# INSTITUTO TECNOLÓGICO Y DE ESTUDIOS SUPERIORES DE OCCIDENTE



Reconocimiento de validez oficial de estudios de nivel superior según acuerdo secretarial 15018, publicado en el Diario Oficial de la Federación el 29 de noviembre de 1976.



Departamento de Electrónica, Sistemas e Informática

MAESTRÍA EN DISEÑO ELECTRÓNICO


# REPORTE DE FORMACIÓN COMPLEMENTARIA EN ÁREA DE CONCENTRACIÓN EN SISTEMAS EMBEBIDOS Y TELECOMUNICACIONES

Trabajo recepcional que para obtener el grado de

MAESTRO EN DISEÑO ELECTRÓNICO


Presenta: Luis José Rincón Castelo

Asesor: Dr. Omar Humberto Longoria Gándara


San Pedro Tlaquepaque, Jalisco. 16 de marzo del 2020

# Contenido

# Introducción

El presente documento integra los trabajos más representativos del conocimiento adquirido durante el tiempo que curse la Maestría en Diseño Electrónico.

El área de concentración que elegí para presentar este reporte es la de Sistemas embebidos y Telecomunicaciones, por el impacto que esta área tuvo en el giro que le dio a mi carrera profesional, en donde estos tres trabajos me permitieron encontrar un horizonte nuevo el cual me llevó a salir de mi área de confort y que abrió nuevas oportunidades que impulsaron significativamente mi desarrollo profesional, tanto así que me llevó a cambiar de Empresa, de Industria y de País de residencia.

Los tres proyectos que integran este reporte son:

1.1. Ingeniería de Software en Ambientes Embebidos, el proyecto "Luces direccionales y luces intermitentes";
1.2. Diseño de Sistemas Analógicos Basados en Dispositivos Comerciales, el proyecto "Diseño de Sistema de Audio de Alta Definición";
1.3. Diseño de Sistemas Operativos en Ambientes Embebidos, el proyecto "Sistema integral de riego con protección de bajo nivel en la reserva de agua".

A continuación, describo en resumen cada uno de los proyectos, los conocimientos adquiridos y las conclusiones a las que se llegaron.

# 1. Resumen de los proyectos realizados

En esta sección del documento describo el resumen de cada uno de los proyectos elegidos, sus particularidades, el conocimiento obtenido, el método utilizado para diseñar la solución y las conclusiones a las cuales se llegaron.

## 1.1. PROYECTO 1 - Luces Direccionales y Luces Intermitentes

### 1.1.1 Introducción

El objetivo del proyecto de “Luces direccionales y luces intermitentes” fue el de desarrollar de manera metodológica la documentación necesaria para poder describir un producto a detalle, con la finalidad de que la solución realizada cumpla con las necesidades para la cual se diseñó y con la calidad requerida.

### 1.1.2 Antecedentes

Este proyecto me dio la oportunidad de por primera vez conocer el método formal en el cual se diseñan los productos que incluyen sistemas embebidos en la industria, en particular en la industria Automotriz.

Pude ver cómo se desarrolla el llamado Ciclo V, cómo se parte desde los requerimientos del cliente, a desarrollar más requerimientos para describir a detalle la solución requerida y su relación con las pruebas que se deben realizar en cada nivel del desarrollo para que el producto final cumpla con todas las expectativas de calidad, durabilidad y usabilidad.

Herramientas tales como el Modelo de desarrollo V, DFMEA o “Design Failure Mode Effects Analysis”, Diagramas de bloques y Diagramas de Interfaces se utilizaron durante el desarrollo del diseño.

### 1.1.3 Solución desarrollada

El desarrollo del proyecto comenzó con describir el producto que se requería diseñar, para lo cual se generó un archivo de Excel como se encuentra en el Apéndice A, en el cual se definieron los requerimientos (Requerimientos del Cliente), y desde el cual partiría toda la trazabilidad.

A cada uno de esos requerimientos se le asignó un número identificador único, y se le calificó para saber si era claro, o si más información era necesaria para darle claridad (Análisis de Requerimientos).

Teniendo los requerimientos claros, se realizaron una serie de diagramas que soportan el diseño a alto nivel del producto, sus dependencias y la interrelación que tiene con todas las partes del sistema (Diseño Funcional del Sistema) como se muestra en la Fig. 1.

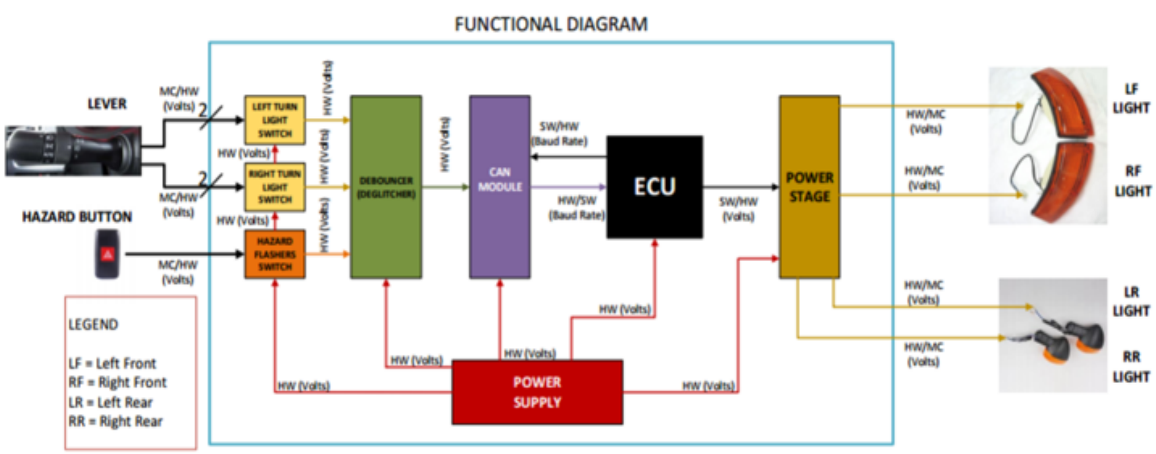



*Fig. 1 Diagrama Funcional del Sistema*

El Diagrama funcional describe todos los componentes del sistema y su interacción, parte fundamental para poder describir el comportamiento esperado del software, y los requerimientos de procesamiento de información necesarios.

Esta información dio paso a la realización del Modelo (Fig. 2) de las principales funciones del Software (Arquitectura del Software), así como la descripción de cada uno de los módulos representados (Diseño Modular).

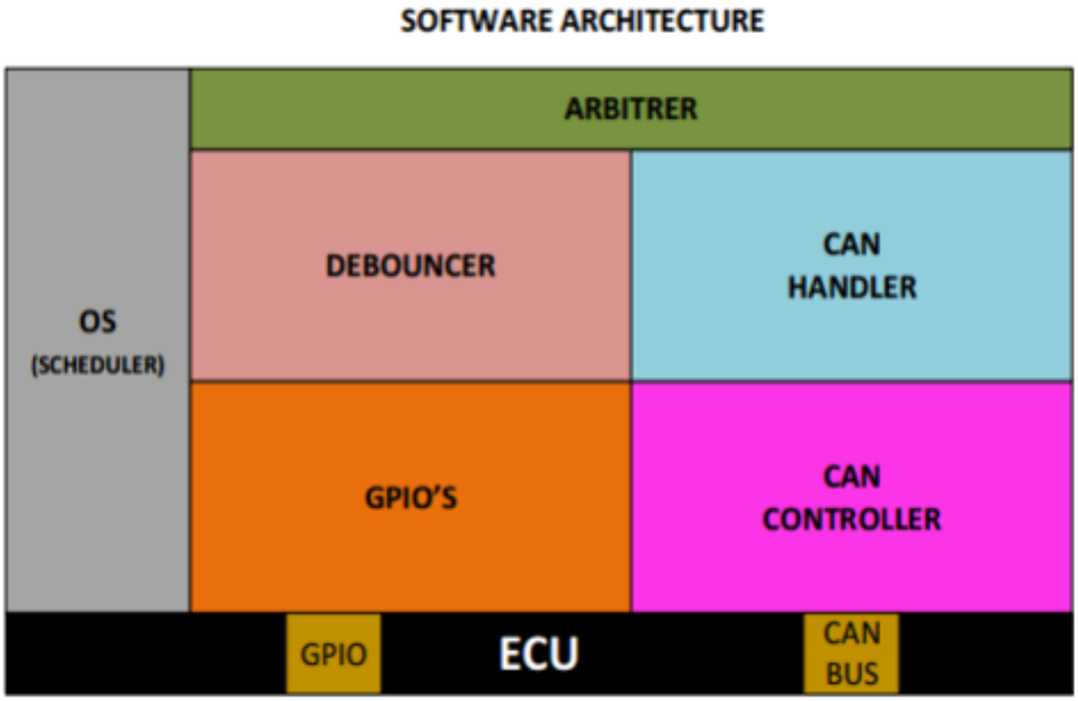



*Fig. 2 Modelo de la Arquitectura de Software*

Al llegar a este nivel, se describieron que pruebas eran necesarias, tanto para cada Módulo (Pruebas Unitarias), para la integración de esos módulos (Pruebas de Integración), para las pruebas de los módulos integrados y su interacción con el exterior (Pruebas de Sistema) y la verificación del cumplimiento de todos los requerimientos del cliente (Pruebas de Aceptación).

### 1.1.4 Análisis de resultados

El resultado de este proyecto fue un archivo de Excel en el cual se encuentra toda la trazabilidad de cada uno de los niveles descritos en la Sección 1.1.3 que explica la Solución desarrollada.

El documento muestra claramente cómo cada nivel interactúa para la descripción del producto deseado, tanto a alto nivel como al mínimo detalle, y cómo deben realizarse las pruebas a cada nivel y su correspondiente resultado esperado.

### 1.1.5 Conclusión

Este proyecto me abrió un panorama en el cual el diseño y desarrollo de cualquier producto o servicio se puede llevar a cabo de una manera metodológica, que existen herramientas para facilitar el proceso y para identificación de riesgos que pudieran poner la realización de los proyectos en una situación en la que no se pudiera terminar.

Sin lugar a duda este proyecto y esta materia influyeron en gran manera al paso profesional que di en incursionar como Ingeniero de Sistemas.

## 1.2. PROYECTO 2 - Diseño de Sistema de Audio de Alta Definición

### 1.2.1 Introducción

Al comenzar este proyecto, tenía la idea de que los diseños que se utilizan en la industria comenzaban desde cero, diseñando cada módulo del sistema para después proceder a buscar componentes en el mercado que cumplan las necesidades del diseño.

Esta materia y este proyecto me permitieron conocer que partiendo del diagrama a bloques se pueden encontrar componentes, donde el proveedor incluye un diseño base o un diseño sugerido el cual puede ser integrado con más componentes del sistema.

### 1.2.2 Antecedentes

Un sistema de audio de alta definición es capaz de reproducir más canales con mayor calidad en diferentes formatos de audio. Cada vez más consumidores se están moviendo para disfrutar de música o películas digitales con audio multicanal de última generación.

Con mejores altavoces conectados, las limitaciones de los subsistemas de sonido actuales ya sean integrales o complementarios, pueden degradar la experiencia digital.

El objetivo del proyecto fue poder desarrollar un sistema de audio el cual tuviera como entrada diferentes dispositivos, así como diferentes formatos, procesar la información, y entregar como salida audio estéreo el cual sea de la calidad especificada en los requerimientos.

### 1.2.3 Solución Desarrollada

Para la realización de este proyecto, los requerimientos para las entradas, salidas y la fuente de poder fueron especificados por el Profesor.

En resumen, los requisitos específicos son:

I. Entrada para dispositivos de audio digital (ipad, ipod).

II. La salida estéreo en los altavoces debe cumplir con los requisitos de definición y potencia especificados en la Sección 2 del Apéndice B.

III. Fuente de alimentación que permita mantener los requisitos de potencia y definición requeridos.

El diagrama a bloques propuesto que describe cada etapa necesaria para el procesamiento de la entrada y su despliegue a la salida se muestra a continuación (Fig. 3):

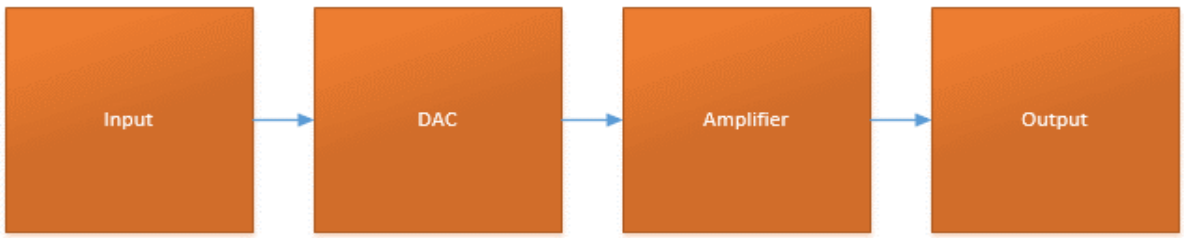



*Fig. 3 Diagrama a bloques del Sistema de Audio de Alta Definición*

Partiendo de los requerimientos como referencia, utilizamos herramientas en línea, en particular las ofrecidas por digikey.com, para filtrar la búsqueda de componentes, y buscar a su vez, diseños de referencia para cada etapa descrita en el diagrama a bloques.

Esto nos llevó a desarrollar un diagrama detallado el cual lista aquellos componentes clave para desarrollar el proyecto (Fig. 4).

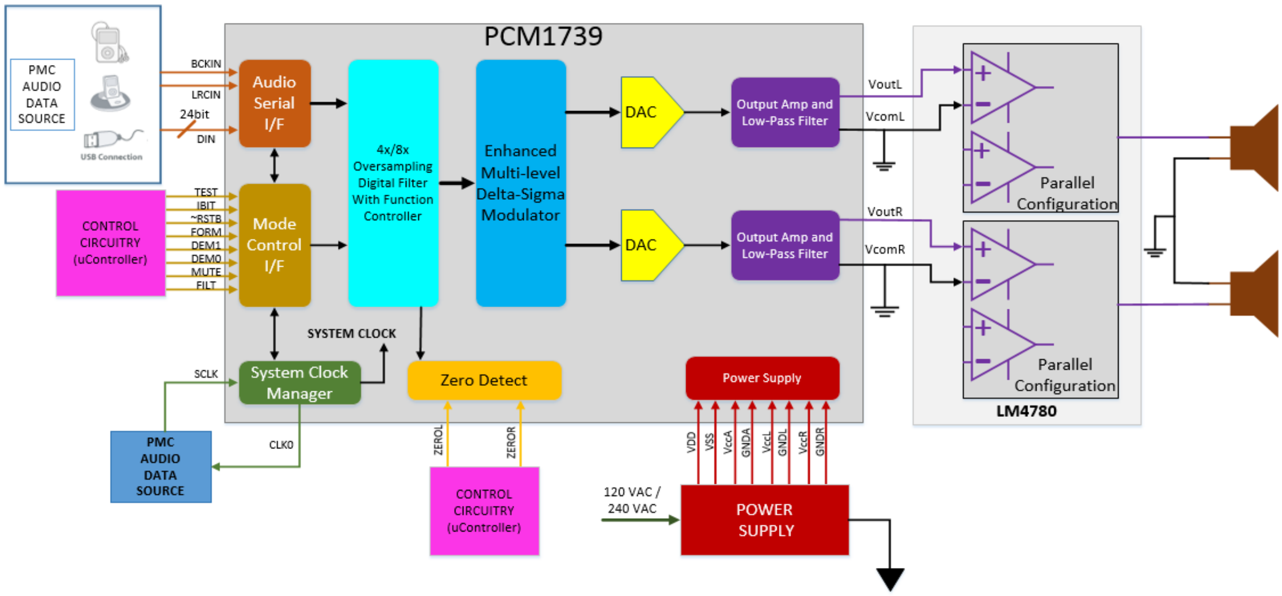



*Fig. 4 Diagrama propuesto basado en dispositivos comerciales*

Se decidió utilizar el circuito integrado PCM1739 para la etapa de conversión de la señal digital (DAC: Convertidor Digital-Analógico) basándonos en que cumple con los requerimientos tanto en su entrada como en su salida. Este dispositivo acepta los formatos de datos de audio más comunes en la industria de 16- o 24-bit de datos, provee una interfaz fácilmente integrable para dispositivos DSP de audio, así como circuitería de decodificación. Soporta velocidad de muestreo de hasta 192 kHz.

