485-A compatible serial network

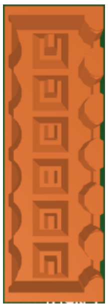
This function will provide the transceivers for a 4-wire TIA-422-B compatible network or a 2-wire TIA-485-A compatible network. The network type will be selectable. See 10.5 below.

No handshaking lines will be implemented.

Methods
This device will be provided with a, vertically mounted, 6-way screw terminal.

The pin-out of this connector will be as follows:

Mode	422	485
1	TX-	TX-/RX-
2	TX+	TX+/RX+
3	GND	GND
4	RX-	N/C
5	RX+	N/C
6	GND	GND



Electrical interface specifications
The electrical characteristics for the TIA-422-B send/receive function must meet the *TIA/EIA-422-B standard*.
The electrical characteristics for the TIA-485-A send/receive function must meet the *TIA-485-A standard*.

Temporal Specifications (Timing constraints)
The data packets for the TIA-422-B send/receive function must meet the *TIA/EIA-422-B standard*.
The data packets for the TIA-485-A send/receive function must meet the *TIA-485-A standard*.

Provision will be made, in the design, for both a termination resistor and bias resistors to be fitted, but these will not be fitted as standard.

10.5 TIA-422-B/TIA-485-A Interface selection

This function will enable the selection of the interface type, between RS485, 2-wire, half duplex and RS422, 4-wire, full duplex modes.

Methods
This port will be switchable between 2-wire and 4-wire modes, via an on-board jumper.

10.6 microSD Card Connector

This function will provide the capability of connecting a microSD card to the microcontroller.

Electrical interface specifications
The connection should conform to the *SD Specifications Version 3.01 SPI Mode*

10.7 Configuration storage

This function will provide additional, EEPROM based, storage, for application use. This could be used to store configuration parameters.

Methods

This function should use an SPI device connected in a de-facto industry standard 8-pin package.

10.8 NVRAM

This function will provide non-volatile storage, for application use.
This could be used to store run-time variables that need to be retained despite power failures, such as a tachometer total value.

Methods

This function should use an SPI device connected in a de-facto industry standard 8-pin package for flash and EEPROMs.

10.9 Thermocouple interface

This function will provide the connection for an external thermocouple, cold-junction compensation, for the thermocouple, and translation from the thermocouple voltage into a temperature value[8].

Methods

This device will be provided with a, vertically mounted, 2-way screw terminal.

Use of specific components

If a Maxim MAX31855 device was used, this provides a cold-junction compensated digital temperature output via SPI bus. This part is available for K, J, N, S, T, E and R-type thermocouples, allowing provision for the most popular K-type in the development kit and support for all of the other types for custom designs.

10.10 4-20mA current loop driver

This function will provide a 4-20mA current loop transmitter, with the current output to be controlled by the application.

This function will also provide the means necessary to connect the current loop power supply to the loop, if required by the end user.

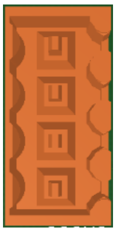
[8] The voltage to temperature conversion may use a linear equation and therefore any non-linearity, of the thermocouple used, may need software compensation to be applied.

Methods

This device will be provided with a, vertically mounted, 4-way screw terminal.

The pin-out of this connector will be as follows:

1	EXITATION VOLTAGE +
2	EXITATION VOLTAGE -
3	4-20mA +
4	4-20mA -



10.10.1 Isolation

This will provide isolation for the current loop and power supply to the rest of the circuit.

10.11 Temperature sensor

This provides the ability to detect the current ambient temperature.

Use of specific components

This will use an LM75 compatible device with the I^2C bus directly connected to the microcontroller.

10.12 CAN-bus transceiver

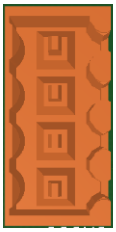
This function will provide the physical and transfer layers of a CAN-bus transceiver, meeting the ISO 11898 standard.

Methods

This device will be provided with a, vertically mounted, 4-way screw terminal.

The pin-out of this connector will be as follows:

1	CAN V+ (5V)
2	CAN H
3	CAN L
4	GND



Electrical interface specifications

The electrical specification for this interface shall meet the ISO 11898 standard.

