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Validation of Harness Designs in Cars

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Abstract

A particular car model would have many variants, e.g. with or without navigation/sunroof/etc., the type of the stereo system in the car, etc. The number of potential variants grows exponentially with the number of options and can reach to billions even for a low-end model.

The wiring used in a car changes based on the options used in that particular model, again e.g. if the car has a navigation or not. The manufacturers do not design a wiring for each particular variant. Instead they have a potential set of wiring for each part of the car, e.g. wiring for the stereo, wiring inside the door, wiring inside the trunk etc. For a variant of the car, one wiring is selected from a potential set of cables for the stereo, one for the door, etc. The problem then is to make sure that the selected set of cables can be used together to satisfy the requirements of the particular variant. This analysis cannot be made for tens of thousands of the variants manually.

The purpose of this project is to design and develop a software to perform this analysis automatically.

Introduction

Car manufacturers distribute design tasks of a car to different organizations and different units inside the company. In this project we will be dealing with the wire harness design of the car. A wire harness -as shown in figure 1- is an assembly of electrical cables or wires which transmit signals or electrical power, and they are usually designed according to physical and electrical requirements [1].

First a high-level wire harness design is prepared, which does not consider physical requirements such as the placement of the components in the car. This high-level design is only interested in the electrical connections between the components like sensors, processors, actuators, etc. This high-level design is then refined into a lower level design by taking into account some physical constraints such as the placement of the component and the current requirements of the electrical connections. Due to these constraints the new detailed design will necessarily have connectors and splices that do not exist in the high-level design. Finally, yet another design phase follows. In this final design, wire harness is considered from the manufacturer point of view and several optimizations might be applied to reduce costs without changing functionality.

Dealing with designs at 3 different levels and managing so many variants of wire harness designs make the process error prone. As detailed designs are prepared manually, it is quite easy to introduce errors at this step. Also, the number of potential variants add to the complexity a lot.

In this project, an automated system will be implemented to test if the final design of wire harness corresponding to a given variant of a car has the same electrical connections as the high-level design of the corresponding variant. The system will identify all the electrical connections in the high-level design for the given variant. It will virtually connect the final designs of the wire harness parts (i.e. the door harness, dashboard harness, etc.) corresponding to the given variant, and check if the high-level design and the final design have identical electrical connections.

This process is being performed manually at the customer after producing a prototype of a wire harness. In other words, engineers test it on a bench physically, by using actual electrical components of cars, such as cables, sensor, actuators. However, they can do this only for limited number of variants and it takes time. The system that will be developed in this project will do the same test computationally. It will be able to perform the test much faster, and for a much larger number of variants.

Fig.1 An example of wire harness of a car

Fig.2 An example of wire harness test bench

References

1: https://en.wikipedia.org/wiki/Cable_harness
2: https://en.wikipedia.org/wiki/Component_(graph_theory)

Proposed Solution

We will be transforming each wire harness design to separate graphs. In these graphs nodes will be the pins of electrical components. For example, each pin of a processor will be a separate node in this graph. A pin of a sensor will be a node in this graph. A wire connects two pins, therefore a wire will correspond to an edge in this graph.

In graph theory, a connected component, of an undirected graph is a subgraph in which any two vertices are connected to each other by paths, and which is connected to no additional vertices in the supergraph [2]. In our instance power and ground cables are generally distributed amongst a group of electrical components, we can see them as connected components in the graph, hence we can use these connected components to reduce our tracing efforts, instead of tracing cables from pin to pin, we can compare connected components to check equivalences. Data cables of the sensors are connected directly to the processors if they are close to each other. So connected components consisting of the data pins of the sensors will be relatively small in size compared to the connected components that consists of power and/or ground cables.

In figures 3 and 4, we see examples of high and low level designs schematics, in high-level design, cables are connected together for power and ground connections, this is shown in the schematic using dot symbols on the wire, as opposed to this, in low-level design power and ground connections are done using an electrical component called splice, this component simplifies the cable organization process.

Figures 5 and 6 are transformed graphs of schematics in figures 3 and 4, colors identify connected components, we can see that both graphs have equal number of connected components, only the number of nodes in the connected components differ, and we can clearly see that connected components in high-level design are smaller than or equal to that of low-level design, hence they will be equivalent if we remove splice and connector nodes from the low-level design graph.

