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Taking Fieldbus into Hazardous Areas

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The need for hazardous-area capability

Any industrial bus system which does not allow sensors and actuators to be placed in a hazardous area will find limited application in today's process industry environments. As a result of the presence of potentially explosive gases and vapours, hazardous areas exist in many manufacturing industries—from foodstuffs to oil refining.

The requirement for hazardous-area capability for fieldbus systems has led to the development of physical-layer specifications which exploit the international acceptance and user benefits of intrinsic safety (IS).This paper discusses two such systems:

(i) FOUNDATION™ fieldbus, which employs the IEC 1158-2 Physical Layer Standard; and

(ii) Intrinsically safe LonWorks®, which uses a physical channel developed by Measurement Technology Limited and adopted by the LonMark™ Interoperability Association.

Some intrinsic safety principles

Intrinsic safety is one of a number of recognised techniques for the protection of electrical apparatus in hazardous areas. Its chief advantage over the alternative techniques is that it allows live working to be carried out in the presence of a flammable atmosphere, subject to local operating practices and work permit systems. For fieldbus applications, the ability to make and break connections to the bus segment without first having to switch off the bus is, of course, desirable. Intrinsic safety also offers potential savings in terms of the size and weight of enclosures when compared with, for example, the flameproof technique.

An intrinsically safe installation uses the principle that electrical energy within the installation is insufficient to ignite a surrounding flammable atmosphere, even under prescribed fault conditions. Energy which emerges as electrical sparks or hot surfaces is simply too weak to cause ignition even in the most easily ignitable mixture of gas and air. The rules which govern the allowable levels of voltage and current for a given hazard are well established and are published as "ignition curves". An example for simple resistive circuits is shown in Figure 1. Energy stored in component capacitances and inductances (including interconnecting cables) is also taken into account. Intrinsic safety is therefore an inherently energy-limited technique and, as such, is ideal for instrumentation and contol circuits operating at low levels of voltage and current.

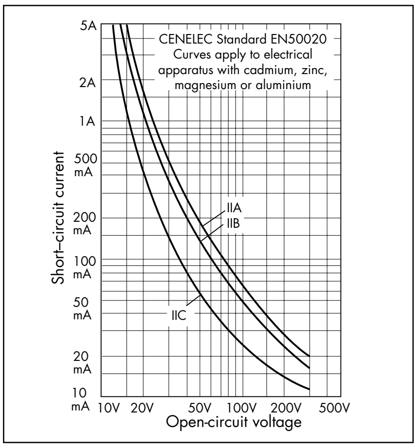

Figure 1: Ignition curves for resistive intrinsically safe circuits

The practical operating region for intrinsically safe circuits is shown in Figure 2, where the usable region is bounded not only by the ignition curves but also by limitations imposed by stored energy at higher levels of voltage and current and by a matched power restriction (typically 1.2W at 60°C) to govern surface temperature. These factors define an operating region below about 30V, 300mA and 1.2W for a typical intrinsically safe circuit.

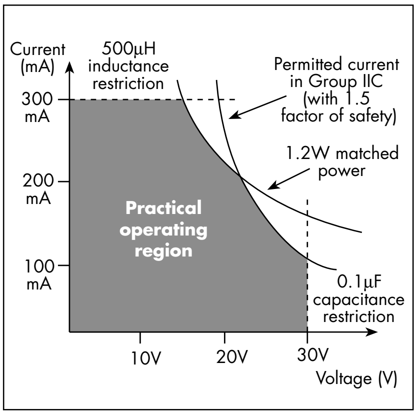

Figure 2: Practical operating region for intrinsically safe circuits

Assembling safe systems

Unlike the other methods of protection for electrical apparatus in hazardous areas, the safety of an intrinsically safe installation considers the compatibility of the separate items of apparatus and the cables used to interconnect them. The compatibility assessment ensures that no item of apparatus is subjected to higher levels of voltage, current or power than was accounted for when it was certified. The total energy storage in unsuppressed capacitance and inductance, in individual devices and interconnecting cable, is also taken into account.

In a typical conventional intrinsically safe instrument loop, the analysis shown in Figure 3 is undertaken. The example shows a 4-20mA process transmitter connected to intrinsically safe interface via a two-wire circuit. The maximum voltage, current and power that the field device can safely receive must be less than the corresponding values supplied by the energy source. The approval code awarded to the complete system is taken from the most restrictive aspects of the individual codes for the transmitter and Zener barrier. This analysis may be undertaken by competent users, without the need for formal third-party certification of the complete system.