Temporal Specifications (Timing constraints)

All temporal specifications will meet the *CAN protocol version 2.0 A/B*.

10.13 LAN

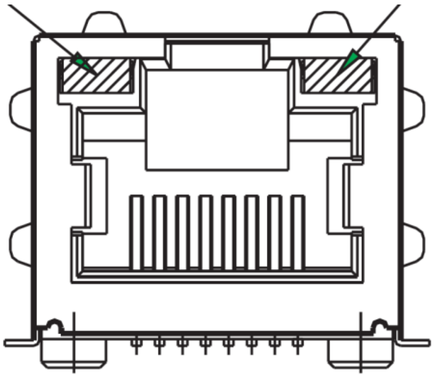
This function will provide the termination for the Ethernet controller, including the Ethernet 1:1 transformer and connector.

Methods

This device will be provided with a, horizontally mounted, 8-way RJ45 (Modular) connector.

The pin-out of this connector will be as follows:

1	TX+	2	TX-
3	RX+	4	N/C
5	N/C	6	RX-
7	N/C	8	N/C



To Maximise the EMI performance the unused (N/C) conductors will be terminated with 75Ω and 1.5nF to the RJ45 shield.

Electrical interface specifications

The interface should conform to the *IEEE 802.3, 2000 Edition* specifications.

Temporal Specifications (Timing constraints)

The interface should conform to the *IEEE 802.3, 2000 Edition* specifications.

10.14 USB OTG

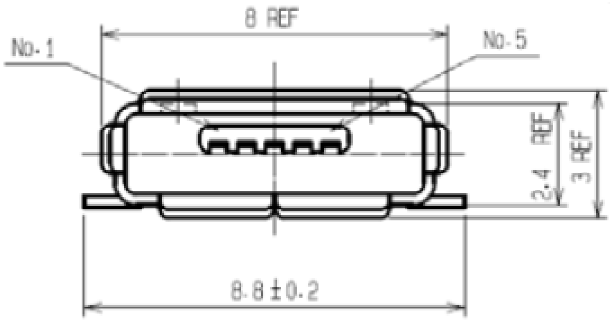
This function will provide a connection to either a USB device or to a USB Host.

Methods

This port will be provided with a USB microAB socket.

The pin-out of this connector will be as follows:

1	VBUS
2	D-
3	D+
4	ID
5	GND



To enable the connection of a USB device a USB microA plug to USB A socket adapter will be provided.
To enable the system to be connected to a host a USB microB to USB A plug will be provided.

Electrical interface specifications
The interface used should meet the *Universal Serial Bus Revision 2.0 specification*.

Temporal Specifications (Timing constraints)
The interface used should meet the *Universal Serial Bus Revision 2.0 specification*.

10.15 USB Switching

As power is drawn through the USB interface when connected to a USB device, both the product and external peripherals will be protected from excess current draw either damaging devices or crashing the system.

This function should also provide the facility for the power to be turned off by the microcontroller when a USB host is plugged in.

Electrical interface specifications
A maximum of 500mA can be drawn from the USB port.
If a device draws in excess of 500mA the USB power will be removed and a signal will be provided to the microcontroller.

10.16 Analogue inputs

This function will provide 4 Analogue 0-3V inputs, for application use.
Any signal conditioning and signal attenuation required for the final application needs to happen externally.

Variable/Data precision
These inputs need to have, a minimum, of 10 bit resolution.

Methods

This device will be provided with a, vertically mounted, 8-way screw terminal.

The pin-out of this connector will be as follows:

1	AI1
2	AI_GND
3	AI2
4	AI_GND
5	AI3
6	AI_GND
7	AI4
8	AI_GND

Use of specific components

These can be implemented using the microcontroller 10-bit ADC inputs[9].

Temporal Specifications (Timing constraints)

These inputs need to be capable of a throughput of, at least, 100kS/s.

10.16.1 Isolation

This will provide isolation for the analogue inputs to the rest of the circuit.

10.174-20mA current loop receiver

This function will provide a 4-20mA current loop receiver.

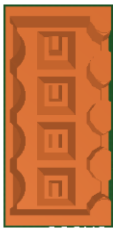
This function will also provide the means necessary to connect the current loop power supply to the loop, if required by the end user.

