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3. The document attached as Exhibit A is a scan of a portion of a periodical that I located in the Milson S. Eisenhower Library's collection of periodicals. Specifically, Exhibit A shows the article titled "Communication Protocols for Embedded Systems" as in appears in the November 1994 issue of *Embedded Systems Programming*. This is volume 7, issue 11 of this publication.

4. The stamp on the back cover of the November 1994 issue of *Embedded Systems Programming* reads "OCT 28 1994." It is the regular practice of the Milton S. Eisenhower Library to stamp periodicals with the date the periodical is added to the library's catalog. Once a periodical is in the library's catalog, it is made available in the library for viewing by any visitor of the library.

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Jon Mears

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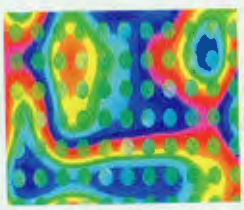

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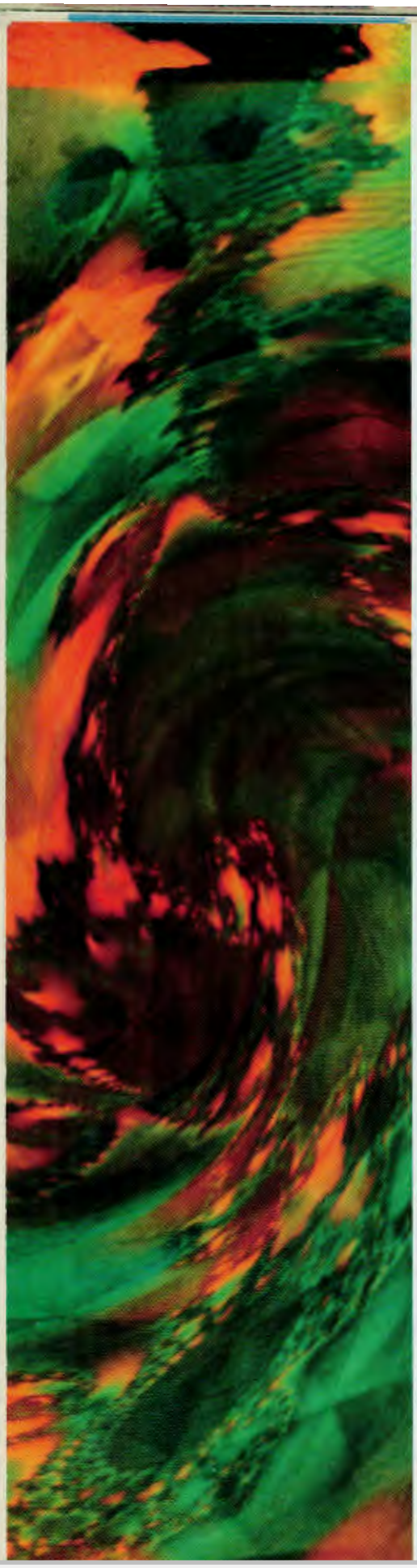

by BHARGAV UPENDER and PHILIP KOOPMAN

Communication Protocols for Embedded Systems

There's more to connecting multiple CPUs than just stringing wires or cable. Your choice of network protocol, in particular, will determine system performance.

The past few years have seen a growing trend to dramatically increase the embedded electronics content of automobiles, elevators, building climate control systems, jet aircraft engines, and other traditionally electro-mechanically controlled systems. In many large systems, this increasing electronics content is accompanied by a proliferation of subsystems with separate CPUs.

The increase in the number of processors in a system is often driven by computation and I/O growth. In some development environments, the increase may also be driven by a need to ease system integration burdens among multiple design groups or to provide system flexibility through "smart sensors" and "smart actuators." Whatever the reasons, once there is more than one CPU in a system, there must be some means of communication to coordinate action.

While some high-end embedded systems communicate over a VME backplane or similar arrangement, the embedded systems we're working on use physically distributed CPUs involving some sort of local area network (LAN), also called a multiplexed transmitter for access to the shared network medium, typically a wire, fiber, or RF frequency.

In this article, we will discuss the special considerations for networked real-time embedded systems, and look at several media access protocols that demonstrate fundamentally different ways of accessing the shared medium. The protocols are: connection-oriented protocols, polling, time division multiple access (TDMA), token ring, token bus, binary countdown, carrier sense multiple access with collision detection (CSMA/CD), and carrier sense multiple access with collision avoidance (CSMA/CA). For each of these, we will evaluate the strengths and weaknesses against special considerations. A protocol tradeoff chart will enable you to select a protocol to fit your needs. While no protocol is perfect for all purposes, a variation of CSMA/CA offers the most versatility for many embedded systems.[1]

SPECIAL CONSIDERATIONS

In practice, we have found that embedded real-time networks require high efficiency, deterministic latency, operational robustness, configuration flexibility, and low cost

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