Para la etapa de amplificación, se decidió utilizar el dispositivo LM4780 el cual es un amplificador de audio estéreo capaz de entregar típicamente 60W por canal de potencia de salida promedio continua en una carga de 8Ω con menos de 0.5% THD + N (Total Harmonic Distortion plus Noise) de 20Hz-20KHz.

Por simplicidad, buen rendimiento y costo razonable, se propuso una fuente no regulada siendo el diseño más común para un amplificador de potencia de audio. La fuente no regulada consta de un transformador, un puente rectificador y varios capacitores.

### 1.2.4 Análisis de resultados

Como resultado de este proyecto obtuvimos una lista de materiales y el costo estimado del prototipo (véase Apéndice B Sección 4) basándonos en cada uno de los diseños sugeridos por el proveedor para cada etapa mostrada en el Diagrama a Bloques (Fig. 3).

Además, utilizando sitios de venta de componentes pudimos estimar el costo promedio de la lista de materiales requeridos para realizar una muestra de este.

### 1.2.5 Conclusiones

Como lo mencioné al principio, este proyecto abrió un panorama en el cual pude entender de qué manera grandes diseños comienzan con la idea, después se describen las etapas requeridas a alto nivel para obtener el resultado deseado; y como al ir bajando el nivel de detalle, existen herramientas que nos ayudan a no comenzar de cero, y poder enfocar los esfuerzos en el ajuste fino de aquellos circuitos que lo requieran.

El utilizar componentes de uso comercial, reduce el tiempo de diseño, así como el riesgo, ya que muchos de esos componentes han sido verificados por diversas empresas en diversos tipos de productos, en los cuales cualquier falla encontrada ha sido reportada y las mejoras al componente han sido efectuadas.

## 1.3. PROYECTO 3 - Sistema integral de riego con protección de bajo nivel en la reserva de agua

### 1.3.1 Introducción

Una de las materias que más disfruté fue la de Sistemas Operativos para ambientes Embebidos. Me pareció muy interesante cómo sistemas tan básicos en el mercado se pueden controlar con sistemas operativos que funcionan como sistemas de control, y el gran campo de acción que hay para implementación de tareas automatizadas.

### 1.3.2 Antecedentes

El problema que se planteó para el proyecto fue el de resolver lo siguiente: los sistemas de riego actuales son programables mediante un módulo con horas predeterminadas, este diseño resuelve en gran manera las necesidades de los agricultores, pero no toman en cuenta los factores ambientales, así como poder también apoyar en disminuir el consumo de agua.

La propuesta de este proyecto fue diseñar e implementar un sistema integral de riego con protección de bajo nivel en la reserva de agua, así como contar con un modo adaptativo en función de la temperatura, todo esto enfocado en ahorro de agua en lugares donde es requerido rellenar los depósitos, por ejemplo, zonas rurales donde no existe llega el servicio de agua por tuberías.

### 1.3.3 Solución Desarrollada

Para resolver el problema planteado en la introducción, se dividió el proyecto en los siguientes módulos (Fig. 5):

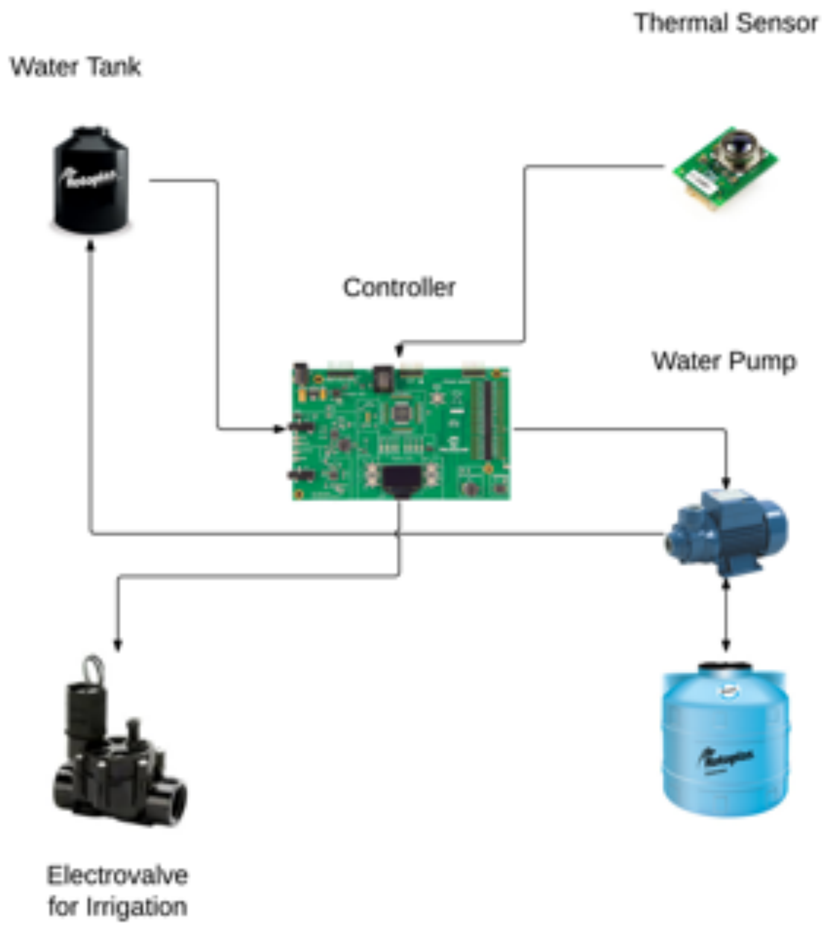



*Fig. 5 Diagrama a Bloques del Sistema de Riego*

El microprocesador central lleva el control mediante el uso de un sistema operativo para sistemas embebidos. En esta ocasión se utilizó el sistema operativo picOS, y la implementación se llevó a cabo en el DemoBoard con un PIC18lf46k22.

Se planteó utilizar un sensor de temperatura el cual nos estará reportando la temperatura ambiental en la que el sistema está trabajando. La razón de tener este control es que, en caso de temperaturas altas, se deberá restringir el riego, ya que pondría en riesgo las plantas que se desean regar. El sistema detecta que la señal de inicio de riego se activó, pero al sensar que la temperatura es alta, esperará un mejor momento para proceder con el riego.

Por otro lado, se planteó tener un control para la activación de la bomba que transporta el agua desde una cisterna hacia el tinaco. El nivel de la cisterna se monitorea continuamente. Al llegar al 30% de su nivel mínimo, el sistema deberá entrar en bajo consumo de agua. Esta tarea tiene mayor prioridad que las señales de inicio del riego, así como de la activación de la bomba, donde, en modo de bajo consumo de agua, no deberá encenderse para llenar el tinaco.

El nivel del agua del tinaco es también monitoreado, tanto en su nivel máximo como mínimo; con el máximo desactivaremos la bomba para no sobre llenarle, y en su nivel mínimo, encenderemos la bomba para comenzar el llenado.

Finalmente tenemos el control de las válvulas, con lo cual controlaremos el encendido y apagado del riego, ya sea en modo manual, como automático.

### 1.3.4 Análisis de resultados

Con el sistema implementado, se mejora el uso del agua, así como la efectividad en el riego. Al no permitir que el sistema de riego inicie cuando existe alta temperatura, se minimiza el riesgo de dañar la siembra, así como el desperdiciar el agua por no tener mayor beneficio.

El sistema de detección de bajo nivel en la cisterna nos ayuda a alertar al usuario, sin quedar sin suministro de agua. Tendrá suficiente agua para uso común durante el tiempo en el que se solicita el llenado por medio de una pipa, optimizando el uso de la reserva.

Al no permitir el consumo completo de la reserva de agua, también se protege a las tuberías de agua de introducir aire, el cual podría disminuir la presión en la misma.

### 1.3.5 Conclusiones

Excelente experiencia la que obtuve con este proyecto, que me permitió obtener tanto el conocimiento de cómo desarrollar un sistema operativo desde sus fundamentos, hasta crear un sistema de monitoreo y control que tiene el potencial de ser reutilizado en diversas aplicaciones. Disfrute del desarrollo de cada capa del diseño basado en sistema operativo, y me ayudó a entender y reconocer cómo cada sistema, por más simple, tiene tareas básicas que realizar en tiempos determinados y que deben ser monitoreados para asegurar su correcto funcionamiento.

# 2. Conclusiones

Este documento muestra algunas de las tantas cosas aprendidas durante el tiempo en el que curse la Maestría.

La Maestría me ayudo a reafirmar conocimiento adquirido durante la Ingeniería, a ir mas a detalle en algunas otras materias, pero principalmente a adquirir mayor conocimiento en áreas de la Electrónica que no había tenido la oportunidad de explorar.

Como lo describí durante el desarrollo de este documento, la Maestría en Diseño Electrónico abrió nuevos horizontes con los cuales se abrieron nuevas oportunidades, que me llevaron a desarrollar nuevas habilidades permitiéndome cambiar de Industria, del diseño de semiconductores a la Industria Automotriz.

La Maestría me ha permitido desarrollarme de forma satisfactoria en el área de Diseño y Desarrollo de Sistemas, Ingeniería de Sistemas, Gerencia Técnica de Proyectos, así como la interacción con cliente final.

Me parece que el programa, la oferta de asignaturas y los Profesores que impartieron cada una de las materias que curse fueron excelentes.

Quedo agradecido por el conocimiento adquirido y por las oportunidades que este me ha dado.

# 3. Apéndices

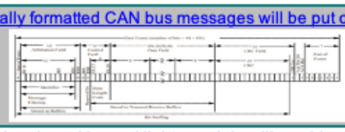
# A. Luces Direccionales y Luces Intermitentes

## 1. Requerimientos del Cliente

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project Name** | | Directionals and Hazard Flashers | | | | | | | | | | | |
| **Students:** | | Francisco Mendez Alatorre<br>Adriana Galindo Vergara<br>Luis Jose Rincon Castelo | | | | | | | | | | | **Extra requirement traceability information Comments and deviations** |
| | | | **Necesary** | **Unambiguous** | **Feasible** | **Implementation free** | **Complete** | **Concise** | **Consistent** | **Maintainable** | **Traceable to origin** | **Verifiable** | |
| **DOORS Id** | **Section** | **Requirements** | | | | | | | | | | | **Comments 1** |
| UC_01 | Use Case | Direction Blinking Left: When moving the lever in position "turn left" the vehicle flashes all left direction indicators (front left, exterior mirror left, rear left) synchronically with pulse ratio bright to dark 1:1. | x | x | x | x | x | x | x | x | x | x | |
| UC_02 | Use Case | Tip-Blinking Left: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking left", all left direction indicators should flash for three flashing cycles. | x | x | x | x | x | x | x | x | x | x | |
| UC_03 | Use Case | If the driver holds the lever for more than 0.5 seconds in position "tip-blinking right", flashing cycles are released for all direction indicators on the right until the lever leaves the position "tip-blinking right". | x | x | x | x | x | x | x | x | x | x | |
| UC_04 | Use Case | Direction Blinking Right: When moving the lever in position "turn right" the vehicle flashes all right direction indicators (front right, exterior mirror right, rear right) synchronically with pulse ratio bright to dark 1:1. | x | x | x | x | x | x | x | x | x | x | |
| UC_05 | Use Case | Hazard Warning Light: As long as the hazard warning light switch is released, all direction indicators flash synchronically. | x | x | x | x | x | x | x | x | x | x | |

## 2. Requerimientos del Sistema

| DOORS Id | Section | Requirements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Software | | | | | | | | | | |
| SW_01 | Requirement | Direction Blinking Left: When moving the lever in position "turn left" the vehicle flashes all left direction indicators (front left, exterior mirror left, rear left) synchronically with pulse ratio bright to dark 1:1. | X | X | X | X | X | X | X | X | X | X |
| SW_02 | Requirement | The maximum deviation of the pulse ratio should be below the cognitive threshold of a human observer. | X | X | X | X | X | X | X | X | X | X |
| SW_03 | Requirement | A deviation of the pulse ratio with less than 0.5% is accepted as cognitive threshold of a human observer. | X | X | X | X | X | X | X | X | X | X |
| SW_04 | Requirement | The reaction time between the activation of the lever and the beginning of the first flashing cycle should be below the cognitive threshold of a human observer. | X | X | X | X | X | X | X | X | X | X |
| SW_05 | Requirement | A deviation of less than 0.05s is accepted as cognitive threshold of a human observer. | X | X | X | X | X | X | X | X | X | X |
| SW_06 | Requirement | Tip-Blinking Left: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking left", all left direction indicators (see UC_01) should flash for three flashing cycles. | X | X | X | X | X | X | X | X | X | X |
| SW_07 | Requirement | If the driver activates the lever in another direction or activates the hazard warning light switch during the three flashing cycles of the tip-blinking, the tip-blinking cycle must be stopped and the requested flashing cycle must be released (direction of turn Signal, tipblinking, hazard warning light) | X | X | X | X | X | X | X | X | X | X |
| SW_08 | Requirement | If the driver holds the lever for more than 0.5 seconds in position "tip-blinking left", flashing cycles are released for all direction indicators on the left until the lever leaves the position "tip-blinking left". | X | X | X | X | X | X | X | X | X | X |
| SW_09 | Requirement | Direction blinking: Daytime running light must be dimmed by 50% during direction blinking on the blinking side. | X | X | X | X | X | X | X | X | X | X |
| SW_10 | Requirement | If the driver activates the lever during the three flashing cycles of tip-blinking again, only the current flashing cycle is completed. | X | X | X | X | X | X | X | X | X | X |
| SW_11 | Requirement | If the driver holds the lever for more than 0.5 seconds in position "tip-blinking right", flashing cycles are released for all direction indicators on the right until the lever leaves the position "tip-blinking right". | X | X | X | X | X | X | X | X | X | X |
| SW_12 | Requirement | Tip-Blinking Right: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking right", all right direction indicators should flash for three flashing cycles. | X | X | X | X | X | X | X | X | X | X |
| SW_13 | Requirement | Direction Blinking Right: When moving the lever in position "turn right" the vehicle flashes all right direction indicators (front right, exterior mirror right, rear right) synchronically with pulse ratio bright to dark 1:1. | X | X | X | X | X | X | X | X | X | X |
| SW_14 | Requirement | Hazard Warning Light: As long as the hazard warning light switch is released, all direction indicators flash synchronically. | X | X | X | X | X | X | X | X | X | X |
| SW_15 | Requirement | If the ignition key is in the ignition lock, the pulse ratio is bright to dark 1:1. | X | X | X | X | X | X | X | X | X | X |
| SW_16 | Requirement | If the ignition key is not in the lock, the pulse ratio is 1:2. | X | X | X | X | X | X | X | X | X | X |
| SW_17 | Requirement | The adaptation of the pulse ratio must occur at the latest after two complete flashing cycles. | X | X | X | X | X | X | X | X | X | X |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SW_18** | **Requirement** | The reduction of the pulse performed due to energy saving reasons, such that, in case of an emergency situation, the hazard warning light is active as long as possible before the car battery is empty. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_19** | **Requirement** | When hazard warning is deactivated and the lever is in position "direction blinking left" or "direction blinking right", the direction blinking cycle should be released. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_20** | **Requirement** | If tip-blinking was activated shortly before deactivation of the hazard warning, this is not considered during the deactivation of the hazard warning. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_21** | **Requirement** | The duration of a flashing cycle is 1 second. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_22** | **Requirement** | Also after 1000 flashing cycles the cumulated deviation must not exceed 0.05s. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_23** | **Requirement** | A flashing cycle (bright to dark) must always be completed, before a new flashing cycle can occur. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_24** | **CAN** | Data will be transmitted on a central CAN bus | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_25** | **CAN** | Messages will be read by a ECU connected to the bus. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_26** | **CAN** | Specially formatted CAN bus messages will be put on the bus  | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_27** | **CAN** | Turn signals and hazard lights module will use identification values of: Receive: 0x250, Transmit: 0x260 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **SW_28** | **CAN** | Checksums are contained within the 6th byte of each message | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SW_29 | CAN | If received checksum does not match calculated checksum, ignore the received data, and request a re-transmission of the message if it is not one that is periodically sent | X | X | X | X | X | X | X | X | X | X |
| SW_30 | CAN | The Instrument Cluster (also known as the CPU for this project) is required to interpret diagnostic error broadcasts and determine which errors need to be displayed to the driver | X | X | X | X | X | X | X | X | X | X |
| SW_31 | CAN | If an error is to be reported to the driver, the tell-tale light of malfunctioning module is lit up. | X | X | X | X | X | X | X | X | X | X |
| SW_32 | CAN | The driver may clear the messages on the message center by pushing a reset button. It will not affect the tell-tale lights, which may only be turned off by a technician or as a result of the problem no longer being detected | X | X | X | X | X | X | X | X | X | X |
| SW_33 | CAN | Off lever position CAN message Id shall be 5CD27AF76 | X | X | X | X | X | X | X | X | X | X |
| SW_34 | CAN | Tip Blinking lever position CAN message Id shall be 5CD27AF77 | X | X | X | X | X | X | X | X | X | X |
| SW_35 | CAN | Turn Left lever position CAN message Id shall be 5CD27AF78 | X | X | X | X | X | X | X | X | X | X |
| SW_36 | CAN | Tip Blinking right lever position CAN message Id shall be 5CD27AF79 | X | X | X | X | X | X | X | X | X | X |
| SW_37 | CAN | Turn Right lever position CAN message Id shall be 5CD27AF80 | X | X | X | X | X | X | X | X | X | X |
| SW_38 | CAN | Hazard lever position CAN message Id shall be 5CD27AF81 | X | X | X | X | X | X | X | X | X | X |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SW_39 | CAN | Hazard lights shall have priorito over turn signals | X | X | X | X | X | X | X | X | X | X |
| SW_40 | CAN | Left Front Lamp CAN message Id shall be 5CD27AF82 | X | X | X | X | X | X | X | X | X | X |
| SW_41 | CAN | Right Front Lamp CAN message Id shall be 5CD27AF83 | X | X | X | X | X | X | X | X | X | X |
| SW_42 | CAN | Left Rear Lamp CAN message Id shall be 5CD27AF84 | X | X | X | X | X | X | X | X | X | X |
| SW_43 | CAN | Right Rear Lamp CAN message Id shall be 5CD27AF85 | X | X | X | X | X | X | X | X | X | X |
| SW_43 | CAN | Right Rear Lamp CAN message Id shall be 5CD27AF85 | X | X | X | X | X | X | X | X | X | X |
| SW_44 | CAN | Driver shall follow the process flow SWD_04 | X | X | X | X | X | X | X | X | X | X |
| SW_45 | CAN | Driver shall comply with the following truth table | X | X | X | X | X | X | X | X | X | X |