Methods

This device will be provided with a, vertically mounted, 4-way screw terminal.

The pin-out of this connector will be as follows:

1	EXITATION VOLTAGE +
2	EXITATION VOLTAGE -
3	4-20mA +
4	4-20mA -



10.17.1 Current to voltage converter

This converts the current to a voltage.

[9] Support for analogue comparators should be provided where possible

10.17.2 DC-DC converter

This takes power from the current loop to power any isolated circuitry on the loop side of the isolation.

10.17.3 Isolation

This will provide isolation for the current loop and power supply to the rest of the circuit.

10.17.4 Analogue to Digital converter

This will create a digital representation of the current in the loop.

Variable/Data precision
These inputs need to have, a minimum, of 10 bit resolution.

Use of specific components
This can utilise one of the microcontroller 10-bit ADC inputs.

Temporal Specifications (Timing constraints)
This needs to be capable of a throughput of, at least, 100kS/s.

10.18 GPIO

This function provides I/O functionality to be driven by the application.

10.18.1 Isolated inputs

This provides eight opto-isolated inputs, for application use.

Methods
This device will be provided with a, vertically mounted, 16-way screw terminal.

The pin-out of this connector will be as follows:

1	DI1
2	DI_GND
3	DI2
4	DI_GND
5	DI3
6	DI_GND
7	DI4
8	DI_GND
9	DI5
10	DI_GND
11	DI6
12	DI_GND
13	DI7
14	DI_GND
15	DI8
16	DI_GND

10.18.2 Open Collector Outputs

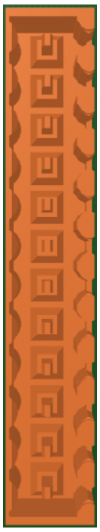
This provides six open drain outputs, for application use.

Methods

This device will be provided with a, vertically mounted, 12-way screw terminal.

The pin-out of this connector will be as follows:

1	DO1
2	DO_VCC
3	DO2
4	DO_VCC
5	DO3
6	DO_VCC
7	DO4
8	DO_VCC
9	DO5
10	DO_VCC
11	DO6
12	DO_VCC



Any inductive load transient suppression necessary will be included within the design, rather than requiring external components.

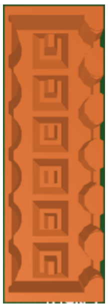
10.18.3 Change-over relay outputs

This provides two change-over relays, with 240VAC 5A switching capability, for application use.

Methods
This device will be provided with a, vertically mounted, 6-way screw terminal.

The pin-out of this connector will be as follows:

1	R1 NO
2	R1 COM
3	R1 NC
4	R2 NO
5	R2 COM
6	R2 NC



10.19 LCD character display

This will provide a 16x2 cost-effective alphanumeric LCD module, to be used under application control, as part of a human machine interface where necessary.

10.20 Push buttons

This will provide four momentary push buttons, to be used under application control, as part of a human machine interface where necessary.
E.g. MENU, UP, DOWN and SELECT.

These will correctly recognise separate button presses but are not required to recognise any concurrent presses.
Concurrent presses can be ignored or recognised as one of the buttons pressed.

10.21 LEDs

This will provide two LED outputs, to be used under application control, as part of a human machine interface where necessary.
E.g. HEATING ENABLED and HOT WATER ENABLED.

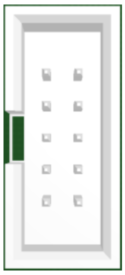
10.22 Expansion

This function will provide an expansion interface.
A second connector will provide a TTL level UART with the full complement of hand-shaking lines to allow the connection of AT modems.

Methods
This will use a 10-way 0.1” shrouded header in a UEXT configuration.

The pin-out of this connector will be as follows:

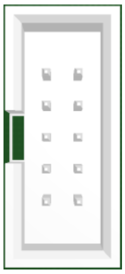
1	3.3V	2	GND
3	TTL UART TXD	4	TTL UART RXD
5	I2C SCL	6	I2C SDA
7	SPI MISO	8	SPI MOSI
9	SPI SCK	10	SPI CSn



This UART will use a 10-way 0.1” shrouded header.