Intrinsically safe FOUNDATION™ fieldbus

The Fieldbus Foundation™ Physical Layer Profile Specification (FF-816) for 31.25kbit/s wire media defines eight "profiles" for fieldbus devices. Of these, four are specified as suitable for connection to an intrinsically safe fieldbus:

Type 111: standard-power signalling, powered from bus

Type 112: standard-power signalling, separately powered

Type 121: low-power signalling, powered from bus

Type 122: low-power signalling, separately powered

The common characteristic which makes them suitable for connecting to an intrinsically safe fieldbus is that they introduce no electrical energy onto the bus during either reception or transmission of signals. The intrinsic safety analysis is therefore simplified because there is only one source of energy onto the bus—the fieldbus power supply.

The output of the power supply must be within the energy constraints already set out, and this must be sufficient to energise all the devices connected on the bus. This factor will limit the number of devices that may be connected onto an intrinsically safe fieldbus, as discussed later in this paper. Only field devices carrying appropriate intrinsic safety approval may be connected onto the hazardous-area bus.

The difference between the bus-powered and separately-powered profiles is that separate powering allows additional power for application circuits. The interface to the bus is otherwise identical. Bus-powered field devices draw their power as a constant current taken

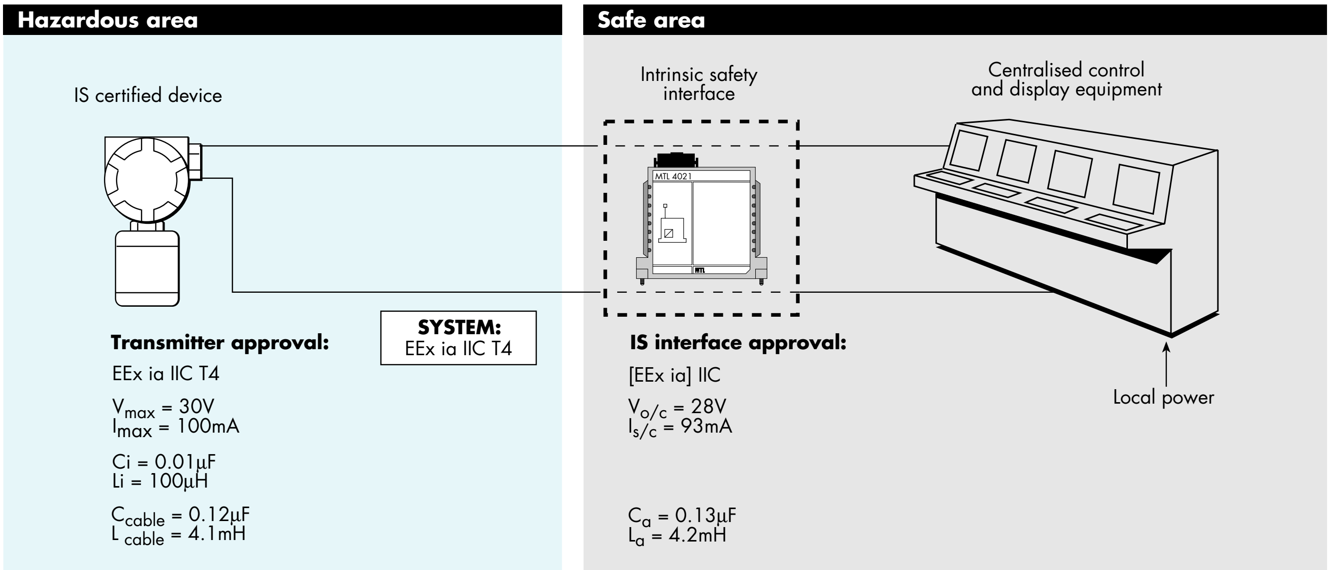

Figure 3: Safety analysis for typical conventional intrinsically safe instrument loop

from the bus and communicate by modulating this current using Manchester bi-phase digital encoding, as shown in Figure 4.

