A Preliminary Investigation into the Design of Distributed Architectures based on Cost Decisions

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This paper presents preliminary findings from research into a methodology for ascertaining nodal cost from the number of nodes and signal information. An estimation of nodal cost is useful in Design to Cost processes and can therefore be used to help partition CAN based systems using cost based decisions and help decide the number of networks and nodes. Published costing work and methodologies are reviewed. Then work on the estimation of microcontroller ROM and RAM requirements from the number of nodes and signals is presented and it is shown how this relates to nodal cost. The paper closes with a discussion on how this may fit into a Design to Cost process for distributed automotive electrical architecture design. This is shown for CAN and LIN based systems which are popular automotive networking technologies. However, the process discussed may also be useful for non-automotive distributed control systems.

1 Introduction

Early microcontroller based automotive control systems had a small number of stand-alone ECUs with sensors and actuators connected directly to the ECU that used the signal. This often resulted in duplicate sensors providing the same information being used. This also resulted in redundant processes at several ECUs. An improvement to stand alone ECUs was to integrate ECUs with hard-wired signals. Therefore if two ECUs required the same signal, they could share the information from one sensor. This provided the benefit of cost saving by reduction of duplicate sensors. However, as the number of ECUs and sensors grew, this approach to ECU integration became very complicated and the weight and size of the wiring harness grew significantly. A large number of connectors within the wiring harness were required which in turn led to reliability problems. Another problem of the hardwired integration method is cross-talk between wires caused by induced electrical interference [1].

The problems associated with hard-wired integration led to the adoption of digital networks. Networks can have ring, star or bus architectures. The single bus architecture was adopted by the automotive industry for integration of ECUs. This provided the many benefits such as [2]:

- Reduced wiring harness weight and size
- Reduction of the number of connectors
- Reduction of sensors
- Reduction CPU processing requirements
- Increased reliability
- Simplified assembly
- Reduction in electrical architecture cost
- Ease of upgradeability for new ECUs
- Improved electrical diagnostics

CAN (Controller Area Network) was adopted as the de-facto automotive bus standard. A limitation of CAN is message latency can be very unpredictable at higher bus loads. Therefore to maintain reasonable message latency for hard real time control loops, it became appropriate to partition the automotive electrical architecture between hard real time and soft real time functionality. This partitioned type of electrical architecture is typical of current architectures using the de-facto standard CAN and LIN (Local Interconnect Network) technologies.

Modern high-end-passenger vehicles have complicated distributed architectures and often up to five CAN buses and 12 LIN buses to achieve their control aims.