The pin-out of this connector will be as follows:

1	DCD#	2	DSR#
3	RXD	4	RTS#
5	TXD	6	CTS#
7	DTR#	8	RI#
9	GND	10	GND



10.23 In-Circuit Debug Interface

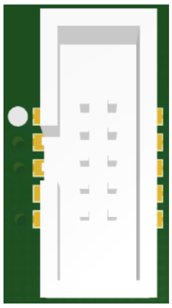
The microcontroller flash can be programmed via the JTAG/SWD port, on the device.
This can also be used, with a number of the development tools, to provide software debugging support.

This will also provide 1 USB to UART interface that can be used with the Texas Instruments® TIVA™ boot loader or serial flash loader code to program the microcontroller flash.

Methods
The JTAG connection will be made using a 10-way 0.05” pitch shrouded header[10].

The pin-out of this connector will be as follows:

1	3.3V	2	TMS/SWDIO
3	GND	4	TCK/SWCLK
5	GND	6	TDO/SWO
7	Key	8	TDI
9	GNDDetect	10	RESETn



[10] Whilst this is a lesser recognised connector for ARM® JTAG/SWD, it will take much less board space than a 20-way 0.1” shrouded header.

The UART connection will be made using a 10-way 2mm pitch pin header.

The pin-out of this connector will be as follows:

1	N/C	2	RxD
3	TxD	4	N/C
5	GND	6	N/C
7	N/C	8	N/C
9	N/C	10	+5V

The programming hardware consists of a USB to JTAG adapter using an FTDI FT2232 USB debug controller.
Reference designs for these are available from TI and FTDI.

Whilst this functionality will be integrated into the board design, the PCB should be laid out in such as fashion that this can be removed from the finished board and used to debug a finished product designed from the development kit.
This will draw no power from the board in normal use, allowing the power requirement for a design to be ascertained.

11 Technological Specifications

11.1 Geographical distribution constraints

The Ethernet network allows for a maximum of 100m between devices.
The TIA485-A network allows for a maximum network length of 1200m.

11.2 Maintenance and operating safety

11.2.1 Maintenance Functions

The JTAG/SWD interface, in combination with the ICDI, can be used to both program the microcontroller flash and to debug any application, where supported by the development software.

The Texas Instruments® TIVA™ boot loader code, loaded into ROM on selected TIVA™ microcontrollers, also provides flash loading via serial connections.
This provides flash loading over UART, SSI, I2C, SSI, Ethernet, CAN and USB.
The microcontroller fitted to the development kit will include ROM.

TIVA™ microcontrollers without ROM have a one-time-use serial flash loader loaded into flash.
This provides flash loading over UART or SSI.
Microcontrollers without ROM may be used in designs created from the development kit.

11.2.2 Safety

The system does not include any high voltage, or high current, interfaces.

This system is not intended for medical or military use. As such there are no requirements for fault tolerance.

The system should meet *Council Directive 73/23/EEC, the Low Voltage Directive*.

All due diligence will be applied during design to ensure that the system does not compromise the user’s safety.

11.3 Electrical specifications

The system should be powered by a 5V regulated supply[11].
No current consumption limit has been specified, although this should be kept to a minimum and any potentially unused interfaces, in end user applications, should have the facility to be turned off.
This will facilitate the design of battery powered end-user applications.

[11] The external power supply MUST be monotonic at power-up. Careful consideration of the current capacity of the external power supply and the entire loading it will experience at power-on, due to in-rush currents, should be assessed to ensure that this will be the case.

11.4 Miscellaneous specifications

11.4.1 Product Constraints

- The system operating conditions will meet the following:
  - Operating Temperature   -40ºC to +85ºC
- All parts, selected by DSL, will either be lead free or have a lead free alternative, such that the product may meet the requirements of the *Restriction of Hazardous Substances directive (RoHS)*.
- The system design must be made in consideration for European electromagnetic compatibility (EMC) laws. This includes; protecting all interfaces, where they leave the system, from vulnerabilities to electrostatic discharge (ESD); and protecting the system from electromagnetic interference (EMI).