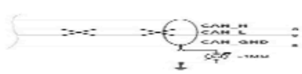
| Inputs | | | | | | Outputs | | | |
|---|---|---|---|---|---|---|---|---|---|
| Turn right | Flash right | Off | Flash left | Turn left | Hazard | LF | RF | LR | RR |
| X | X | X | X | X | 1 | ON | ON | ON | ON |
| 1 | 0 | 0 | 0 | 0 | 0 | OFF | ON | OFF | ON |
| 0 | 1 | 0 | 0 | 0 | 0 | OFF | ON | OFF | ON |
| 0 | 0 | 1 | 0 | 0 | 0 | OFF | OFF | OFF | OFF |
| 0 | 0 | 0 | 1 | 0 | 0 | ON | OFF | ON | OFF |
| 0 | 0 | 0 | 0 | 1 | 0 | ON | OFF | ON | OFF |

***Hardware***

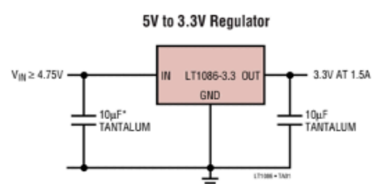
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EE_01 | Thermal | System shall work on temperature range around -40C to 125C | X | X | X | X | X | X | X | X | X | X |
| EE_02 | CAN | Bit rate to use shall be 1Mbit/s calculating a wire length of 40m according to the table below | X | X | X | X | X | X | X | X | X | X |

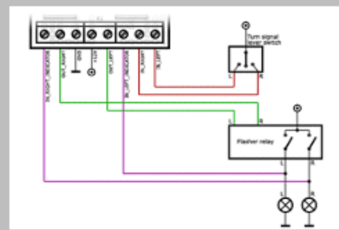
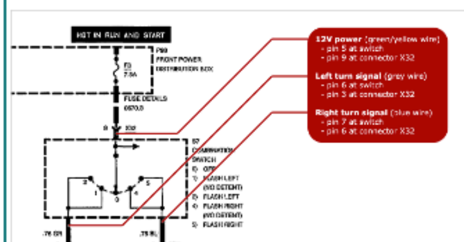
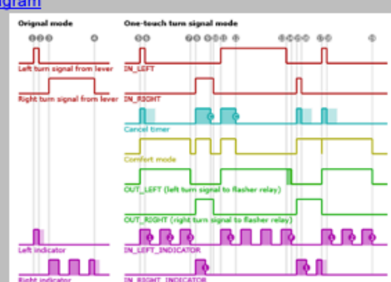
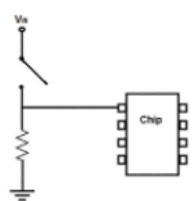
| | |
|---|---|
| 1 Mbit/s | 40 m |
| 500 kbit/s | 110 m |
| 250 kbit/s | 240 m |
| 125 kbit/s | 500 m |
| 50 kbit/s | 1.3 km |
| 20 kbit/s | 3.3 km |
| 10 kbit/s | 6.6 km |
| 5 kbit/s | 130 km |

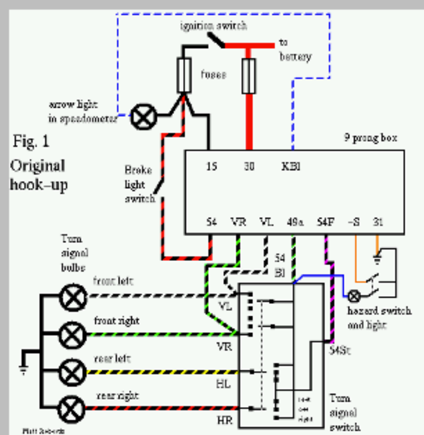
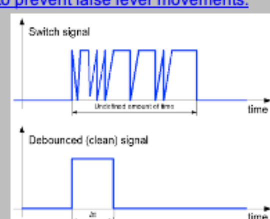
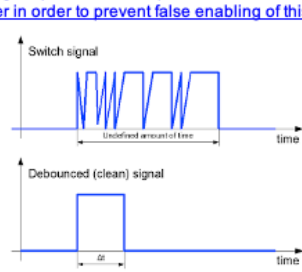
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EE_03 | CAN | CAN Bus shall use single terminated twisted pair cable | X | X | X | X | X | X | X | X | X | X |

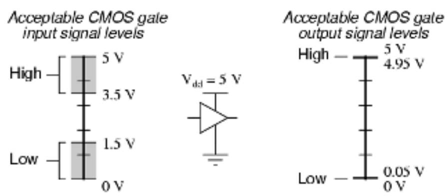
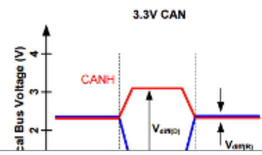


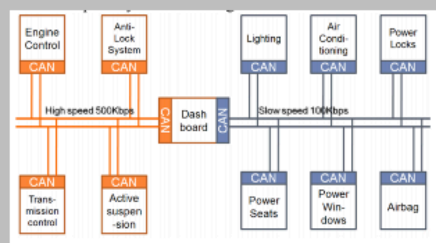

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EE_04 | CAN | Protocol to be use shall be CAN 2.0 for automotive applications | X | X | X | X | X | X | X | X | X | X |

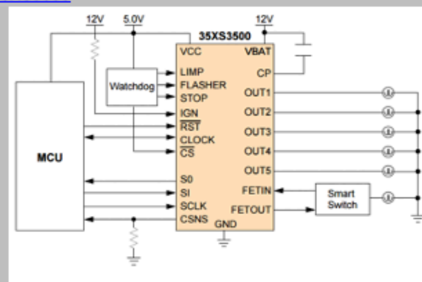
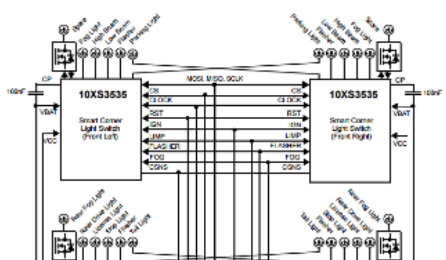
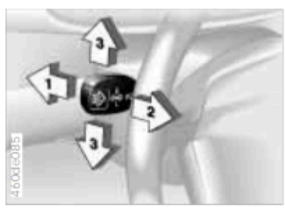
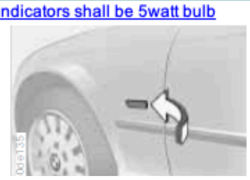
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EE_05** | **Fuse** | The fuse should be locate in the fuse box and has a table in order to know where is located the wiper fuse.<br> | x | x | x | x | x | x | x | x | x | x |
| **EE_06** | **ECU** | The UJA1078A core System Basis Chip (SBC) replaces the basic discrete components commonly found in Electronic Control Units (ECU) with a high-speed Controller Area Network (CAN) and two Local Interconnect Network (LIN) interfaces<br> | x | x | x | x | x | x | x | x | x | x |
| **EE_07** | **Power Supply** | System shall have a 12V power supply (battery)<br> | x | x | x | x | x | x | x | x | x | x |
| **EE_08** | **Power Supply** | System shall have a 5V regualtor to manage digital I/O pins<br> | x | x | x | x | x | x | x | x | x | x |
| **EE_09** | **Power Supply** | System shall have 3.3V regulator to source CAN tranceivers and MCU's.<br> | x | x | x | x | x | x | x | x | x | x |
| **EE_10** | **Power Supply** | Input voltage for 3.3V regualtor shall come from the 5V regulator | x | x | x | x | x | x | x | x | x | x |
| **EE_11** | **Power Supply** | Turn signals module shall not work with car's ignition off | x | x | x | x | x | x | x | x | x | x |
| **EE_12** | **Power Supply** | Turn signals module shall not be connected to permanent 12V | x | x | x | x | x | x | x | x | x | x |
| **EE_13** | **Power Supply** | Turn signals module shall be connected to switched 12V | x | x | x | x | x | x | x | x | x | x |

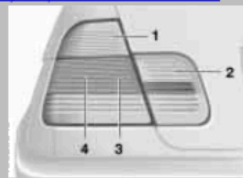
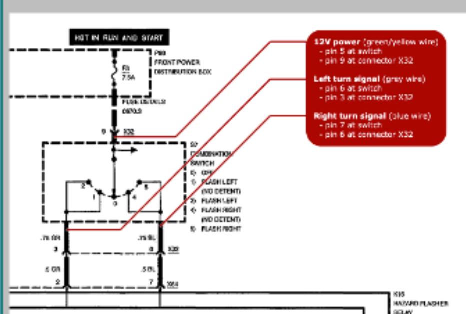
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EE_14** | **Wiring** | Turn signal indicators and hazard lights shall have the following wiring:<br> | X | X | X | X | X | X | X | X | X | X |
| **EE_15** | **Lever** | Turn signal lever's switch shall have 6 states, this is 5 poles 1 throw:<br><br>0) OFF position<br>1) Flash Left (No Detent -OTTS (One-Touch Turn Signal))<br>2) Flash Left<br>4) Flash Right (No Detent -OTTS (One-Touch Turn Signal))<br>5) Flash Right<br> | X | X | X | X | X | X | X | X | X | X |
| **EE_16** | **Lever** | One-Touch Turn Signal (OTTS) shall behave as deescribed in below diagram<br> | X | X | X | X | X | X | X | X | X | X |
| **EE_17** | **Lever** | Lever's switch positions shall be configured in pull-down configuraiton when closed<br> | X | X | X | X | X | X | X | X | X | X |

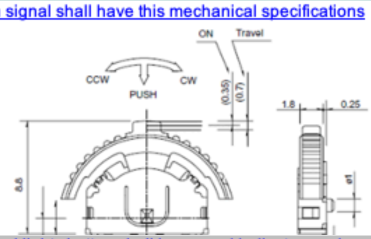
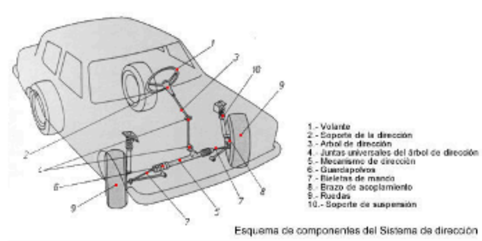
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EE_18** | **Lever** | Output from each lever's swithch shall be maximum 12V when closed  | X | X | X | X | X | X | X | X | X | X |
| **EE_19** | **Hazard Lights** | Hazard lights shall be enabled thru a push button  | X | X | X | X | X | X | X | X | X | X |
| **EE_20** | **Hazard Lights** | Pressing hazard light push button shall turn front and rear lights  | X | X | X | X | X | X | X | X | X | X |
| **EE_21** | **Power** | Output from hazard lights push buton shall be 12V when closed  | X | X | X | X | X | X | X | X | X | X |
| **EE_22** | **Debouncer** | Lever's switch outputs shall be connected to a debouncer or deglitcher in order to prevent false lever movements.  | X | X | X | X | X | X | X | X | X | X |
| **EE_23** | **Debouncer** | Hazard lights' push button output shall be connected to a debouncer or deglitcher in order to prevent false enabling of this signal.  | X | X | X | X | X | X | X | X | X | X |

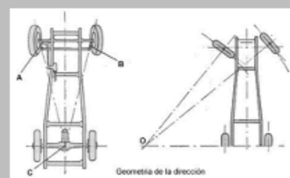
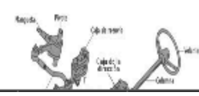
| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EE_24** | **Debouncer** | Debouncer shall support 12V inputs for each switch coming from the Lever or hazard lights | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **EE_25** | **Power** | Debouncer shall support CMOS output signal level specifications   | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **EE_26** | **Debouncer** | Debouncer digital outputs shall connect to CAN module for input post-processing | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **EE_27** | **CAN** | CAN Bus shall work at 3.3V   | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EE_28 | ECU | ECU shall support CAN Bus working at 3.3V | X | X | X | X | X | X | X | X | X | X |
| EE_29 | ECU | ECU GPIO's shall support CMOS signal levels | X | X | X | X | X | X | X | X | X | X |
| EE_30 | CAN | ECU shall interact with lever switch as well as with the whole system thru CAN protocol, as shown by below diagram   | X | X | X | X | X | X | X | X | X | X |
| EE_31 | ECU | ECU shall keep updated power stage on any update from lever or hazard lights | X | X | X | X | X | X | X | X | X | X |
| EE_32 | ECU | ECU shall support 16-bit SPI communication protocol | X | X | X | X | X | X | X | X | X | X |
| EE_33 | ECU | ECU shall communicate to Power Stage thru 16-bit SPI | X | X | X | X | X | X | X | X | X | X |
| EE_34 | Power Stage | Power stage shall support 16-bit SPI communication protocol | X | X | X | X | X | X | X | X | X | X |
| EE_35 | Power Stage | Power stage inputs shall be CMOS signal level compliant | X | X | X | X | X | X | X | X | X | X |
| EE_36 | Power Stage | Power stage shall feedback on status of lighting system | X | X | X | X | X | X | X | X | X | X |
| EE_37 | Power Stage | Power Stage shall implement a high side driver per light | X | X | X | X | X | X | X | X | X | X |