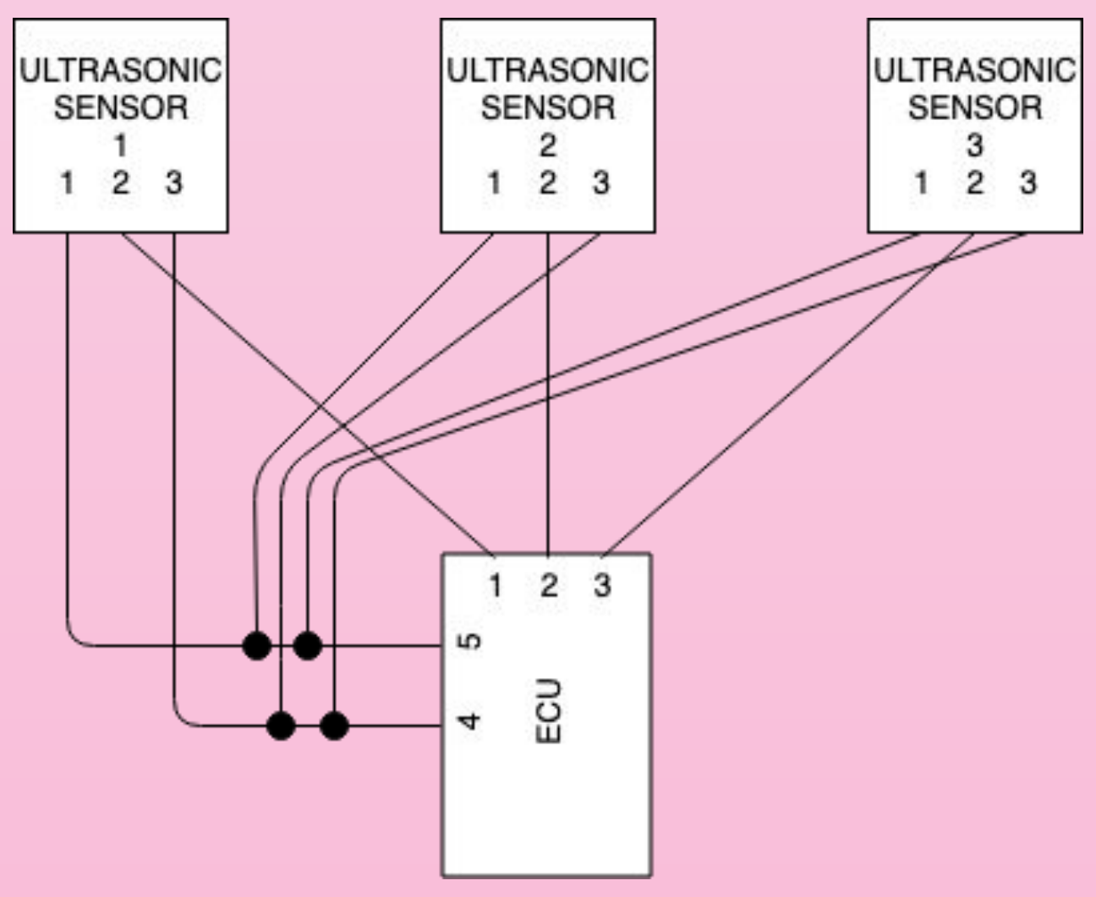

Fig.3 High-level design sample schematic

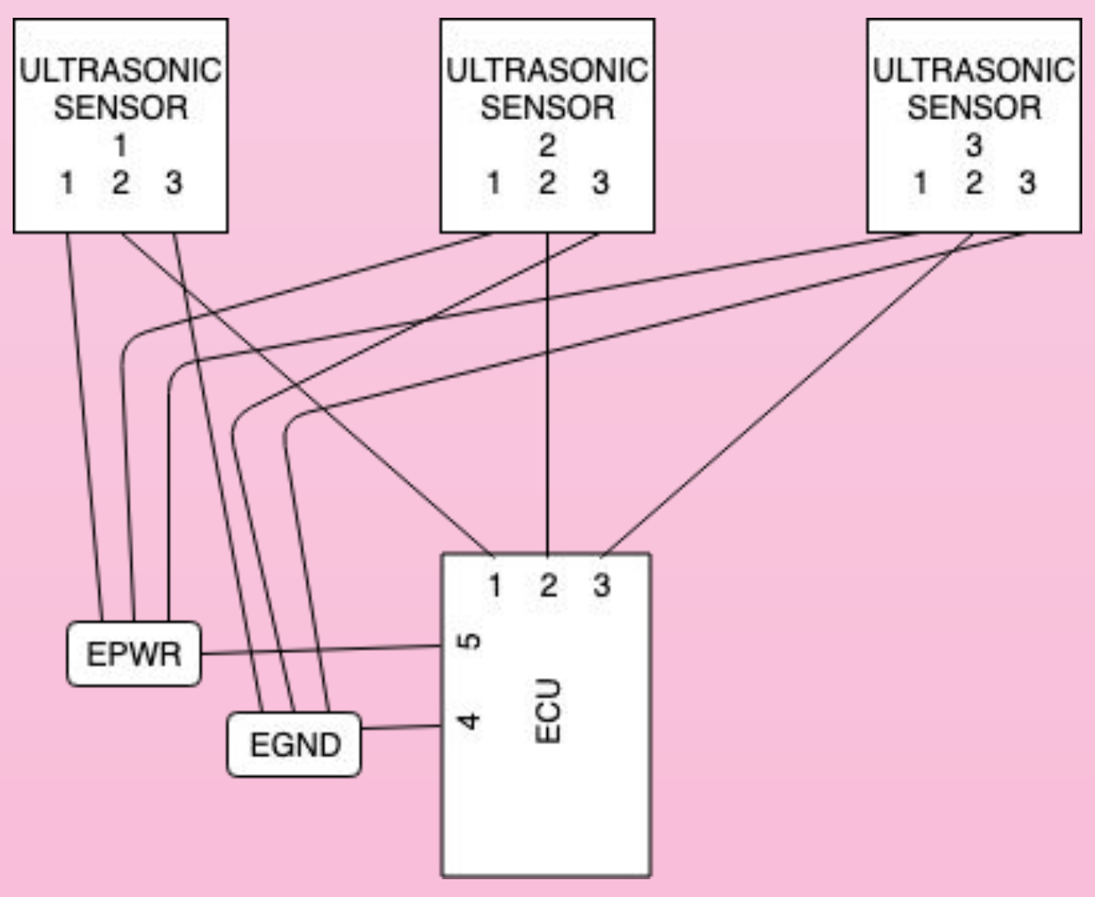