12 Test and Certification Plan

12.1 Prototype testing

All printed circuit boards (PCBs) for prototype units will be bare board tested.
All prototype units will be visually inspected prior to testing. Inspection will determine if components are correctly fitted, solder joints are of sufficient quality and the units meet the required overall quality, including cleanliness et cetera.
Static handling requirements will be adhered to throughout all stages.
All power supplies will be tested to determine that they supply the correct voltage, they regulate over the required input range and that they provide an acceptable ripple voltage level.
All functions of the system will be functionally tested and all aspects tested to the specifications outlined in this document, where viable.

All prototype boards will be serial numbered and individual record sheets of the following tests will be kept for each unit.

Function	How to test	Result
Power Supply	The 3.3V rail will be checked, using an oscilloscope for the correct output and ripple voltages.	
In-Circuit Debug Interface	The system will be programmed, using the ICD, with the demonstration firmware: This provides a simple menu to exercise the outputs and display the inputs and major system parameters.	
LCD character display	The LCD is used by the demonstration firmware. Different menu items will drive each character on the LCD, such that its correct operation can be confirmed.	
Push buttons	All four push buttons will be used to navigate the menu during the tests.	
LEDs	The LEDs will alternately flash, at 1Hz, when the demonstration firmware is operational.	
TIA-232-F compatible serial network	This port will echo all received characters. An external system will be connected, with the port configured for 9600 baud and 8-N-1 operation, and the received characters will be compared to the sent to ensure that these match.	
TIA-422-B/TIA-485-A compatible serial network	This port will echo all received characters. An external system will be connected using a USB to RS485 adapter configured for 4-wire, full duplex, operation, with the port configured for 9600 baud and 8-N-1 operation, and the received characters will be compared to the sent to ensure that these match.	
TIA-422-B/TIA-485-A Interface selection	The AMPIC will be reconfigured for 2-wire RS485 operation. The USB to RS485 adapter will be reconfigured for 2-wire, half duplex operation and set to enable its drivers only when transmitting. The port will then be rechecked to ensure that all echoed characters match those previously sent.	
microSD Card	The microSD Card will store a log file of changes to the digital	

Connector	outputs, Relays and 4-20mA driver, driven from the menu. For instance ‘Digital Output 1 set to high’. After making some of these changes the micro SD card will be removed from the AMPIC system and the log file verified.	
Configuration storage	The EEPROM will be used to store the data to display when booting. As this is written when not found in the EEPROM the value to write will be changed in the firmware whilst ensuring that the sign on text does not change.	
NVRAM	The currently set values for the Digital Outputs, Relays and 4-20mA drivers will be stored in NVRAM when changed. The values will then be verified following a power cycle.	
Thermocouple interface	A K-Type thermocouple will be connected and the reading, shown in the menu, compared to the reading from a digital thermometer with a K-Type thermocouple.	
4-20mA current loop driver	The current loop driver will be set in steps of 1mA, from 4mA to 20mA, and the output verified, within 1%, using a, UKAS Calibrated, Volt/mA Loop Calibrator.	
Temperature sensor	The reading of the LM75 temperature sensor will be verified using a digital thermometer, with K-Type thermocouple attached to the top of the part.	
CAN-bus transceiver	An external CAN Bus node will send a request, using a base frame format with an 11-bit identifier, to 0x101. The AMPIC will reply with the string ‘-AMPIC!-’	
LAN	The LAN port will be verified by connecting to a 100 speed Ethernet network with DHCP server. Correct communication will be verified by ensuring that an IP address has been leased to the AMPIC via the menu.	
USB	The USB port will be verified, in host mode, by connecting a USB keyboard and using this to drive the menu. Right Arrow or ENTER keys = SELECT. Left Arrow = MENU. Up Arrow = Up. Down Arrow = Down.	
Analogue inputs	Each analogue input will be independently driven using a 1.5V and adjustable voltage divider. The menu reading, for each, will be verified using a digital multi-meter.	
4-20mA current loop receiver	The 4-20mA receiver will be driven using a, UKAS Calibrated, mA Loop Calibrator in steps of 1mA, from 4mA to 20mA, and the value verified within 1% using the menu.	
Isolated inputs	The digital inputs will be controlled using external switches and the current state verified using the menu.	
Open Collector Outputs	The digital outputs will be independently controlled, using the menu, and their state verified using external LEDs.	
Change-over relay outputs	The relays will be energised using the menu and the state measured using a multi-meter.	