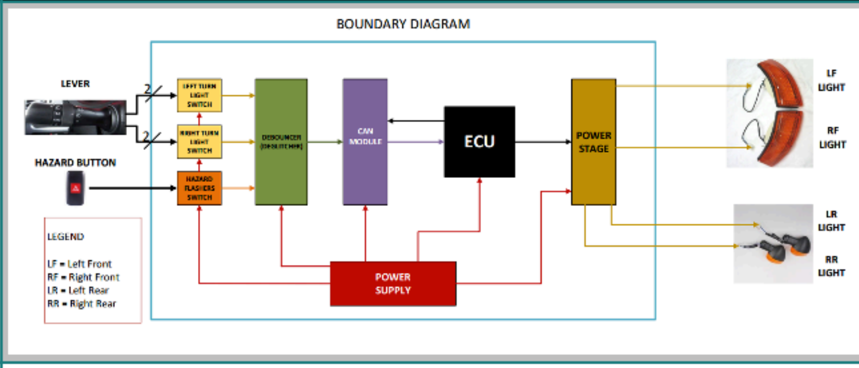
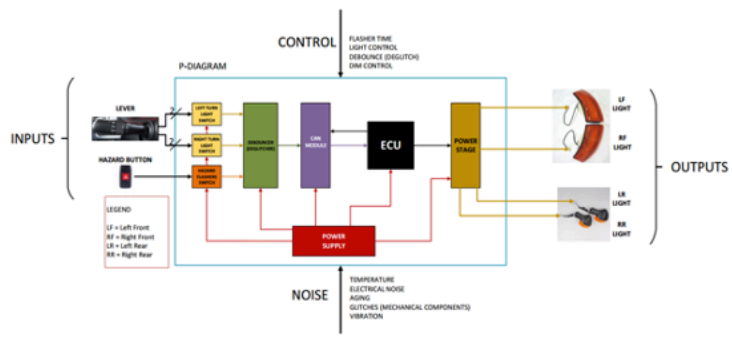
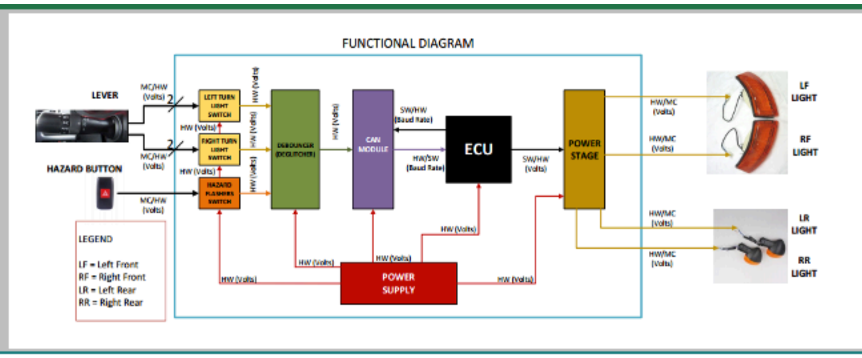
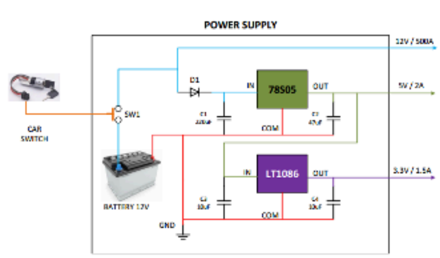
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EE_38** | **Power Stage** | Power Stage high side drivers shall be implemented using chip 35XS3500<br> | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **EE_39** | **Power Stage** | Power Stage full implementation shall replicate below application:<br> | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| | | ***Mechanical*** | | | | | | | | | | |
| **MC_01** | | Turn signal lever shall have 4 degrees of freedom<br> | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **MC_02** | | Front turn signal indicators shall be 21watt bulb<br> | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **MC_03** | | Side turn indicators shall be 5watt bulb<br> | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

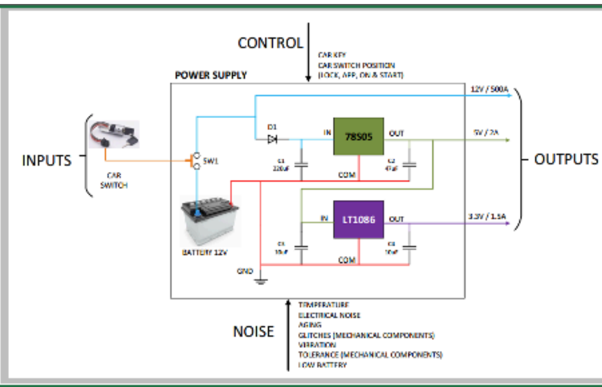
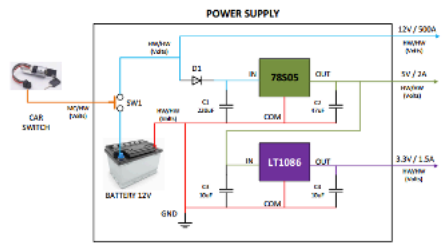
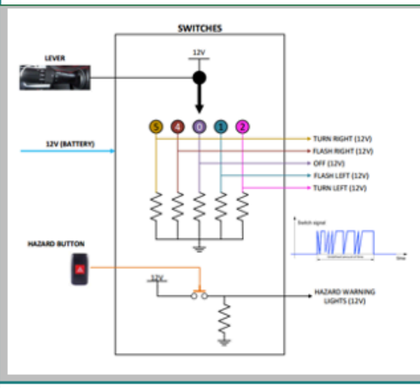
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MC_04** | | Tail (rear) lamps shall be 21watt bulb   | X | X | X | X | X | X | X | X | X | X |
| **MC_05** | | Turn signal indicators shall be yellow color | X | X | X | X | X | X | X | X | X | X |
| **MC_06** | | Turn signal indicator shall flash when the turn signal indicator is actuated  | X | X | X | X | X | X | X | X | X | X |
| **MC_07** | | The turn signal function takes no precedence over the hazard warning flashers function. | X | X | X | X | X | X | X | X | X | X |
| **MC_08** | | Turn signal lever shall have 6 states, this is 6 poles 1 throw:<br><br>0) OFF position<br>1) Flash Left (No Detent -OTTS (One-Touch Turn Signal))<br>2) Flash Left<br>4) Flash Right (No Detent -OTTS (One-Touch Turn Signal))<br>5) Flash Right<br>  | X | X | X | X | X | X | X | X | X | X |
| **MC_09** | | Pressing the lever up to but not beyond the detent shall signal right turn signal briefly | X | X | X | X | X | X | X | X | X | X |
| | | Pressing the lever down to but not beyond the detent shall signal left turn signal briefly | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MC_11** | | Pulling lever CW (Clock Wise) shall turn on all right turn signals<br> | X | X | X | X | X | X | X | X | X | X |
| **MC_12** | | Pulling level CCW (Counter Clock Wise) shall turn on all left turn<br> | X | X | X | X | X | X | X | X | X | X |
| **MC_13** | | Turn signal shall have this mechanical specifications<br> | X | X | X | X | X | X | X | X | X | X |
| **MC_14** | | Hazard lights button shall havea red indicator as shown in below image:<br> | X | X | X | X | X | X | X | X | X | X |
| **MC_15** | **System Directional** | They have the task of guiding the front wheels so that the vehicle's intended path taken by the driver. So the driver does not have to make efforts in the direction of the wheel (these wheels are called "guidelines"), the vehicle has a servo assistance (in today's vehicles).<br> | X | X | X | X | X | X | X | X | X | X |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MC_16** | | As the paths to cover on the steering wheels are different in a curve (the outside wheel must travel a longer way to be larger turning radius, as shown in the figure below), the orientation to be given to each also different (outer should open more), and both follow the desired path, provided that all the wheels of the vehicle, at any point in its orientation, follow curved paths of a center O (concentric) should be met, located in the extension of the axis of the rear wheels. To achieve the coupling arms A and B send the orientation of the wheels, so that in the position in a straight line, their extensions intersect at the center C of the rear or close to this bridge are arranged.   | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **MC_17** | | The steering system for front wheel independent suspension: When an independent suspension for each front wheel, as the separation between these varies slightly to save the irregularities of the road, a steering system that is not affected by these changes and leave the steering wheel always in need position. The gear (ASE is transversely move the arm (R) which controls the coupling, in turn supported by the swing lever (O) in the joint (F) on the frame.   | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

# 3. Arquitectura del Sistema

| DOORS Id | Section | Diagram |
|---|---|---|
| DG_01 | System Boundary Diagram |  |
| DG_02 | System P-Diagram |  |
| DG_03 | Funtional Diagram |  |
| DG_04 | Power Supply Boundary Diagram |  |

<table>
<tr><td>DG_05</td><td>Power Supply P-Diagram</td><td>
</td></tr>
<tr><td>DG_06</td><td>Power Supply Functional Diagram</td><td>
</td></tr>
<tr><td>DG_07</td><td>Switches Boundary Diagram</td><td>
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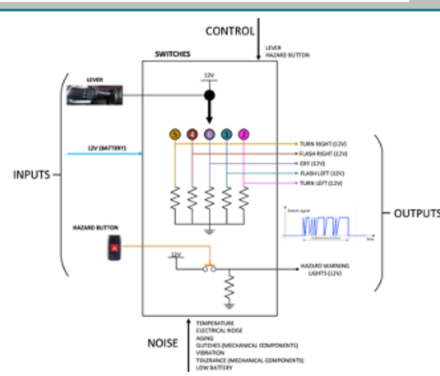
<tr><td>DG_08</td><td>Switches P-Diagram</td><td>
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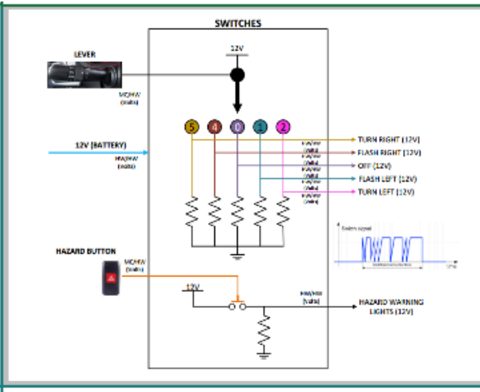
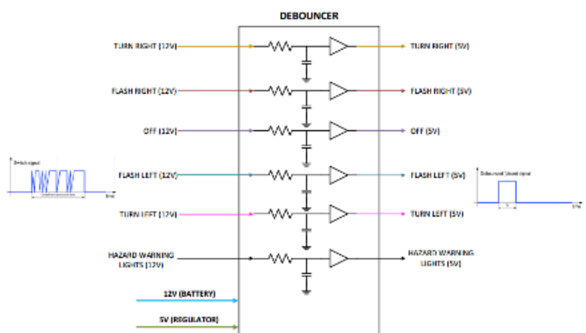
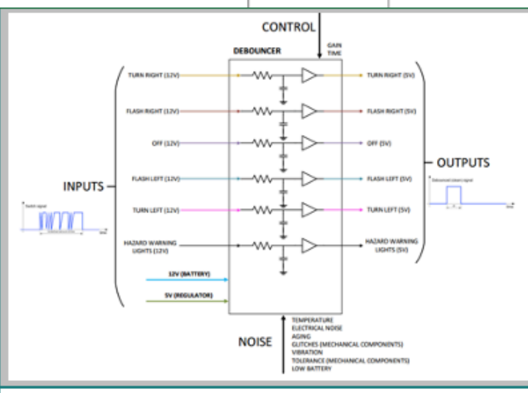
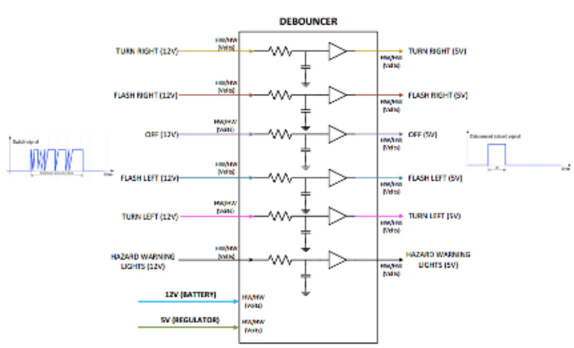
|---|---|---|
| DG_09 | Switches Fucntional Diagram |  |
| DG_10 | Debouncer Boundary Diagram |  |
| DG_11 | Debouncer P-Diagram |  |
| DG_12 | Debouncer Functional Diagram |  |