Fig.4 Low-level design sample schematic

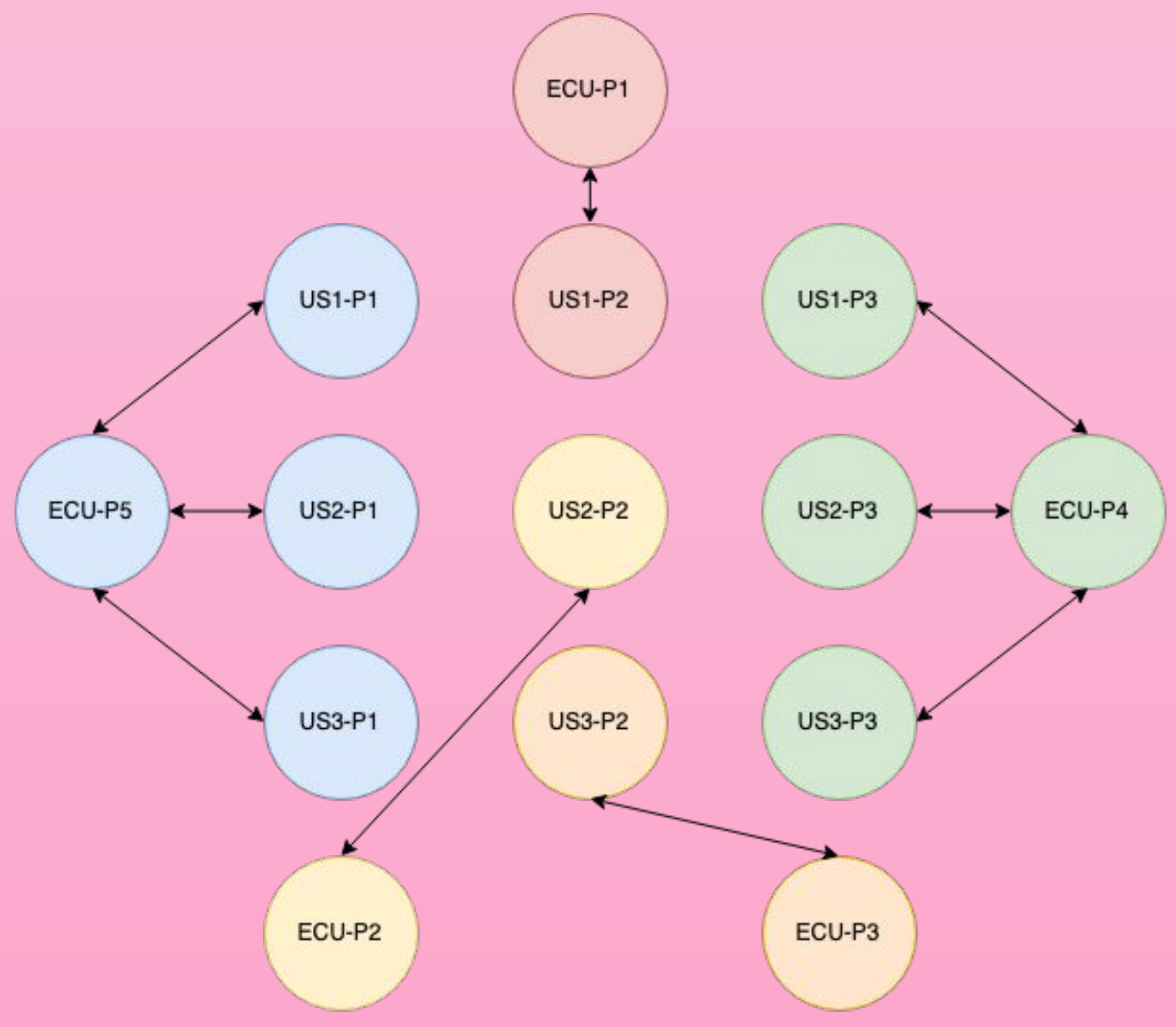

Fig.5 Graph generated from high-level