12.2 Production testing

All printed circuit boards (PCBs) for production units will be bare board tested.
All production units will be visually inspected prior to testing. Inspection will determine if components are correctly fitted, solder joints are of sufficient quality and the units meet the required overall quality, including cleanliness et cetera.
No components will be reused on production units.
Static handling requirements will be adhered to throughout all production stages.
All production units will be fully functionally tested prior to shipment.

12.3 Customer certification

The customer will be required to verify acceptance that the following elements of the design comply with the requirements of this document:

- Electronic Design
- Mechanical Design
- PCB Layout
- Firmware
- Software

The approval tests can occur at the customer's premises or, following prior application, may occur at DSL's premises with one of DSL's engineers present.

12.4 Notes

DSL will use best practice, throughout the design, to ensure that the electromagnetic effects, emitted by and affecting the product, are limited.
As type approval tests may often be applied to prototype units the following statements should be noted:

- Prototype units may be delivered a number of track cuts and wire modifications applied. These will be considered acceptable providing that the reliability and functionality of the system is not impaired.
- Initial production units will not have any wire modifications applied.
- Due to component lead times prototypes may use parts which do not comply with the requirements of this document. These deviations must be agreed with the customer.

13 Documentation

13.1 Implementation Documentation

All design steps will be documented. Thus any technological or implementation specifications will be formally documented. All documents and calculations used to develop a solution will be included.
The design will be verified at all stages and documents used for verification and validation will be signed and retained.

13.2 Manufacturing Pack

The following documents will be supplied for manufacturing the product:

- Full parts list.
- Artwork in the form of extended Gerber Files in RS274X format.
- List of programmed parts with object file(s), source file(s) and documentation of the programming hardware and software necessary.
- PCB and programmed parts labelling instructions.
- Any additional documentation required to manufacture and assemble electronic circuits, such as cleaning requirements.
- Assembly drawings
- Cable drawings
- Test procedure including software required to test.

Following initial manufacture any modifications or changes made to affect functionality, reliability or manufacturability will be documented using an engineering change note or additional work instruction.

13.3 User Manual(s)

A User Manual will be supplied for this system. It will fully describe the completed system, in all its iterations, and describe all interfaces and their connection.
An installation manual will be supplied.

14 Additional Information

14.1 Technical Explanations

14.1.1 TIA/EIA-422-B Termination

Termination is used to match the impedance of a transmitting or receiving node to the impedance of the transmission line used.
If the impedances are mismatched the transmitted signal cannot be fully absorbed by the load and some portion of the signal will be reflected back onto the transmission line. This reflected signal will travel up and down the cable reducing in amplitude over time.
The disadvantages of terminating are:

- Driver loads are increased.
- Biasing requirements are changed.

Whether termination is required, on a network, should be based upon the total cable length and the data rate employed. If all signal reflections will be damped out prior to the centre of a data bit, at which point the receiver will be sampling, termination will not be required.
For example the propagation delay of any cable can be calculated from its length and propagation velocity (typically 66-75% of the speed of light (c)).
If a cable of 100m has a round trip of 200m and a propagation velocity of 66% of c, one round trip is completed in approximately 1µs.
Assuming that the reflections are completely damped after 5 round trips, the signal will stabilise after 5µs.
At 9600 baud each bit is 104µs wide. As the signal is stable well before the centre of the bit termination should not be required.
At 115.2k baud each bit is 8.7µs wide. As the signal is not stable before the centre of the bit termination will be required.

Termination resistors should only be placed at the extreme ends of a network, and no more than two termination resistors should be used per network.

The above calculation shows that, we should be able to have a network length of about 160m before termination is needed at 115.2k baud.
To allow use of this product in many different networks termination will not be included, although provision will be added should termination be necessary in the future.

14.1.2 TIA/EIA-422-B Biasing

When a TIA/EIA-422-B or TIA-485-A network is idle all nodes are set to receive data and therefore all drivers are tri-stated. Without anything driving the network the state of the line is unknown.
If the voltage at the receiver inputs is less than ±200mV the receiver output logic level will show that of the last bit received.

