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TECHNICAL REPORT

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inside

Multimedia systems and equipment – Multimedia signal transmission – Dependable line code with error correction

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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**MULTIMEDIA SYSTEMS AND EQUIPMENT –
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FOREWORD

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IEC TR 63094, which is a technical report, has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
100/2823A/DTR	100/2871/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

This document defines a line code that incorporates error correction capability to communicate reliably among multimedia components, I/O peripherals and computers. A number of complex multimedia machines, in particular 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 and multimedia computing environment. Unlike conventional PC applications for documentation and Internet applications that exchange texts without hard time constraints, these types of cooperative computing require reliable real-time responses to physical events occurring in the real world. In order for distributed nodes to cooperate in real-time, an interconnecting network shall realize real-time and dependable communication without re-sending on noisy environments. The 4b/10b provides a dependable line code for such real-time communications between multimedia components, I/O peripherals and/or computers by providing embedded clock, DC balance, error detection and error correction features.

The real-time aspect means that the exactness of the system including operations and communications depends not only on the result, but also on the time it took to achieve the result. In the narrow sense, the real-time aspect means that the time constraint, including deadlines or cycles, must be met.

Real-time tasks with the time constraints are generally scheduled and executed by a real-time scheduler and a real-time operating system. Most real-time scheduling algorithms assume that the WCET (worst-case execution time) of each task is given. A real-time scheduling algorithm converts a time constraint of each real-time task to a priority. Most real-time operating systems based on such real-time schedulers pre-empt and execute tasks in order of priority at every tick to meet the time constraint.

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 A. These algorithms commonly schedule tasks based on priorities determined by the time constraints.

Most real-time scheduling algorithms assume that the WCRT (worst-case response time) of each communication packet is given in case of communication. In order to apply real-time scheduling algorithms to real-time communications, pre-emptive communication, which is achieved by Responsive Link (ISO/IEC 24740), and the error correction capability to prevent the re-sending a broken packet are required.

A line code is a lowest-level communication protocol on a communication line. Most current line codes have a few typical functions including embedded clock, DC balance and basic error detection features. The 8b/10b codec is a major example, which is used for PCI Express, USB 3.0, SATA, IEEE1394b, and 10GbE. But no conventional line code has an error correction capability.

When an encoded code (a 10b code) is broken during communication, the multi-bits of the decoded code (the 8b code) are corrupted. In other words, when a single bit error occurs in an encoded 10-bit code, the decoded 8-bit code (a byte) is completely broken.

When an error is detected on the decoder, the broken data is normally re-transmitted under an upper-level communication protocol. However, re-transmission is not allowed in order to realize real-time communication.

It is hard for a bit-level error correction code that includes the Hamming code and the BCH code to incorporate error correction capability, because multi-bits of the decoded code are broken even if a single-bit error occurs on the encoded code.

In order to incorporate error correction capability on the 8b/10b codec, a block-level error correction including RS (Reed-Solomon) is required as a large packet-level error correction. But the block-level error correction is not suitable for real-time communication, because the communication latency becomes longer as it is impossible to correct the corrupted data until all corresponding packets are received.

The line code 4b/10b has the following distinctive features for real-time communications:

a) embedded clock;

b) DC balance;

c) error detection;

d) error correction.

No conventional line code supports the above features at one time. For example, the industry-wide standard 8b/10b codec can be easily replaced with the 4b/10b line code for highly reliable communications.

Figure 1 shows a distributed control configuration of a humanoid robot as one of the typical applications of the 4b/10b line code. 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 communication links such as the Responsive Link that is a point-to-point serial link.
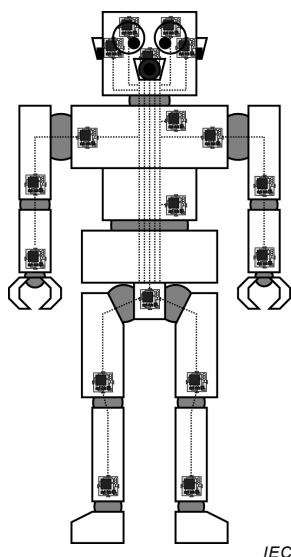

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Figure 1 – A humanoid robot

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. Since many actuators that generate noises are embedded inside the robot, the line code is required for noise tolerance. The 4b/10b is the line code that has error correction capability.

Currently many I/O interfaces and communication standards, including PCI Express (PCIe), USB 3.0, SATA, IEEE 1394b, and 10GbE use the 8b/10b codec as a line code. The 8b/10b has a lot of functions and its code rate is relatively high (about 80 %). However if one bit error occurs in an encoded data (10b), the decoded data (8b) will be broken completely. Therefore when the 8b/10b codec is used on noisy environment such as inside the robot, an upper-level error correction code is required. For error correction, it is hard to apply any bit-level error codec including the Hamming code and the BCH code, because multiple decoded bits (1-byte) will be broken even if an encoded bit is inverted. So, block-level error correction including

Reed-Solomon, which is long latency ECC that is not suitable for real-time applications, is required. Hence, a reliable line code with ECC is required for such applications.

Patent

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**MULTIMEDIA SYSTEMS AND EQUIPMENT –
MULTIMEDIA SIGNAL TRANSMISSION –
DEPENDABLE LINE CODE WITH ERROR CORRECTION**

1 Scope

This document specifies the line code 4b/10b for dependable multimedia signal transmission required for complex machines, such as robots and automobiles. This document corresponds to the functions specified in layer 1 to layer 2 of the OSI reference model (ISO/IEC 7498).

The purpose of this document is to facilitate the development and use of the 4b/10b in dependable systems by providing a line code protocol. This document provides a line code protocol for interconnections among distributed real-time systems, including embedded systems, control systems, amusement systems, robot systems, and intelligent buildings. The 4b/10b can achieve the line code with ECC (error code correction). The 4b/10b is the line code that realizes embedded clock, DC balance, error detection and error correction at a time; it is not possible to satisfy these functions in one codec by conventional schemes, and the 4b/10b line code can achieve highly reliable and dependable digital communications.

2 Normative references

There are no normative references in this document.