Safety assessment for IS fieldbus

If an arrangement of intrinsically safe fieldbus devices from different manufacturers is to be assembled, it must be possible to demonstrate that the complete system is safe. The analysis is similar to that for the conventional instrument loop in Figure 3, except that there is now more than one interconnected device and the cable may comprise a number of parallel spurs instead of a linear run (depending on the bus topology). It must be possible to show that no device's input parameters are exceeded and that the total lumped inductance and capacitance in the system are within allowed limits. If the manufacturers of the separate devices were allowed to certify them without reference to common guidelines on safety parameters, it is probable that incompatibilities would prevent certain combinations from being used.

For this reason, the Fieldbus Foundation's Physical Layer Profile Specification recommends the minimum requirements for input voltage, current and power with which intrinsically safe devices should be certified to operate. These are stated in Figure 5.

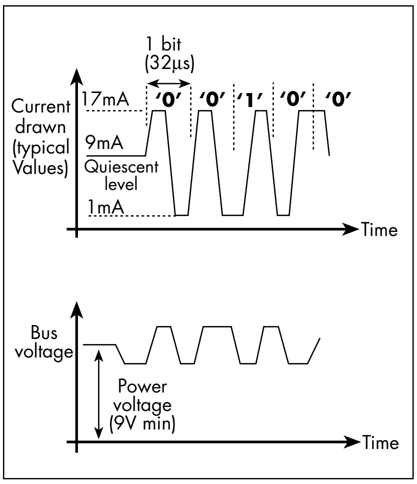

Figure 4: Bus waveforms for bus-powered field devices

Parameter	Recommended value
Device approval voltage	minimum of 24V
Device approval current	minimum of 250mA
Device input power	minimum of 1.2W
Device residual capacitance	less than 5nF
Device residual inductance	less than 20µH
Certification code	EEx ia IIC T4

Figure 5: Recommended certification parameters for field devices

A minimum certification requirement of intrinsic safety category ia, temperature classification T4 is also recommended.

In addition, the physical layer specification states maximum recommended values for voltage, current and power output for an IS fieldbus power supply, as shown in Figure 6.

It clearly follows that devices and power sources certified in accordance with the recommendations will be compatible from an intrinsic safety point of view. Their compatibility in other respects is guaranteed by conformance with the other parts of the Fieldbus Foundation's profile specification.

Figure 7 shows a typical intrinsically safe fieldbus system, comprising a power supply, field devices and terminators. The safety analysis for this arrangement is straightforward if all the devices have been certified in accordance with the recommendations of the physical layer specification, since the input parameters of devices designed to receive energy from the bus will be compatible with those of the bus power supply. Where this is the case, safety may be demonstrated easily and the overall certification code for the complete system deduced. In the same way as for the conventional 4-20mA circuit, the allowable capacitance and inductance for the interconnecting cable may be determined by subtracting the lumped values for the field devices (in this case more than one) from the corresponding values allowed by the source. These may be translated into a maximum allowable cable length for the intrinsically safe bus where the capacitance and inductance per metre of the cable is known, either from published figures or by measurement. All the relevant safety parameters and data are taken from approval certificates, for individual pieces of apparatus, which must form part of the documentation file for the installed system.

Cable length and available current

The voltage available on an intrinsically safe fieldbus depends both on the number of devices attached and on the length of the bus cable. This is due to ohmic losses in the IS interface and cable. The IEC Physical Layer Standard requires a minimum operating voltage of 9V for field devices which, together with the requirement for a maximum bus length of 1900 metres, places a restriction on the total current available to bus-powered devices.

Figure 8 is a graph of available current against bus length for a Type A cable ($0.8mm^2$), a 19V power supply and an IS interface having 22V, 214mA certification parameters. The number of devices that may be connected to the intrinsically safe bus is limited, in practice, by

Parameter	Recommended value
Open circuit voltage	maximum of 24V
Short circuit current	maximum of 250mA
Matched output power	maximum of 1.2W
Certification code	[EEx ia] IIC