design sample schematic

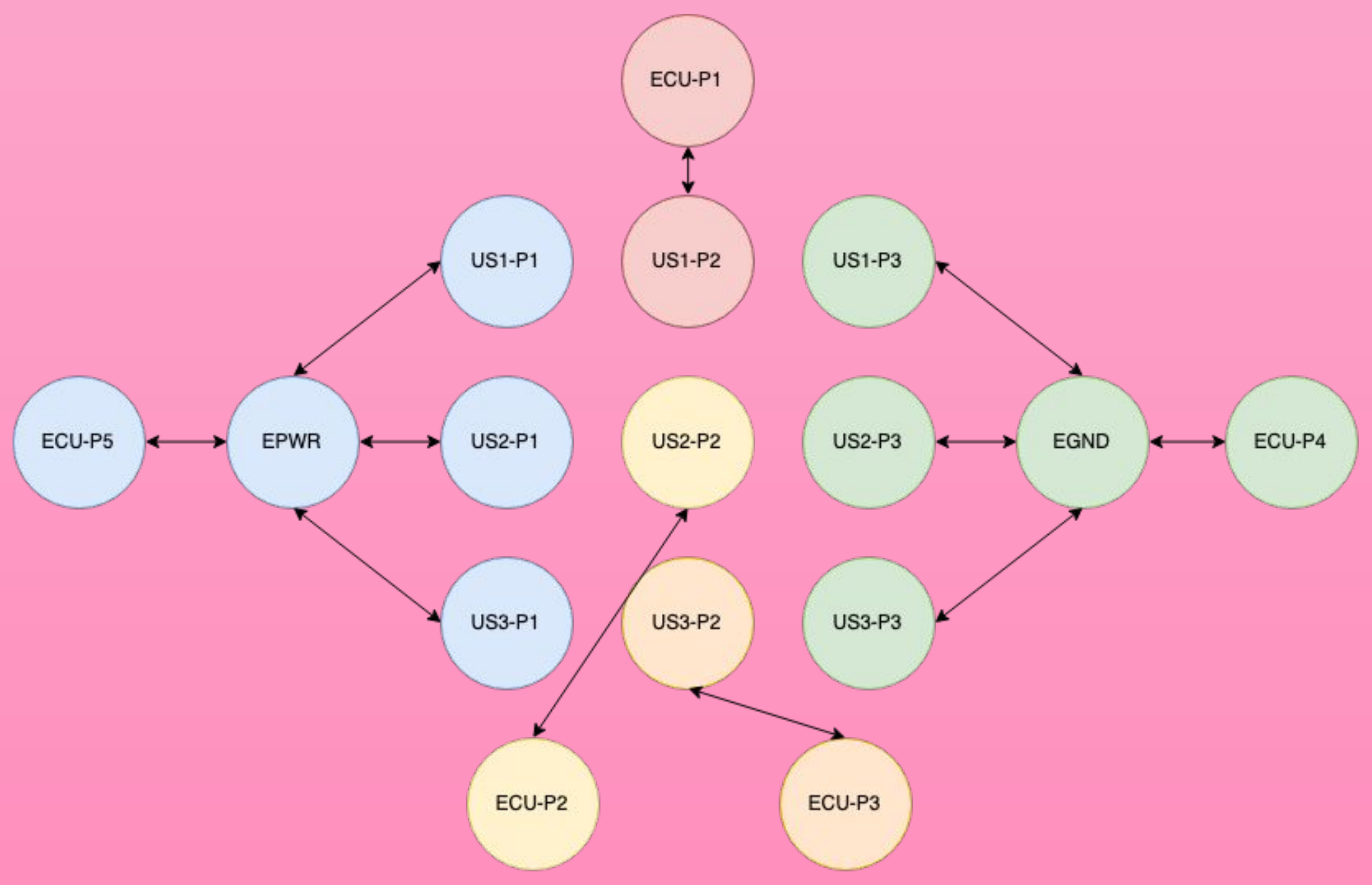

Fig.6 Graph generated from low-level design sample schematic