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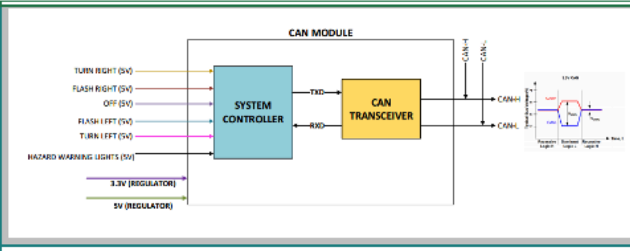
<tr><td>DG_13</td><td>CAN Module Boundary Diagram</td><td>
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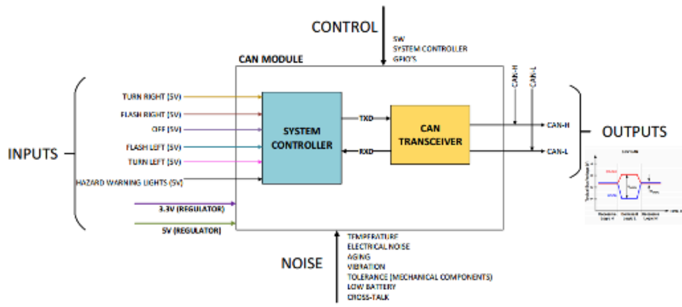
<tr><td>DG_14</td><td>CAN Module P-Diagram</td><td>
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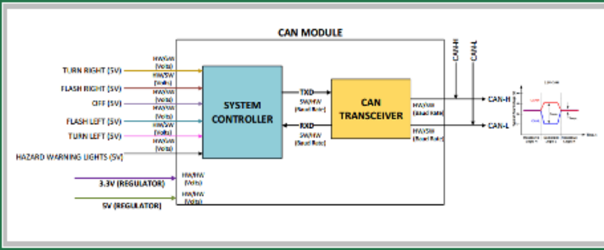
<tr><td>DG_15</td><td>CAN Module Functional Diagram</td><td>
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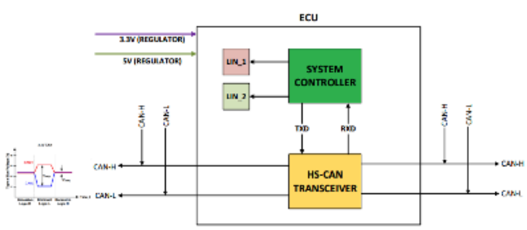
<tr><td>DG_16</td><td>ECU Boundary Diagram</td><td>
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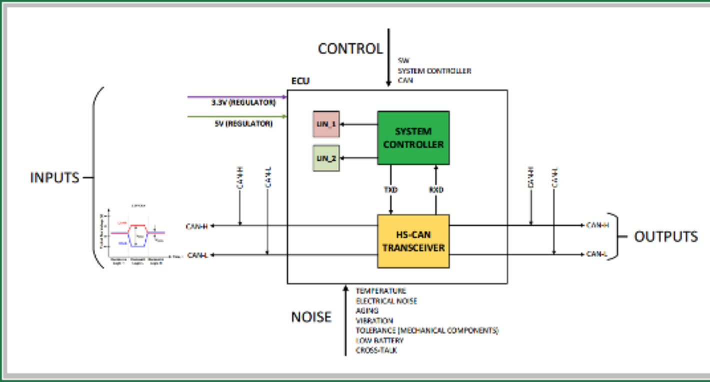
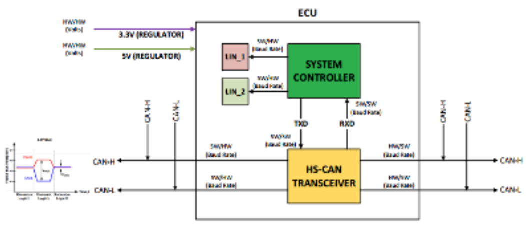
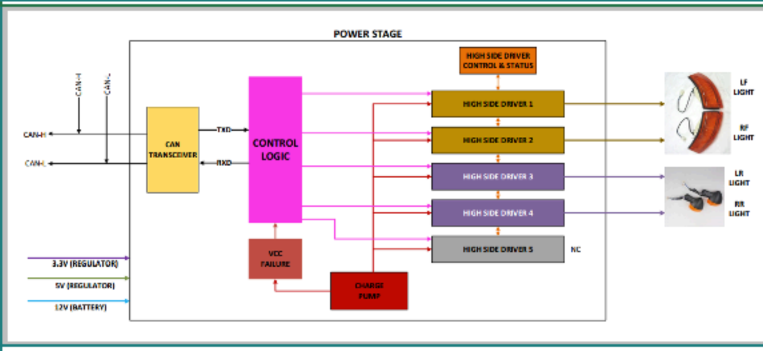
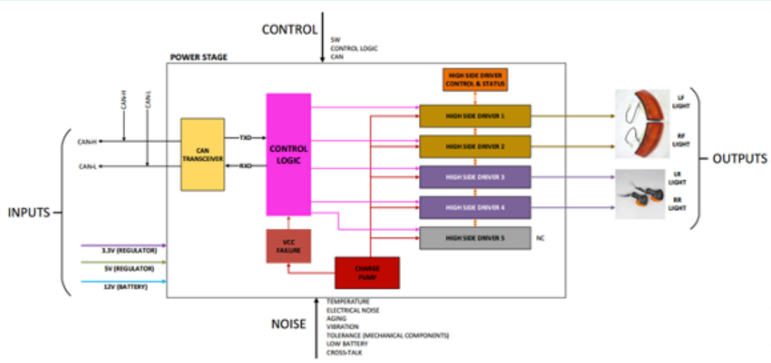
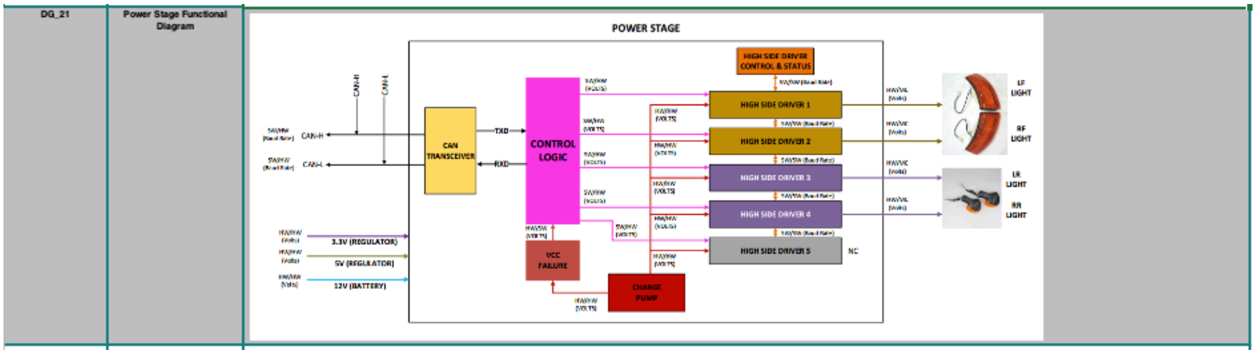
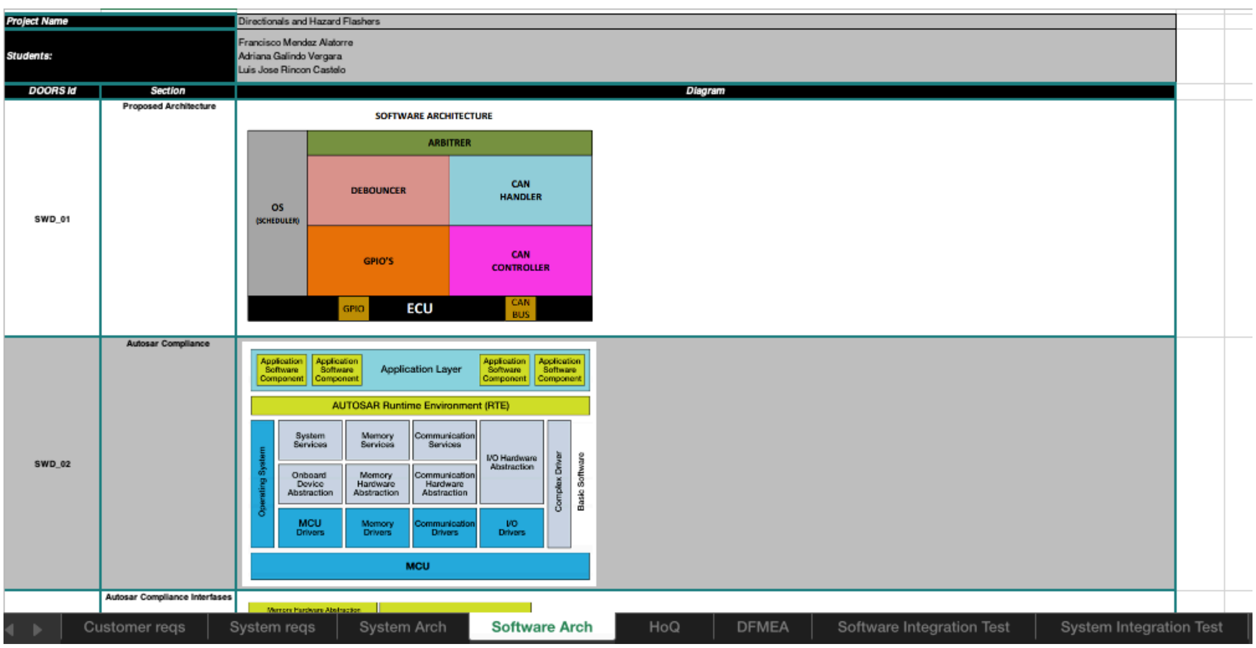
|---|---|---|
| DG_17 | ECU P-Diagram |  |
| DG_18 | ECU Functional Diagram |  |
| DG_19 | Power Stage Bouundary Diagram |  |
| DG_20 | Power Stage P-Diagram |  |




# 4. Arquitectura del Software



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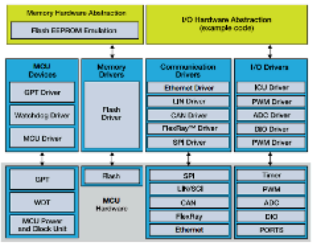
|---|---|---|
| SWD_03 | **Autosar Compliance Interfases** |  |
| SWD_04 | **Process Flow Diagram** |  |

# 5. Diseño de análisis de modos de fallas y efectos

**FAILURE MODE AND EFFECTS ANALYSIS**

| | | | |
|---|---|---|---|
| Item: | Directionals and Hazard Flashers | Responsibility: | Francisco Mendez ,Adriana Galindo, Luis Rincon |
| Model: | 1 | Prepared by: | Francisco Mendez ,Adriana Galindo, Luis Rincon |
| Core Team: | | | |

| Process Function (What is the process step/output?) | Potential Failure Mode (What can go wrong with the process step/output? | Potential Effect(s) of Failure (What is the impact on the customer (output variables) or internal requirements?) | Sev | Potential Cause(s)/ Mechanism(s) of Failure (What are the root cause reasons for the process step/input to go wrong? These are the x's) | Occur | Current Process Controls (What are the existing controls that prevent or detect either the cause or the FM prior to leaving the process step? ) | Detec | RPN | Recommended Action(s) (What are the actions for reducing the OCC. Of the cause or improving DET?) |
|---|---|---|---|---|---|---|---|---|---|
| Lever | Lever's switch open for OFF position | No active signal is present leading to tell-tale signaling | 5 | Switch is damaged or has an unsoldered terminal | 2 | lever encoding is one-hot topology thus easy to detect when all Lever's swithces are open (this is 0V) | 1 | 10 | heavy duty Lever switches |
| Lever | Lever's switch open for Turn Left position | No active signal is present leading to not LF & LR ligths turning on | 5 | Switch is damaged or has an unsoldered terminal | 2 | lever encoding is one-hot topology thus easy to detect when all Lever's swithces are open (this is 0V) | 1 | 10 | heavy duty Lever switches |
| Lever | Lever's switch open for Flash Left position | No active signal is present leading to not LF & LR ligths turning on | 5 | Switch is damaged or has an unsoldered terminal | 2 | lever encoding is one-hot topology thus easy to detect when all Lever's swithces are open (this is 0V) | 1 | 10 | heavy duty Lever switches |
| Lever | Lever's switch open for Flash Right position | No active signal is present leading to not RF & RR ligths turning on | 5 | Switch is damaged or has an unsoldered terminal | 2 | lever encoding is one-hot topology thus easy to detect when all Lever's swithces are open (this is 0V) | 1 | 10 | heavy duty Lever switches |
| Lever | Lever's switch open for Turn Right position | No active signal is present leading to not RF & RR ligths turning on | 5 | Switch is damaged or has an unsoldered terminal | 2 | lever encoding is one-hot topology thus easy to detect when all Lever's swithces are open (this is 0V) | 1 | 10 | heavy duty Lever switches |
| Lever | Wheeldrive does not release lever from Turn Left position | LF & LR lights remain ON after turn left action | 5 | Wheeldrive's Lever release mechanism is broken | 2 | User must return lever manually to OFF position | 4 | 40 | Implement fault detection message to car's CPU |
| Lever | Wheeldrive does not release lever from Turn Reft position | RF & RR lights remain ON after turn right action | 5 | Wheeldrive's Lever release mechanism is broken | 2 | User must return lever manually to OFF position | 4 | 40 | Implement fault detection message to car's CPU |
| Hazard Light Push button | Hazard Light push button open when pressed | Hazard lights won't turn on | 5 | Push button is damaged, one of the terminals is unsoldered or faulty contact | 2 | visual detection fo the failure, no fault control implemented for this failure. | 1 | 10 | Replace item |
| Hazard Light Push button | Hazard light push button remains closed after release action | Hazard lights will remain ON even after releaseing the signal | 5 | Push button in shortcut or stuck due to mechanical failure or sutck due to enviromental debree. | 2 | visual detection fo the failure, no fault control implemented for this failure. | 1 | 10 | Replace item |
| Debouncer | False detect of hazard ligths push button or lever's switches in ON position | LF, LR, RF & RR lights being turned ON when all switches are in OFF position | 5 | discrete and/or active electronic components are damaged. Circuit is broken. Debounce time is to short | 1 | Debounce time control by SW. Read input pins from system controller | 7 | 35 | Use passive/active electronic components compliant with automotive requirements and ranges |
| Debouncer | NO detecttion of hazard ligths push button or lever's switches in ON position | LF, LR, RF & RR lights will remain off when directed to be ON by user. | 5 | discrete and/or active electronic components are damaged. Circuit is broken. Debounce time os too large | 1 | Debounce time control by SW. Read input pins from system controller | 7 | 35 | Use passive/active electronic components compliant with automotive requirements and ranges |
| Power Supply | Battery si dead - 0V | Car ignition, accessories and other components will not work | 8 | shortcut in battery | 8 | Shortcut detection implemented | 1 | 64 | Warn user when low battery or battery in shorcut thru a tell-tale alert. |
| Power Supply | 0V when car's ignition switch is in ACC | Components sourced by battery on ACC are not functional | 8 | car's ignition switch is open, damaged. | 2 | None | 4 | 64 | Replace battery or ignition switch |
| Power Supply | Battery voltage is less than 12V | Components sourced y 12V may not work or malfunction | 8 | Old battery, low maintenance | 7 | Tell-tale signal thru check-engine symbol | 2 | 112 | Indicator for low battery |
| Power Supply | 5V power supply is off | electronics components such as uController/Transceivers might not work | 9 | 5V voltage regulator is damaged or burned due to high current. | 2 | None | 6 | 108 | Expert inspection and debug |
| Power Supply | 5V power supply is off | electronics components such as uController/Transceivers might not work | 9 | Input voltage to 5V voltage regulator is below specs | 7 | Tell-tale signal thru check-engine symbol | 2 | 126 | Indicator for low battery |
| Power Supply | 3.3V power supply is off | electronics components such as uController/Transceivers might not work | 9 | 3.3V voltage regulator is damaged or burned due to high current. | 2 | None | 6 | 108 | Expert inspection and debug |
| Power Supply | 3.3v power supply is off | electronics components such as uController/Transceivers might not work | 9 | Input voltage to 3.3V voltage regulator is below 4.5V | 7 | Tell-tale signal thru check-engine symbol | 2 | 126 | Indicator for low battery |
| Microcontroller | No input signal detected | Bad reporting of current state of Lever/Hazard Lights | 9 | Input votage level below acceptable CMOS threshold for HIGH level | 1 | JTAG access to microntroller for debug | 10 | 90 | Implement debug access to all microcontrollers. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Microcontroller | No input signal detected | Bad reporting of current state of Lever/Hazard Lights | 10 | broken path between microcontroller pin input signal | 1 | Visual inspection | 10 | 100 | Visual inspection and expert support |
| Microcontroller | Incomplete task. | Bad reporting or not reporting at all of current status of Lever/Hazard Lights | 9 | Watchdog Timer Reset due to code stuck at some point | 2 | JTAG access to microntroller for debug | 10 | 180 | Implement debug access to all microcontrollers. |
| Microcontroller | Incomplete task. | Bad reporting or not reporting at all of current status of Lever/Hazard Lights | 9 | Thermal Catastorphic Event | 4 | JTAG access to microntroller for debug | 8 | 288 | Implement debug access to all microcontrollers. |
| Microcontroller | Incomplete task. | Bad reporting or not reporting at all of current status of Lever/Hazard Lights | 9 | Frequency operation spread sue to thermal event | 2 | JTAG access to microntroller for debug | 10 | 180 | Implement debug access to all microcontrollers. |
| Microcontroller | Incomplete task. | Bad reporting or not reporting at all of current status of Lever/Hazard Lights | 9 | Frequency of operation deviated affecting Master CLK, hence serial communication is affected (SPI) | 2 | JTAG access to microntroller for debug | 10 | 180 | Implement debug access to all microcontrollers. |
| CAN Transceiver | Frame errors | Incomplete message or message with wrong data | 9 | Bad layout, crass-talk | 3 | OBDII bus access for sniffering transactions | 4 | 108 | Need layout expert to avoid cross-talk interference as much as possible and implement according to spec. |
| CAN Transceiver | Clock Frequency out of parameters | Incomplete message or message with wrong data | 9 | Temperature or bad choice of passive components | 2 | OBDII bus access for sniffering transactions | 4 | 72 | Need layout expert to avoid cross-talk interference as much as possible and implement according to spec. |
| CAN Transceiver | Inverted data | CAN-H and CAN-L signals connected in inverted way to the CAN bus | 9 | Wrong layout interconection. | 1 | OBDII bus access for sniffering transactions | 10 | 90 | Need layout expert to avoid cross-talk interference as much as possible and implement according to spec. |
| CAN Transceiver | No communication between CAN modules | Incomplete message or message with wrong data | 9 | Bad selection of CAN modules, this is, CAN version incompatibility | 1 | OBDII bus access for sniffering transactions | 10 | 90 | Need expert designer and SW Engineer. |
| High Side Driver | Open Load Detection | No lighting for the specific High Side Driver reporting this flag. | 6 | Bulb aging, Overcurrent, Broken Bulb | 5 | Open Load Detection, Overcurrent Detection, Overtemperature status messages from power stage to ECU | 1 | 30 | Analyze car's scanning system. |
| High Side Driver | Overcurrent Detection | No lighting for the specific High Side Driver reporting this flag. | 6 | Load Dump not properly handled at car ignition. | 5 | Open Load Detection, Overcurrent Detection, Overtemperature status messages from power stage to ECU | 1 | 30 | Analyze car's scanning system. |
| High Side Driver | Vcc Failure Detection | LF, LR, RF & RR lights will remain off when directed to be ON by user. | 5 | Low battery, or High voltage due to battery shortcut | 6 | Vcc Failure flag status messages from power stage to ECU | 1 | 30 | Analyze car's scanning system. |
| High Side Driver | No lighting system | LF, LR, RF & RR lights will remain off when directed to be ON by user. | 5 | Charge pump malfunction causing low level voltage or no voltage at all. | 3 | Vcc Failure flag status messages from power stage to ECU | 1 | 15 | Analyze car's scanning system. |