Figure 6: Recommended certification parameters for bus power supplies

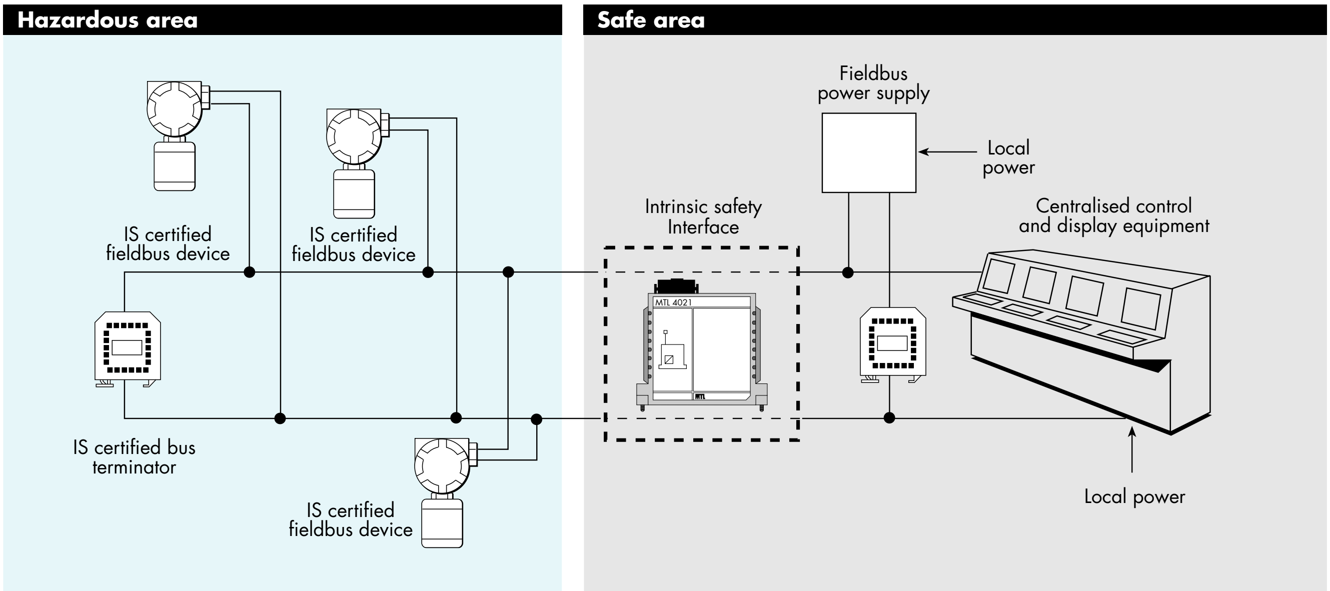

Figure 7: Typical intrinsically safe fieldbus intstallation

the current drawn by each device. Devices available now draw, typically, 30mA but future designs will draw 10mA or less.

LonWorks® network technology

Echelon LonWorks has established itself as a popular, low-cost bus system in applications which require frequent communication of short messages between a large number of nodes. Each node runs independently and is capable of originating "peer-to-peer" communications when stimulated by, for example, a change in the status of an input. Each device connected to the network contains a Neuron® chip which incorporates three microprocessors. Two of the processors handle the network communications but the third is available for applications software and can be programmed by the user.

For safe-area applications there are a number of different physical channels, such as twisted pair cable, modulated power lines, radio frequency transmission and optical fibre. There is also a variety of communication speeds.

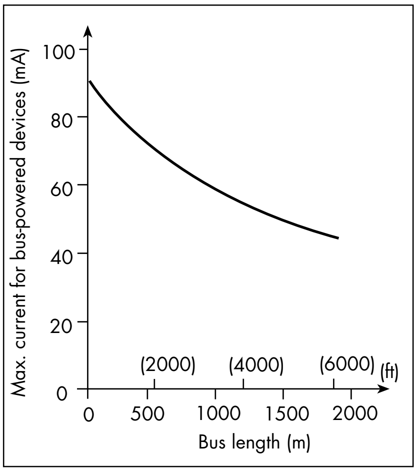

Figure 8: Variation of available bus current with bus length

Transceivers and control modules are available to designers for each of the physical layers, to reduce development times for LonWorks-compatible nodes. If the number of nodes required in a network exceeds the maximum allowed for a single bus segment, then two or more segments may be connected together using routers. A router may also be used to interconnect different physical channels. A block diagram of a typical safe-area LonWorks network is shown in Figure 9.

