ISO/IEC 24740

Edition 1.0 2008-01

INTERNATIONAL STANDARD

Information technology – Responsive link (RL)

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRICE CODE J

ICS 35.200

ISBN 2-8318-9542-1

CONTENTS

FOREWORD 4
INTRODUCTION 5
1 Scope 7
2 Normative reference 7
3 Definitions, terms and abbreviations 7
3.1 Terms and definitions 7
3.2 Abbreviations 8
4 Conformance 8
5 Responsive Link structure 8
5.1 Outline of Responsive Link 8
5.2 OSI reference model 9
6 Layer 1 (physical layer) 9
6.1 Separate transmission of data and event 9
6.2 Physical interface 9
7 Layer 2 (data link layer) 10
7.1 Error correction 10
7.1.1 General 10
7.1.2 CODEC 10
7.1.3 Error correction encoding 10
7.1.4 Bit stuffing 10
7.1.5 NRZI encoding 11
7.2 Frame format 11
7.2.1 Packet 11
7.2.2 Frame 11
7.2.3 Setup pattern 11
7.2.4 Idle pattern 11
7.2.5 Bit synchronization and clock rate 11
7.2.6 Error handling 12
7.3 Automatic reconfiguration (plug and play) 12
8 Layer 3 (network layer) 12
8.1 Packet overtaking function 12
8.2 Responsive Link packet format 12
8.2.1 Header format 12
8.2.2 Priority 13
8.2.3 Data packet 13
8.2.4 Event packet 14
8.3 Routing 15
8.3.1 General 15
8.3.2 Routing table 15
8.3.3 Independent routing of data and event 16
8.3.4 Priority-based routing 16
9 Layer 4 (transport layer) 16
9.1 Priority replacement for packet acceleration/deceleration 16
9.2 Multi-link 17

9.3 Stream data transmission 17
Annex A (informative) Characteristics of real-time communications 18
Annex B (informative) Real-time scheduling 19
Annex C (informative) An implementation of the Responsive Link interface 20
Annex D (informative) Examples of implementation 21
D.1 An implementation of the Responsive Link switch 21
D.2 An implementation of overtaking buffers 22
Annex E (informative) Examples of routing of data and event 23
E.1 An example of independent routing of data and event 23
E.2 An example of priority based routing 23
Bibliography 24

Figure 1 – A humanoid robot 6
Figure 2 – Logical interface of Responsive Link 9
Figure 3 – Header format 13
Figure 4 – Data packet format 13
Figure 5 – Trailer format of data packet 13
Figure 6 – Event packet format 14
Figure 7 – Trailer format of event packet 15
Figure 8 – Routing table 16
Figure B.1 – EDF scheduling 19
Figure C.1 – Responsive Link connector and cable 20
Figure D.1 – A Responsive Link switch 21
Figure D.2 – An overtaking buffer 22
Figure E.1 – An example of routing 23

Table 1 – Syndrome and error digits 10
Table 2 – Frame format 11
Table A.1 – Syndrome and error digits 18
Table C.1 – Maximum cable length 20

INFORMATION TECHNOLOGY – RESPONSIVE LINK (RL)

FOREWORD

1) ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards. Their preparation is entrusted to technical committees; any ISO and IEC member body interested in the subject dealt with may participate in this preparatory work. International governmental and non-governmental organizations liaising with ISO and IEC also participate in this preparation.

2) In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

3) The formal decisions or agreements of IEC and ISO on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC and ISO member bodies.

4) IEC, ISO and ISO/IEC publications have the form of recommendations for international use and are accepted by IEC and ISO member bodies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC, ISO and ISO/IEC publications is accurate, IEC or ISO cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

5) In order to promote international uniformity, IEC and ISO member bodies undertake to apply IEC, ISO and ISO/IEC publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any ISO/IEC publication and the corresponding national or regional publication should be clearly indicated in the latter.

6) ISO and IEC provide no marking procedure to indicate their approval and cannot be rendered responsible for any equipment declared to be in conformity with an ISO/IEC publication.

7) All users should ensure that they have the latest edition of this publication.

8) No liability shall attach to IEC or ISO or its directors, employees, servants or agents including individual experts and members of their technical committees and IEC or ISO member bodies for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication of, use of, or reliance upon, this ISO/IEC publication or any other IEC, ISO or ISO/IEC publications.

9) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

10) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 24740 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

The Responsive Link standard defines a real-time communication protocol between computers networked in a machine or in a site with point-to-point interfaces. Complex machines, such as robots, automobiles and network routers, have a growing demand for distributed processing. In addition, modernization of facilities such as factories, offices, schools and homes is creating a ubiquitous computing environment. Unlike conventional PC applications for documentation and internet applications that exchange texts without hard time constraints, these types of cooperative computing require real-time and reliable responses to physical events occurring in the real world. Although most conventional real-time systems employ a single processor that invokes tasks corresponding to outside events, the need for distributed processing architecture is inevitable for the larger-scale systems mentioned above, because operational targets are physically separated and scalable processing power becomes necessary as the number of components increases. For distributed nodes to cooperate in real-time, an interconnecting network shall realize real-time communication. The Responsive Link provides such real-time communication between computers by providing dual full-duplex communication channels, fixed-size prioritized packets, packet overtaking based on priority, and automatic error correction.