## 6. Pruebas de Integración del Software

| TC-TLS01 | | |
|---|---|---|
| | | SW_01 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Direction Blinking Left: When moving the lever in position "turn left" the vehicle flashes all left direction indicators (front left, exterior mirror left, rear left) synchronically with pulse ratio bright to dark 1:1. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Measure closed Lever switch for left turn indicator | TURN_LEFT = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF78 |
| 4 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS02 | | |
|---|---|---|
| | | SW_02 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | Could relay on TC-TLS01 |
| **Purpose** | The maximum deviation of the pulse ratio should be below the cognitive threshold of a human observer. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Measure closed Lever switch for left turn indicator | TURN_LEFT = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF78 |
| 4 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS03 | | |
|---|---|---|
| | | SW_03 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect Oscilloscope to TURN_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | Could relay on TC-TLS01 |
| **Purpose** | A deviation of the pulse ratio with less than 0.5% is accepted as cognitive threshold of a human observer. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Measure toggle frequency deviation | Toggle frequency for turn lights is around ~ 1.3 Hz and maximum allowed deviation of frequency is 0.5% ,this is ±0.6 Hz |

| TC-TLS04 | | |
|---|---|---|
| | | SW_04 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect Oscilloscope to TURN_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | The reaction time between the activation of the lever and the beginning of the first flashing cycle should be below the cognitive threshold of a human observer. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Measure closed Lever switch for left turn indicator | TURN_LEFT = ON |
| 3 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 4 | Measure activation time | Delta time between TURN_LEFT signal going HIGH and turn lights start toggling must be ~ 1s |

| TC-TLS05 | | |
|---|---|---|
| | | SW_05 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect Oscilloscope to TURN_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | Could relay on TC-TLS04 |
| **Purpose** | A deviation of less than 0.05s is accepted as cognitive threshold of a human observer. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Measure closed Lever switch for left turn indicator | TURN_LEFT = ON |
| 3 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 4 | Measure activation time deviation | Delta time between TURN_LEFT signal going HIGH and turn lights start toggling must be ~ 1s and maximum allowed deviation in activation time should be ± 0.05s |

| TC-TLS06 | | |
|---|---|---|
| | | SW_06 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_LEFT, FLASH_LEFTsignal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Tip-Blinking Left: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking left", all left direction indicators (see UC_01) should flash for three flashing cycles. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash left position (press CCW). This is midway to left position | Lever should reach halfway to Left position ,this is Flash Left position, and comeback to OFF position |
| 2 | Measure closed Lever switch for flash left turn indicator | FLASH_LEFT = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF77 |
| 4 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking 3 times |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~1.3 Hz |

| TC-TLS07 | | |
|---|---|---|
| | | SW_07 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to FLASH_LEFT & TURN_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | If the driver activates the lever in another direction or activates the hazard warning light switch during the three flashing cycles of the tip-blinking, the tip-blinking cycle must be stopped and the requested flashing cycle must be released (direction of turn Signal, tipblinking, hazard warning light) | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash left position (press CCW). This is midway to left position | Lever should reach halfway to Left position ,this is Flash Left position, and comeback to OFF position |
| 2 | Measure closed Lever switch for flash left turn indicator | FLASH_LEFT = ON |
| 3 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF77 |
| 4 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 5 | Before left lights blink for 3 times, turn lever to right position (press CW) | Lever should stay at Right position |
| 6 | Measure closed Lever switch for right turn indicator | TURN_RIGHT = ON |
| 7 | Observe CAN message for right turn indicator | Observe CAN message ID=5CD27AF80 |
| 8 | Visual verification of lighting system | Left_Front and Left_Read lights must go OFF and Right_Front, Right_Rear shall start toggling |

| TC-TLS08 | | |
|---|---|---|
| | | SW_08 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_LEFT & FLASH_LEFT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | If the driver holds the lever for more than 0.5 seconds in position "tip-blinking left", flashing cycles are released for all direction indicators on the left until the lever leaves the position "tip-blinking left". | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at left position |
| 2 | Measure closed Lever switch for left turn indicator | TURN_LEFT = ON |
| 3 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF78 |
| 4 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |
| 5 | Turn lever to flash left position (press CCW) and hold 1s. This is midway to left position | Lever should reach halfway to Left position ,this is Flash Left position and be hold in there by the user. |
| 6 | Measure closed Lever switch for flash left turn indicator | FLASH_LEFT = ON |
| 7 | Verify active signal high for 1s | FLASH_LEFT = ON for 1s, verify thru oscilloscope |
| 8 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF77 |
| 9 | Visual verification of lighting system | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go OFF. |

| TC-TLS09 | | |
| --- | --- | --- |
| | | SW_09 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Set light sensor in front of Right_Front and Right_Rear lights<br>4.- Enable access to override light sensor<br>5.- Connect Oscilloscope to FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Direction blinking: Daytime running light must be dimmed by 50% during direction blinking on the blinking side. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Override ligh sensor to night status | LIGHT_SENSOR = OFF |
| 2 | Turn lever to flash right position (press CW). | Lever should reach halfway to Right position ,this is Flash Right position, and comeback to OFF position |
| 3 | Measure closed Lever switch for flash right turn indicator | FLASH_RIGHT = ON |
| 4 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF79 |
| 5 | Verify left lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking for 3 times |
| 6 | Measure light intensity in lumens. | Record measurement in lumens |
| 7 | Override ligh sensor to day status | LIGHT_SENSOR = ON |
| 8 | Turn lever to flash right position (press CW). | Lever should reach halfway to Right position ,this is Flash Right position, and comeback to OFF position |

| TC-TLS10 | | |
|---|---|---|
| | | SW_10 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connectorConnect<br>3.- Connect Oscilloscope to FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | If the driver activates the lever during the three flashing cycles of tip-blinking again, only the current flashing cycle is completed. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash right position (press CW). | Lever should reach halfway to Right position ,this is Flash Right position, and comeback to OFF position |
| 2 | Measure closed Lever switch for flash right turn indicator | FLASH_RIGHT = ON |
| 3 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF79 |
| 4 | Verify left lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking for 3 times |
| 5 | Before right lights blink for 3 times, again turn lever to flash right position (press CW). | Lever should reach halfway to Right position ,this is Flash Right position, and comeback to OFF position |
| 6 | Measure closed Lever switch for flash right turn indicator | FLASH_RIGHT = ON |
| 7 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF79 |
| 8 | Verify right lights complete cycle | Right lights should only blink 3 times despite the second flash righ command, this is due to request is in the middle of an outstanding request. |

| TC-TLS11 | | |
|---|---|---|
| | | SW_11 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_RIGHT & FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | If the driver holds the lever for more than 0.5 seconds in position "tip-blinking left", | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to right position (press CW). | Lever should stay at right position |
| 2 | Measure closed Lever switch for right turn indicator | TURN_RIGHT = ON |
| 3 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF80 |
| 4 | Verify right lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking |
| 5 | Turn lever to flash right position (press CW) and hold 1s. This is midway to right position | Lever should reach halfway to Right position ,this is Flash Right position and be hold in there by the user. |
| 6 | Measure closed Lever switch for flash right turn indicator | FLASH_RIGHT = ON |
| 7 | Verify active signal high for 1s | FLASH_RIGHT = ON for 1s, verify thru oscilloscope |
| 8 | Observe CAN message in protocol analyzer watch window | Observe CAN message ID=5CD27AF79 |
| 9 | Visual verification of lighting system | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go OFF. |

| TC-TLS12 | | |
| --- | --- | --- |
| | | SW_12 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_RIGH, FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Tip-Blinking Right: If the driver moves the lever for less than 0.5 seconds in position "Tip- | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash right position (press CW). This is midway to right position | Lever should reach halfway to right position ,this is Flash right position, and comeback to OFF position |
| 2 | Measure closed Lever switch for flash right turn indicator | FLASH_RIGHT = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF79 |
| 4 | Verify right lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking 3 times |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS13 | | |
|---|---|---|
| | | SW_13 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to TURN_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Direction Blinking Right: When moving the lever in position "turn right" the vehicle | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to right position (press CW). | Lever should stay at Right position |
| 2 | Measure closed Lever switch for right turn indicator | TURN_RIGHT = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF80 |
| 4 | Verify right lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS14 | | |
|---|---|---|
| | | SW_14 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Hazard Warning Light: As long as the hazard warning light switch is released, all direction | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS15 | | |
|---|---|---|
| | | SW_15 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in LOCK position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Hazard Warning Light: If the ignition key is in the ignition lock, the pulse ratio is bright | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS16 | | |
|---|---|---|
| | | SW_16 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Hazard Warning Light: If the ignition key is not in the lock, the pulse ratio is 1:2. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS17 | | |
|---|---|---|
| | | SW_17 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | The adaptation of the pulse ratio must occur at the latest after two complete flashing | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS18 | | |
|---|---|---|
| | | SW_18 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | The reduction of the pulse performed due to energy saving reasons, such that, in case of | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS19 | | |
|---|---|---|
| | | SW_19 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS & TURN_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | When hazard warning is deactivated and the lever is in position "direction blinking left" | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Turn lever to right position (press CW). | Lever should stay at right position |
| 3 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 4 | Measure closed Lever switch for right turn indicator | TURN_RIGHT = ON |
| 5 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 & message ID=5CD27AF80 |
| 6 | Verify all lights are turned on | Notice that Hazard Warning Lights have presedence over right turn signal. Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 7 | Press hazard warning lights push button again | Push button should be un-lathced |
| 8 | Measure hazard warning ligts and turn right switches | HAZARD_WARNING_LIGHTS = OFF<br>TURN_RIGHT = ON |
| 9 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF80 |

| TC-TLS20 | | |
|---|---|---|
| | | SW_20 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS & FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | If tip-blinking was activated shortly before deactivation of the hazard warning, this is not | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Turn lever to right position (press CW). | Lever should stay at right position |
| 3 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 4 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 5 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 6 | Wait 10s | 10s elapsed |
| 7 | Turn lever to flash right position (press CW). | Lever should reach halfway to Right position ,this is Flash Right position, and comeback to OFF position |
| 8 | Press hazard warning lights push button again | Push button should be un-lathced |
| 9 | Measure hazard warning ligts and flash right switches | HAZARD_WARNING_LIGHTS = OFF<br>FLASH_RIGHT = ON |
| 10 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF79 |

| TC-TLS21 | | |
| --- | --- | --- |
| | | SW_21 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS & FLASH_RIGHT signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | 0 |
| **Purpose** | The duration of a flashing cycle is 1 second. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS22 | | |
|---|---|---|
| | | SW_22 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | |
| **Purpose** | Hazard Warning Lights: after 1000 flashing cycles the cumulated deviation must not | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsponse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Measure closed hazard warning ligts switch | HAZARD_WARNING_LIGHTS = ON |
| 3 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF81 |
| 4 | Verify right lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 5 | Measure toggle frequency deviation for 1000+ cycles | Toggle frequency for turn lights is around ~ 1.3 Hz and maximum allowed deviation is 0.05s |
| 6 | Measure toggle frequency using scope | Toggle frequency for turn lights is around ~ 1.3 Hz |

| TC-TLS23 | | |
|---|---|---|
| | | SW_23 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector<br>3.- Connect Oscilloscope to HAZARD_WARNING_LIGHTS signal at Debouncer Module and to four turn signal lights (LF,LR,RF & RR) | Refer to TC-TLS22 |
| **Purpose** | A flashing cycle (bright to dark) must always be completed, before a new flashing cycle | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS24 | | |
|---|---|---|
| | | SW_24 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS19 |
| **Purpose** | Data will be transmitted on a central CAN bus | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS25 | | |
|---|---|---|
| | | SW_25 |
| Requirement Reference | | |
| Pre-Condition | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS19 |
| Purpose | Messages will be read by a ECU connected to the bus. | |
| Test Description | | |
| Step | Action | Expected Repsonse |
| | | |

| TC-TLS26 | | |
|---|---|---|
| | | SW_26 |
| Requirement Reference | | |
| Pre-Condition | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS19 |
| Purpose | Specially formatted CAN bus messages will be put on the bus | |
| Test Description | | |
| Step | Action | Expected Repsonse |
| 1 | Leave lever in OFF position | Lever should stay at OFF position |
| 2 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF76 |
| 3 | Turn lever to right position (press CW). | Lever should stay at right position |
| 4 | Observe CAN message in protocol analyzer | Observe CAN message ID=5CD27AF80 |
| 5 | Turn lever to flash right position (press CW). This is midway to right position | Lever should reach halfway to right position ,this is Flash right position, and comeback to OFF position |

<table>
<tr><th colspan="3">TC-TLS27</th></tr>
<tr><td></td><td></td><td>SW_27</td></tr>
<tr><td colspan="3">Requirement Reference</td></tr>
<tr><td>Pre-Condition</td><td>1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector</td><td>Refer to TC-TLS26</td></tr>
<tr><td>Purpose</td><td colspan="2">Turn signals and hazard lights module will use identification values of: Receive: 0x250,</td></tr>
<tr><td colspan="3">Test Description</td></tr>
<tr><td>Step</td><td>Action</td><td>Expected Repsonse</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="3">TC-TLS28</th></tr>
<tr><td></td><td></td><td>SW_28</td></tr>
<tr><td colspan="3">Requirement Reference</td></tr>
<tr><td>Pre-Condition</td><td>1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector</td><td>Refer to TC-TLS26</td></tr>
<tr><td>Purpose</td><td colspan="2">Checksums are contained within the 6th byte of each message</td></tr>
<tr><td colspan="3">Test Description</td></tr>
<tr><td>Step</td><td>Action</td><td>Expected Repsonse</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

| TC-TLS29 | | |
|---|---|---|
| | | SW_29 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS26 |
| **Purpose** | If received checksum does not match calculated checksum, ignore the received data, and | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS30 | | |
|---|---|---|
| | | SW_30 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS26 |
| **Purpose** | The Instrument Cluster (also known as the CPU for this project) is required to interpret | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS31 | | |
|---|---|---|
| | | SW_31 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS26 |
| **Purpose** | If an error is to be reported to the driver, the tell-tale light of malfunctioning module is | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

| TC-TLS32 | | |
|---|---|---|
| | | SW_32 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Connect CAN protocol analyzer tool to OBDII connector | Refer to TC-TLS26 |
| **Purpose** | The driver may clear the messages on the message center by pushing a reset button. It | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| | | |