An intrinsically safe physical channel

Measurement Technology Limited has developed an intrinsically safe physical channel to allow LonWorks networks to be extended into hazardous areas. Known as IS-78, it is based on the TP-78 channel operating at 78.125kbit/s over twisted-pair cable and draws on MTL's experience gained in contributing to the IEC intrinsically safe physical layer. Both power and communications are carried on the cable. From a network design point of view, IS-78 behaves just like any other LonWorks physical channel, allowing multiple devices to be connected and maintaining full communications between hazardous-area devices and with other safe-area physical channels via routers.

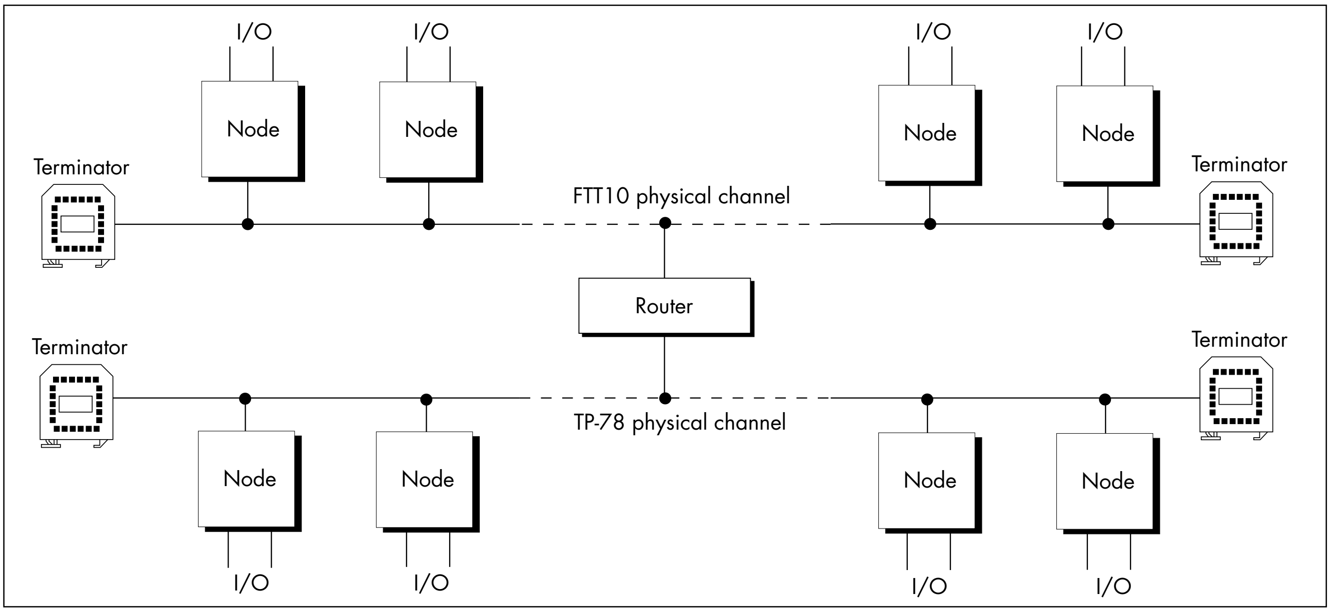

Figure 9 : Typical LonWorks network with router

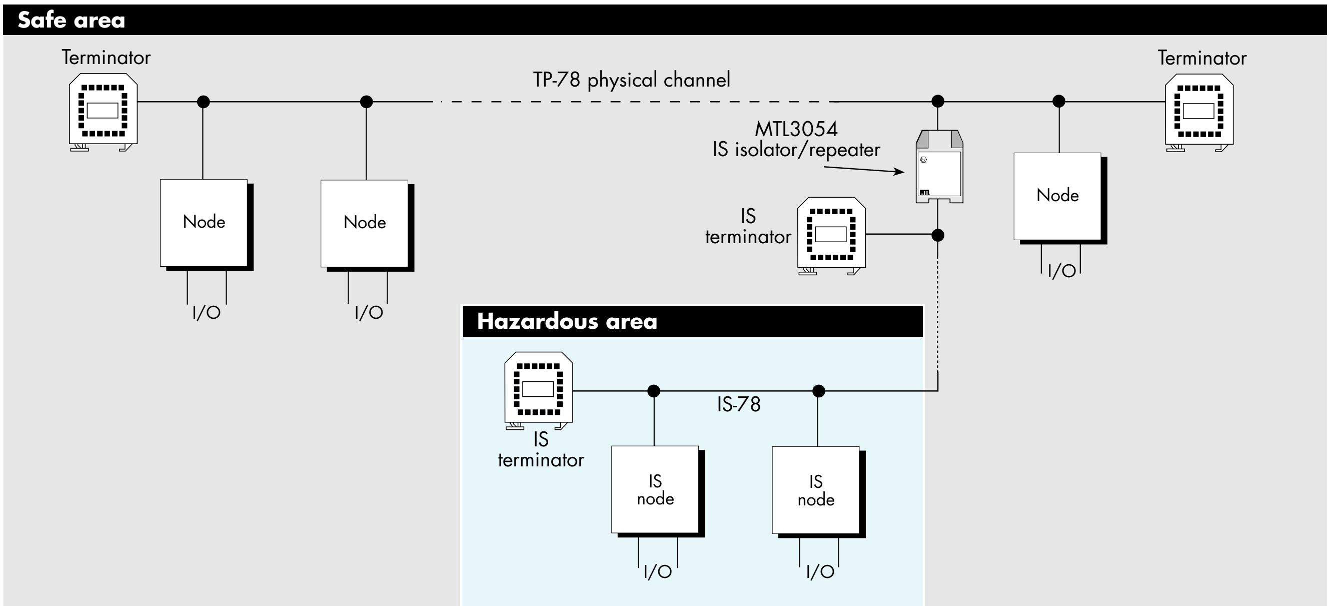

Figure 10: Simple LonWorks network with IS-78 segment

As already described in this paper, intrinsic safety rules require that the levels of electrical energy in the hazardous-area bus must be below prescribed levels. IS-78 achieves this by using an intrinsically safe interface, the MTL3054, which acts as a physical repeater when connected to a standard TP-78 bus. The MTL3054 contains the necessary voltage- and current-limiting components to render the IS-78 bus intrinsically safe, while remaining transparent to LonWorks communications.

As IS-78 has different electrical characteristics from TP-78, any nodes connected to it must have a transceiver which is compatible. The transceiver, Neuron and applications circuitry within the node must also be capable of approval to intrinsic safety standards, so that the entire hazardous-area bus can be made safe. To ease the certification burden on equipment manufacturers who wish to exploit IS-78, pre-certified modules are available which provide an electrical interface with the IS-78 bus. They carry intrinsic safety "component certification" and have input safety parameters that are compatible with the output of the MTL3054.

The IST-78 transceiver connects between the IS-78 physical channel and the serial communication pins of a Neuron. It draws power for itself and the Neuron from the bus, a maximum of 50mA being available for the Neuron, its associated circuitry and any applications circuits.