In order to maintain the correct idle state bias resistors can be added to the transmission lines. A pull-up resistor, typically to +5V, is added to RX+ and a pull-down, to ground, is added to RX-.
The bias resistor values are determined by the network load, including terminations if fitted:
When termination resistors are fitted the loading effect of these is greater than the nodes, which have a typical load of 12kΩ per node. This means that the bias resistor values are approximately 685Ω regardless of the number of nodes.
When termination is not fitted the bias resistors can vary from 122kΩ for two nodes to 4.5kΩ for 32 nodes.

Bias resistors can be added at any point on the network or can be split among multiple nodes. The parallel combination of all bias resistors on a network should be equal to or less than the biasing requirements.

To allow use of this product in many different networks bias resistors will not be included, although provision will be added should bias resistors be necessary in the future.

14.2 CAN bus Termination

ISO 11898-2 describes the electrical implementation formed from a multi-dropped single-ended balanced line configuration with resistor termination at each end of the bus. In this configuration a dominant state is asserted by one or more transmitters switching the CAN- to supply 0V and (simultaneously) switching CAN+ to the +5V bus voltage thereby forming a current path through the resistors that terminate the bus. As such the terminating resistors form an essential component of the signalling system and are included not just to limit wave reflection at high frequency. During a recessive state the signal lines and resistor(s) remain in a high impedances state with respect to both rails. Voltages on both CAN+ and CAN- tend (weakly) towards ½ rail voltage. During a dominant state the signal lines and resistor(s) move to a low impedance state with respect to the rails so that current flows through the resistor. CAN+ voltage tends to +5V and CAN- tends to 0V. A recessive state is only present on the bus when none of the transmitters on the bus is asserting a dominant state. Irrespective of signal state the signals lines are always in low impedance state with respect to one another by virtue of the terminating resistors at the end of the bus.

As the system could be placed at any point within a CAN-Bus network, and the resistor terminations must be placed at either end, the system will not include any termination resistors; however provision will be made to fit them if necessary.

14.3 Documentation sources

IEEE 802.3, 2000 Edition (ISO/IEC 8802-3: 2000) is available from the Institute of Electrical and Electronics Engineers, Inc. More information can be found on the website http://www.ieee.org.
EIA-232 standard is produced by the Electronic Industries Alliance. More information and links to suppliers of these documents can be found on the Electronic Industries Alliance website, http://www.eia.org.
ANSI/TIA-232-F-1997 standard is produced by the Telecommunications Industry Association. More information and links to suppliers of these documents can be found on the Telecommunications Industry Association website, http://www.tiaonline.org.
ANSI/TIA/EIA-485-A-98 standard is produced by the Telecommunications Industry Association. More information and links to suppliers of these documents can be found on the Telecommunications Industry Association website, http://www.tiaonline.org.
ANSI/TIA-422-B-1994 standard is produced by the Telecommunications Industry Association. More information and links to suppliers of these documents can be found on the Telecommunications Industry Association website, http://www.tiaonline.org.
Universal Serial Bus Revision 2.0 specification is available from the USB Implementers Forum, Inc. website: http://www.usb.org.
CAN Specification Version 2.0 is available from Robert Bosch GmbH. More information can be found on the website http://www.semiconductors.bosch.de
ISO 11898 is produced by ISO – International Organization for Standardization. More information can be found on the website http://www.iso.org
SD Specifications Version 3.01 is available from the SD Association website http://www.sdcard.org.
The I^2C-Bus Specifications are available from NXP Semiconductors. More information can be found on the website http://www.nxp.com
IEEE 1149.1 Standard Test Access Port and Boundary-Scan Architecture, commonly known as JTAG is available from the Institute of Electrical and Electronics Engineers, Inc. More information can be found on the website http://www.ieee.org.
DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, covering the regulations referred to as RoHS is available from the European Union website http://europa.eu.
Council Directive 89/336/EEC, the Electromagnetic Compatibility Directive, and its amending directives are available from the European Union website http://europa.eu.
Council Directive 73/23/EEC, the Low Voltage Directive, and its amending directives are available from the European Union website http://europa.eu.
The Electromagnetic Compatibility (Amendment) Regulations 1994 and its amending regulations are available from Her Majesty's Stationary Office website http://www.hmso.gov.uk.
DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, covering the regulations referred to as RoHS is available from the European Union website http://europa.eu.