## 7. Pruebas de Integración de Sistema

| SIT-TLS01 | | |
|---|---|---|
| | | SY_01 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Turn signal lights (LF,LR,RF & RR) shall be OFF | |
| **Purpose** | Direction Blinking Left: When moving the lever in position "turn left" the vehicle flashes all left direction indicators (front left, exterior mirror left, rear left) synchronically with pulse ratio bright to dark 1:1. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |

| SIT-TLS02 | | |
|---|---|---|
| | | SY_02 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Turn signal lights (LF,LR,RF & RR) shall be OFF | |
| **Purpose** | Direction Blinking Left: When moving the lever in position "turn left" the vehicle flashes all left direction indicators (front left, exterior mirror left, rear left) synchronically with pulse ratio bright to dark 1:1. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to left position (press CCW). | Lever should stay at Left position |
| 2 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking |

| SIT-TLS03 | | |
|---|---|---|
| | | SY_03 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Turn signal lights (LF,LR,RF & RR) shall be OFF | |
| **Purpose** | Tip-Blinking Left: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking left", all left direction indicators (see UC_01) should flash for three flashing cycles. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash left position (press CCW). This is midway to left position | Lever should reach halfway to Left position ,this is Flash Left position, and comeback to OFF position |
| 2 | Verify left lights are turned on | Verify that Left_Front and Left_Rear ligths are turned on and blinking 3 times |

| SIT-TLS04 | | |
|---|---|---|
| | | SY_04 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Car's ignition switch must be in ACC or ON position<br>2.- Turn signal lights (LF,LR,RF & RR) shall be OFF | |
| **Purpose** | Tip-Blinking Right: If the driver moves the lever for less than 0.5 seconds in position "Tip-blinking right", all right direction indicators should flash for three flashing cycles. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Turn lever to flash right position (press CW). This is midway to left position | Lever should reach halfway to right position ,this is Flash Right position, and comeback to OFF position |
| 2 | Verify right lights are turned on | Verify that Right_Front and Right_Rear ligths are turned on and blinking 3 times |

| SIT-TLS05 | | |
|---|---|---|
| | | SY_05 |
| **Requirement Reference** | | |
| **Pre-Condition** | 1.- Turn signal lights (LF,LR,RF & RR) shall be OFF | |
| **Purpose** | Hazard Warning Light: As long as the hazard warning light switch is released, all direction indicators flash synchronically. | |
| **Test Description** | | |
| **Step** | **Action** | **Expected Repsonse** |
| 1 | Press hazard warning lights push button | Push button should be lathced |
| 2 | Verify all lights are turned on | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |
| 3 | Verify all lights are turned off | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go OFF and blink. |
| 4 | After 1s , Verify all lights are turned on and keeps the cycle | Left_Front, Left_Rear, Right_Front and Right_Rear lights shall go ON and blink. |

IngSW_Traceability Matrix_Final_hyper

## B. Diseño de Sistema de Audio de Alta Definición

## Table of Contents



## Table of Figures

# 1 Introduction

A High Definition Audio System is capable of playing back more channels at higher quality on different integrated audio formats. More and more consumers are moving to enjoy digital music or movies throughout the house on state-of-the-art multi-channel audio. With better speakers connected, the limitations of current sound subsystems, whether integrated or add-in, can degrade the overall digital experience.

# 2 Requirements Specification

The objective of this work is to design a High Definition Audio System like the one showed in the Figure

*Figure 2-1 High Definition Audio System*

Specific requirements are:

1. Input for Digital Audio Devices (ipad,ipod) with the definition specifications proposed on Figure 2-2, and according to the following statements:
    a) For simplicity, asume that interface to USB/Optical/Coaxial devices is pre selected by the customer.
    b) Is permitted to decrease definition by 20% with the proper justification.
2. Stereo output on speakers should comply with definition and power requirements on Figure 2-3 .
3. Power Supply that permits maintain power and definition requirements described.

| | |
|---|---|
| Audio | -- |
| Total Harmonic Distortion | <0.004% |
| Intermodulation Distortion (60Hz:7KHz) | <0.004% |
| Frequency Response | 10Hz - 95kHz (±3.0 dB) |
| Signal to Noise Ratio (IHF A-weighted) | 128 dB |
| Input Sensitivity /Impedance | 0 dBFs /75 ohms |
| Line Output Level / Impedance (RCA) | 2.0V / 100 ohms |
| Line Output Level / Impedance (XLR) | 4.0V / 200 ohms |
| USB/iPod® Digital Signals | AIFF, AAC (m4a), WAV, MP3, WMA (up to 48kHz 16bit) |
| Decodable Coaxial/ Optical Digital Signals | SPDIF LPCM (up to 24 bit 192kHz) |
| PC-USB File Decoding | Plays all file types supported by PC software player up to 24bit 192kHz |
| General | -- |
| Power Requirements (AC) | 120V, 60Hz (USA)<br>230V, 50Hz (Europe) |
| Power Consumption | 25 watts |
| Standby Power Consumption (normal mode) | < 0.5 watts |
| Dimensions (W x H x D) | 431 x 55 x 316mm<br>17 x 2 1/8 x 12 1/2 in |
| Front panel height | 1U / 43.7mm / 1 3/4 in |
| Weight (net) | 5.1kg/11.24 lb |

*Figure 2-2 DAC Specification*

| | |
|---|---|
| Model | RA-1520 |
| Power Configurations | 2 x 60 watts (20Hz-20kHz, <0.03%, 8 Ohms) |
| THD (20-20,000Hz) 8 Ohms, all channels driven | < 0.03% |
| Phono Input | 20Hz-15kHz, +/- 0.2dB |
| Line Level Input | 10Hz-100kHz, +1, -3dB |
| Damping Factor (8 Ohms) | 150 |
| Line Input Sensitivity | 160mV / 24kOhms |
| Bass | +3, +4dB at 100Hz |
| Treble | + 3dB at 10kHz |
| Line Input Overload | 5V |
| Phono (MM) | 2.4mV / 47kOhms |
| Phono Overload (MM) | 170mV |
| Preamp Output Levels / Output Impedance | 1V / 470 Ohms |
| S/N Ratio (IHF A) | >95dB |
| Power Requirements USA | 115 Volts, 60Hz |
| Power Requirements CE | 230 Volts, 50Hz |
| Power Consumption | 300 watts |
| Dimensions (W x H x D) mm | 432 x 92 x 364 mm |
| Dimensions (W x H x D) in | 17 1/8 x 3 5/8 x 13 5/16 in |
| Front Panel Height | 80 mm / 3 3/16 in |
| Weight (net) | 7.8 kg, 17.2 lbs |

*Figure 2-3 Amplifier Specification*

# 3 System Architecture

## 3.1 Block Diagram

### 3.1.1 General Diagram

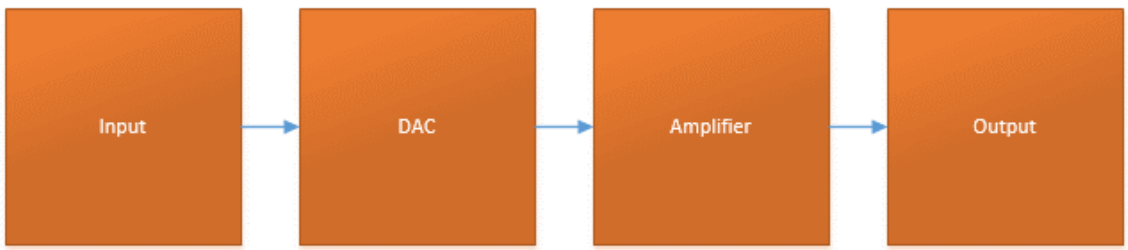



*Figure 3-1 Block Diagram*

### 3.1.2 Proposed Diagram

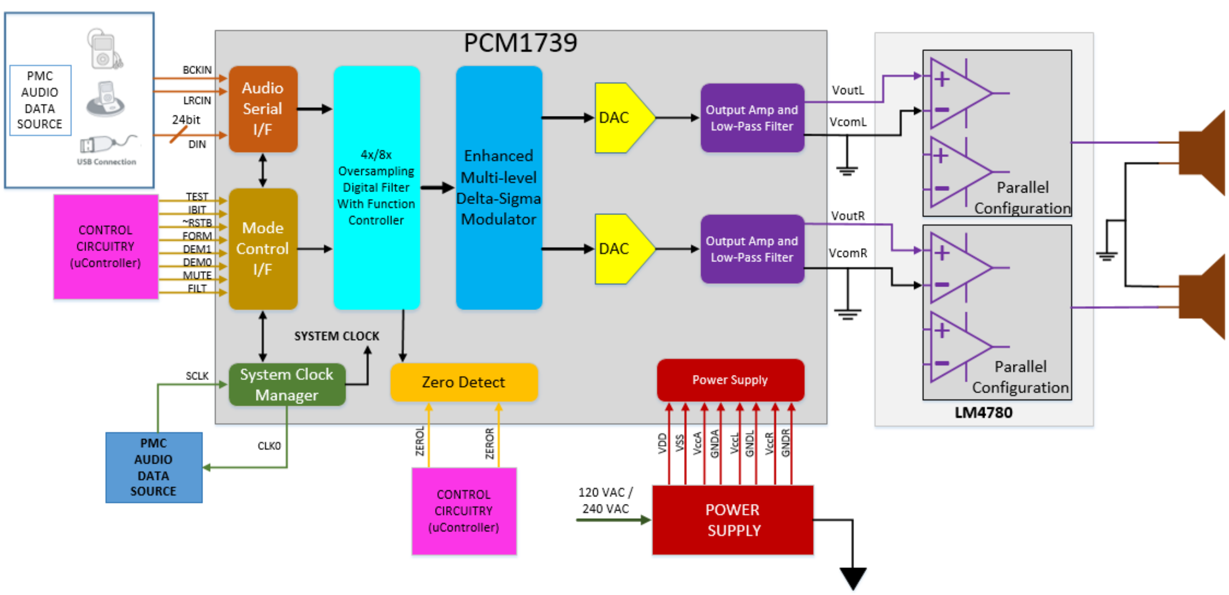



*Figure 3-2 Proposed Block Diagram with commercial devices*

## 3.2 Schematic Diagram

### 3.2.1 DAC

The PCM1739 accepts industry-standard audio data formats with 16- or 24-bit data, providing easy interfacing to audio DSP and decoder chips. Sampling rates up to 192 kHz are supported.
The PCM1739 is a CMOS, monolithic, integrated circuit which includes stereo 24-bit audio digital to analog converters and support circuitry in a small SSOP-28 package.
The data converters utilize Burr-Brown's enhanced multi-level delta-sigma architecture, which employs 4th-order noise shaping and 8-level amplitude quantization to achieve excellent dynamic performance and improved tolerance to clock jitter.

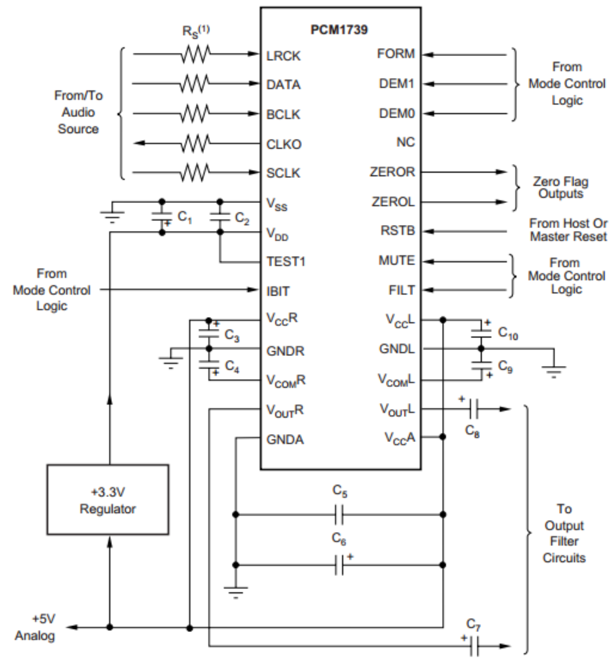



*Figure 3-3 DAC PCM1739 Schematic*

The audio serial interface for the PCM1739 is comprised of a 3-wire synchronous serial port. It includes LRCK (pin1), BCLK (pin 3), and DATA (pin 2). BCLK is the serial audio bit clock, and is used to clock the serial data present on DATA into the audio interface's serial shift registers. Serial data is clocked into the PCM1739 on the rising edge of BCLK. LRCK is the serial audio left/right word clock. It is used to latch serial data into the serial audio interface's internal registers.
Both LRCK and BCLK must be synchronous to the system clock. Ideally, it is recommended that LRCK and BCLK be derived from the system clock input or output, SCLK or CLKO. The left/right clock, LRCK, is operated at the sampling frequency ($f_S$). The bit clock, BCK, may be operated at 48 or 64 times the sampling frequency.
The PCM1739 includes two independent output channels; VOUTL (pin 16) and VOUTR (pin 13). These are unbalanced outputs, each capable of driving 3.1Vp-p typical into a 5kΩ, AC-coupled load (VCC= +5V). The internal output amplifiers for VOUTL and VOUTR are DC biased to a DC common mode (or bipolar zero) voltage, equal to VCC/2.

**FEATURES**

- 24-BIT RESOLUTION
- ANALOG PERFORMANCE ($V_{CC}$ = +5V):
  Dynamic Range: 106dB typ
  SNR: 105dB typ
  THD+N: 0.0015% typ
  Full-Scale Output: 3.1Vp-p typ
- 4x/8x OVERSAMPLING DIGITAL FILTER:
  Passband: $0.454f_S$
  Stopband: $0.546f_S$
  Stopband Attenuation: –82dB
  Passband Ripple: ±0.002dB
- SAMPLING FREQUENCY: 10kHz to 192kHz
- SYSTEM CLOCK: $128f_S$, $192f_S$, $256f_S$, $384f_S$, $512f_S$, or $768f_S$ with Auto Detect
- ACCEPTS 24- or 16-BIT AUDIO DATA
- DATA FORMATS: Standard, I²S
- MODE CONTROLS
  Digital De-Emphasis
  Soft Mute
  Zero Flags for Each Output
- DUAL SUPPLY OPERATION:
  +5V Analog, +3.3V Digital
- 5V TOLERANT DIGITAL INPUTS

*Figure 3-4 PCM1739 Features*

The output amplifiers include an RC continuous time filter, which helps to reduce the out-of-band noise energy present at the DAC outputs due to the noise shaping characteristics of the PCM1739's delta-sigma D/A converters.

Total Harmonic Distortion + Noise (THD+N) is a significant figure of merit for audio D/A converters since it takes into account both harmonic distortion and all noise sources within a specified measurement bandwidth. The true RMS value of the distortion and noise is referred to as THD+N.

### 3.2.2 Amplifier

The LM4780 is a stereo audio amplifier capable of typically delivering 60W per channel of continuous average output power into an 8Ω load with less than 0.5% THD+N from 20Hz-20KHz.

The LM4780 has excellent power supply rejection and does not require a regulated supply. However, to improve system performance as well as eliminate possible oscillations, the LM4780 should have its supply leads bypassed with low-inductance capacitors having short leads that are located close to the package terminals.

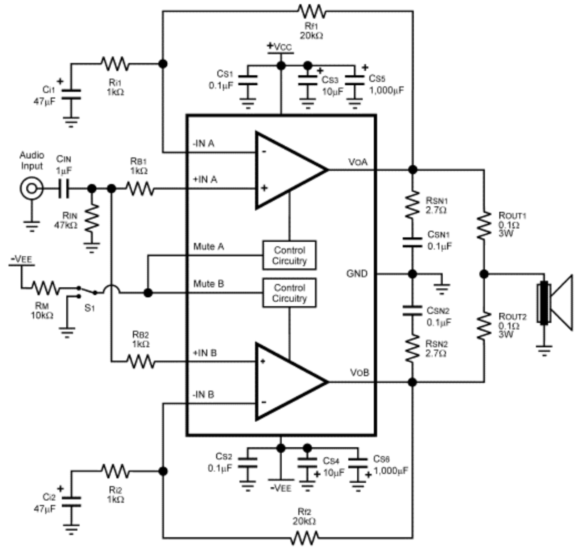



*Figure 3-5 Operational Amplifier LM4780 Schematic*

These instabilities can be eliminated through multiple bypassing utilizing a large tantalum or electrolytic capacitor (10µF or larger) which is used to absorb low frequency variations and a small ceramic capacitor (0.1µF) to prevent any high frequency feedback through the power supply lines. If adequate bypassing is not provided, the current in the supply leads which is a rectified component of the load current may be fed back into internal circuitry. This signal causes distortion at high frequencies requiring that the supplies be bypassed at the package terminals with an electrolytic capacitor of 470µF or more.