The ISC-78 control module includes a Neuron and has the standard 18-way connection to application circuitry. Both the IST-78 and ISC-78 are self-contained circuit boards which may be incorporated by other manufacturers into devices for connection to the IS-78 bus. Such devices must be approved as a whole for locating in a hazardous area but this task is made easier by the existing intrinsic safety certification on the modules.

Hazardous area networks

Figure 10 shows a simple network including an IS-78 segment in a hazardous area. Within this network the two hazardous-area nodes could communicate with each other or with any of the safe-area nodes, as if all the nodes were connected directly to the TP-78 channel. More hazardous-area segments could be connected together in the safe area and they would all, effectively, be connected to the same bus despite having MTL3054 repeaters between them.

IS-78 supports both bus and free topologies. Bus topology requires all the nodes to be connected to a single run of cable having a maximum length of 1000 metres, with terminators connected at each end. With free topology there are no restrictions on the arrangement of the cable, other than a 300 metre limit on cable length and a requirement for two terminators.

The maximum current available on an IS-78 segment is about 85mA, falling to approximately 60mA with 1000 metres of cable. This allows three typical bus-powered nodes to be supported, where each draws 25mA from the bus. The number of nodes may be increased to eight, if separate intrinsically safe power is available for applications circuitry.

Conclusion

This paper has shown how intrinsic safety design rules have been applied to two different fieldbus systems. This allows field devices to be located in even the most onerous hazardous areas while maintaining the ability to make and break connections to the bus without gas clearance procedures. By imposing simple constraints on the parameters of certified system components, the task of demonstrating safety for an assembled system becomes straightforward and routine.