Real-time

An operation of a dynamic system is called a real-time operation if the combined reaction- and operation-time of the task is shorter than the allowed maximum delay, with respect to circumstances outside the operation. A system is said to be a hard real-time system if the correctness of an operation depends not only on logical correctness, but also on the time at which it is performed. An operation performed after the deadline is, by definition, incorrect, and has no value. In a soft real-time system the value of an operation declines steadily after the deadline expires. Whether a system is hard real-time or soft real-time and how much time is allowed before a deadline are application dependent.

Although it is known that static estimation of the time required for generating a response is important for a computer to output a response before a deadline, such static estimation is often very difficult or impossible. Instead, most real-time systems rely on priority-based scheduling.

Real-time scheduling

As real-time scheduling algorithms, the earliest deadline first (EDF) scheduler, the rate monotonic (RM) scheduler and their variations have been established, as explained in Annex B. These algorithms commonly schedule tasks based on priorities determined by margins to deadlines. Thus, an important function is preemption, i.e. the scheduler deprives the execution privilege of the lower-priority task and allows the higher-priority task to run.

In order to realize real-time communication, a function similar to task preemption shall also be employed in communication. There are several methods for this communication preemption: provision of two separate channels for high- and low-priority packets, setting different communication paths according to priority and assigning a shorter path for high-priority communication, and allowing higher-priority packets to overtake lower-priority packets. Responsive Link has all of these capabilities.

Important features

Responsive Link has the following distinctive features that allow realization of real-time communication.

- Separation of data transmission and event transmission (see Annex A).
- Prioritized routing: When multiple packets with different priority levels are sent to the same destination, different routes can be set in order to realize exclusive communication lines or detours (see Annex E).
- Priority-based packet overtaking: The packet with the highest priority overtakes the other packets at each node (see Annex B and Annex D).

- Packet acceleration/deceleration using priority replacement: Packet priority can be replaced with a new priority at each node in order to accelerate/decelerate packets under distributed control and realize real-time communication.
- Fixed packet size: 64-byte data and 16-byte event.
- Point-to-point serial link (see Annex A).
- Independent routing of the data link and the event link (see Annex E).
- Hardware forward error correction to prevent retransmission.
- Other useful features are as follows:
  - variable link speeds (533, 267, 133, 66,7, 33,3, 16,7 and 8,3 Mbit/s),
  - automatic reconfiguration (plug & play),
  - topology free,
  - low latency (240 ns required to pass through one routing node at 66,7 Mbit/s).

Typical applications and operations

As a typical application of the Responsive Link, Figure 1 shows a distributed control configuration of a humanoid robot. The electronic control part of the humanoid robot consists of several control nodes with local sensing and actuating devices. The distributed controllers are connected to each other by Responsive Link. In this figure, rectangles represent node controllers, and dotted lines show the Responsive Link cable, which is a point-to-point serial link.

For a humanoid robot to walk stably, a servo loop of 1 ms or shorter is needed. In this configuration, the farthest two nodes can exchange a 16-byte packet within 5 µs. Since the time is guaranteed not to fluctuate, the distributed control of a humanoid is considered to be sufficiently possible.

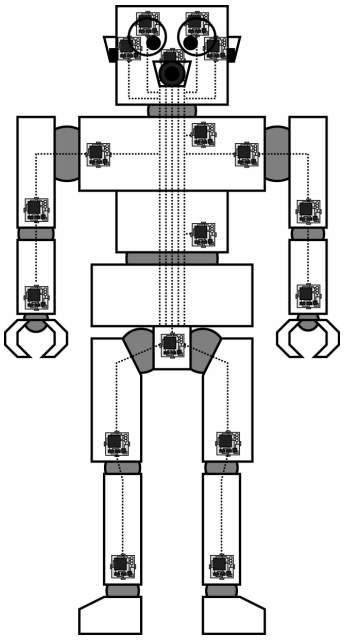

Figure 1 – A humanoid robot

INFORMATION TECHNOLOGY – RESPONSIVE LINK (RL)

1 Scope

This International Standard specifies the communications protocol and interface of Responsive Link, the real-time communication for parallel/distributed control. This standard corresponds approximately to the functions specified in layer 1 to layer 4 of the OSI reference model.

The purpose of this standard is to facilitate the development and use of Responsive Link in real-time systems by providing a common data protocol. This standard provides a real-time communication protocol for interconnections among distributed real-time systems, including embedded systems, control systems, amusement systems, robot systems and intelligent buildings.

2 Normative reference

The following referenced document is indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 7498-1, *Open systems interconnection – Basic reference model: The basic model*