The LM4780 has two operational amplifiers internally, allowing for a few different amplifier configurations. One of these configurations is referred to as bridged mode and involves driving the load differentially through the LM4780's outputs.

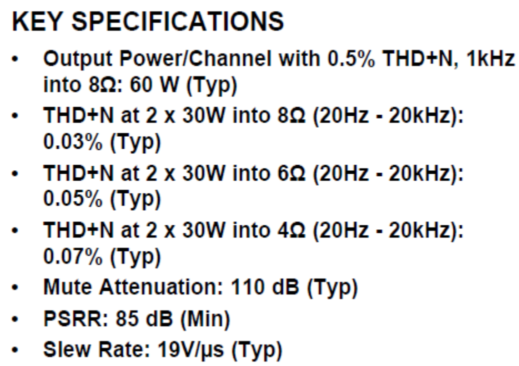
Theoretically, four times the output power is possible as compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped.

**FEATURES**

- **SPiKe Protection**
- **Low External Component Count**
- **Quiet Fade-In/Out Mute Mode**
- **Wide Supply Range: 20V - 84V**
- **Signal-to-Noise Ratio ≥ 97dB (ref. to $P_O$ = 1W)**

*Figure 3-6 LM4780 Features*

THD + N is the residual signal with only the fundamental removed. It is important to note that the THD measurement does not include noise terms, while THD + N does. The noise in the THD + N measurement must be integrated over the measurement bandwidth.


**KEY SPECIFICATIONS**

- **Output Power/Channel with 0.5% THD+N, 1kHz into 8Ω: 60 W (Typ)**
- **THD+N at 2 x 30W into 8Ω (20Hz - 20kHz): 0.03% (Typ)**
- **THD+N at 2 x 30W into 6Ω (20Hz - 20kHz): 0.05% (Typ)**
- **THD+N at 2 x 30W into 4Ω (20Hz - 20kHz): 0.07% (Typ)**
- **Mute Attenuation: 110 dB (Typ)**
- **PSRR: 85 dB (Min)**
- **Slew Rate: 19V/μs (Typ)**

*Figure 3-7 LM4780 Key Specifications*

In narrow-band applications, the level of the noise may be reduced by filtering, in turn lowering the THD + N which increases the signal-to-noise ratio (SNR). Most times when a THD spec is quoted, it is really a THD + N spec, since most measurement systems do not differentiate harmonically related signals from the other signals. The THD measurement is generally made by notching out the fundamental signal and measuring the remaining signal.

The LM4780 has a sophisticated thermal protection scheme to prevent long-term thermal stress of the device. When the temperature on the die exceeds 150°C, the LM4780 shuts down. It starts operating again when the die temperature drops to about 145°C, but if the temperature again begins to rise, shutdown will occur again above 150°C.

### 3.2.3 Power Supply

For simplicity, good performance, and reasonable cost, an unregulated supply is the most common for an audio power amplifier. An unregulated supply uses a transformer, a bridge rectifier, and various rail capacitors. A draw back to the unregulated supply is the voltage fluctuations with load and power mains fluctuations. A design should allow for a minimum 10% high line condition on the power mains. Unregulated supplies may have only a fuse in the power mains input to protect against excessive current unlike more sophisticated regulated designs. Additionally, the power supply voltage rails may have inline fuses to add some additional protection.

Analog audio circuit power supplies can have an audible effect in listening test and quantifiable effect in bench measurement results. Power supply designs that operate from the power mains are of three common types: Switch mode (SMPS), regulated, and unregulated power supplies.

The power supply is an unregulated design with an option to allow connection to either 120V or 240V mains. The design uses toroid transformers, a fully integrated bridge, and various rail capacitors for ripple voltage reduction, noise suppression, and to act as high current reservoirs. Additional circuitry to control inrush current on power up and power up/down Mute control are also included.

For a commercial design, bench and listening test or some other test criteria is recommended to determine the exact number, size, and type of external components required. A short explanation of the purpose of each capacitor at the primary side of the transformers, around the bridge and on the supply rails follows. Some capacitors are doubled up on the PCB for flexibility or to achieve the desired total capacitance. The schematic to use is shown in the Figure 3-8.

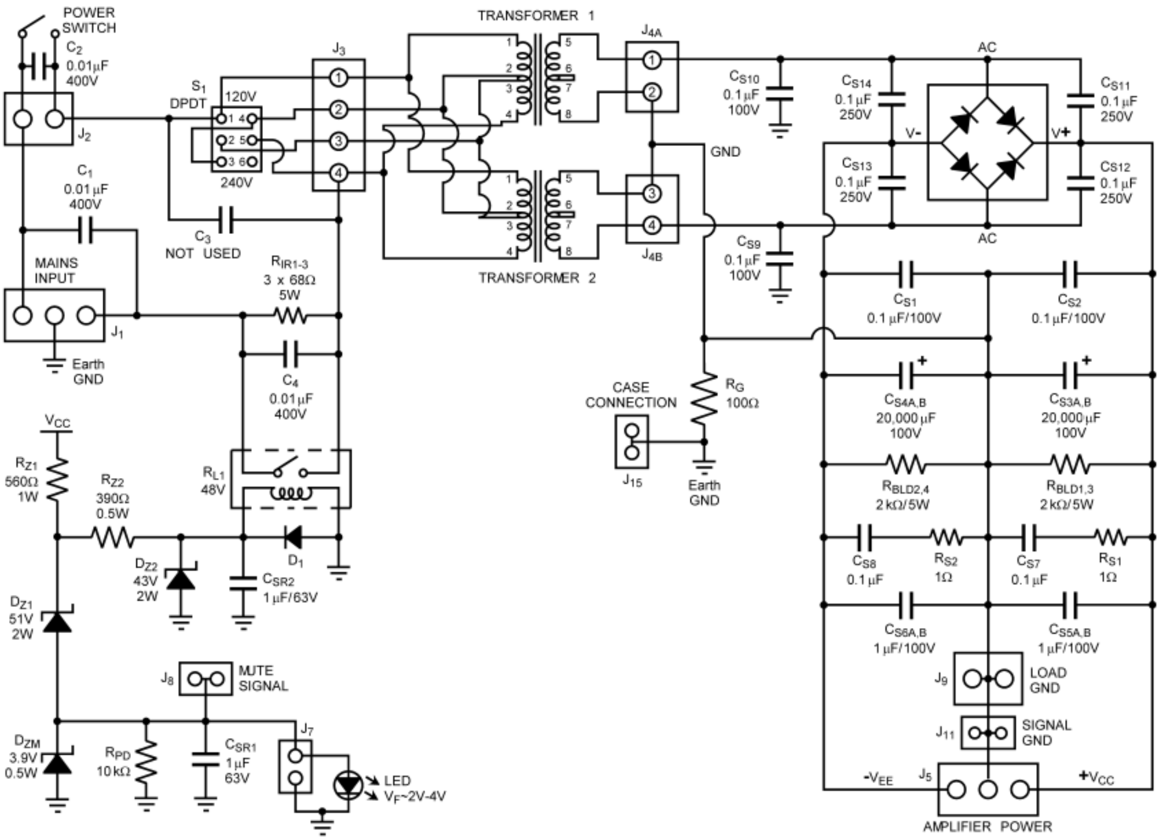



*Figure 3-8 Power Supply Schematic*

# 4 Bill of Materials

Please find in the file attached called BOM.xlsx, According to the file, the estimated total cost of the complete design is **$511.64 USD**

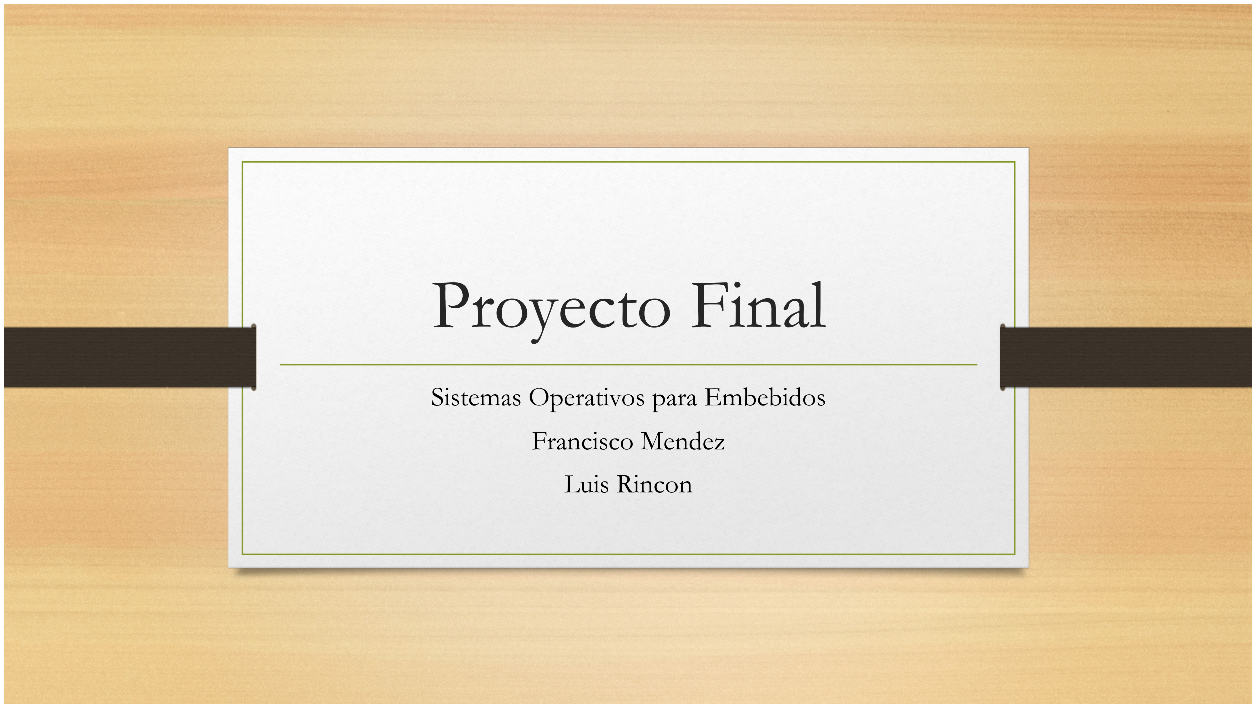
BOM.xlsx

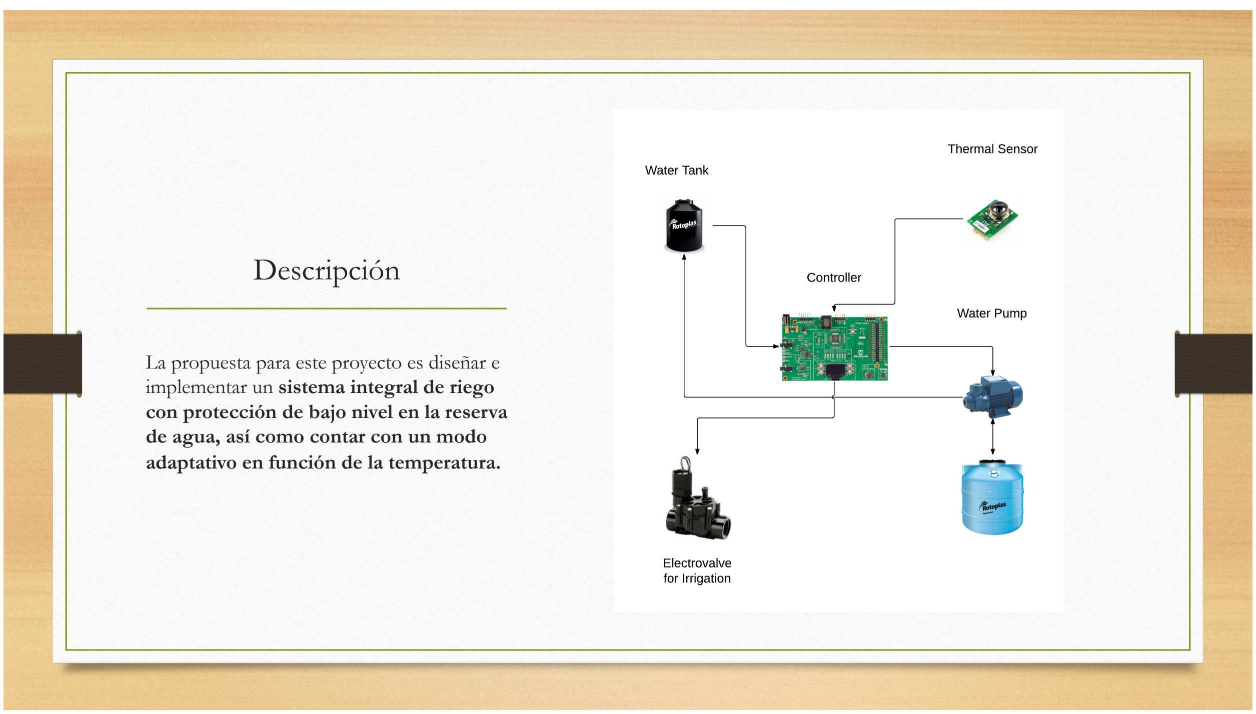
# 5 References

- Burr-Brown, Sound Plus 24-Bit, 192kHz Sampling, Enhanced Multi-Level, Delta-Sigma, Audio DIGITAL-TO-ANALOG CONVERTER Texas Instrument, LM4780 Overture™ Audio Power Amplifier Series Stereo 60W, Mono 120W Audio Power Amplifier with Mute.

- Texas Instrument, LM4780 Overture™ Audio Power Amplifier Series Stereo 60W, Mono 120W Audio Power Amplifier with Mute
- Texas Instrument, AN-1849 An Audio Amplifier Power Supply Design

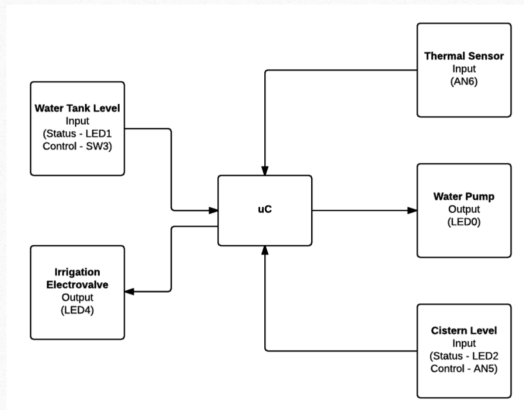
## C. Sistema integral de riego con protección de bajo nivel en la reserva de agua



## Bloque de Control

- El microprocesador central llevará el control mediante el uso de un sistema operativo para sistemas embebidos.
- En esta ocasión, utilizaremos el sistema operativo picOS, y la implementación se llevará en el DemoBoard con un PIC18lf46k22.
- En el diagrama a bloques se describe la arquitectura de señales de entrada/salida para el sistema de control.




## Eventos

- **Nivel bajo en el reservorio de agua (Cisterna)**: Este evento es el de mayor prioridad, de existir un nivel bajo en la cisterna, ninguna alarma podrá ser activada, por lo que el riego no podrá ser activado. Tampoco la bomba podrá ser encendida aún si el nivel del tinaco es bajo.
- **Temperatura mayor a 25ªC:** En el caso de que la temperatura sea mayor a 25ªC, seria un desperdicio ya que no tiene ningún beneficio y se evaporaría en su mayoría, por lo que el sistema esperará a sensar una temperatura segura para proceder con el riego.

# Eventos

- **Nivel bajo en el tanque de agua (Tinaco)**: Este evento es el encargado de encender la bomba para transportar agua desde la cisterna al tinaco.
- **Alarmas fijadas por el usuario:** El sistema cuenta con la opción de fijar dos alarmas (horarios) en los cuales se desea regar, usualmente se fijan a las 6:00am y a las 6:00pm, pero pueden ser ajustadas por el usuario. La duración del tiempo de riego tiene un valor por default de 10 minutos.

# Tabla de verdad del sistema

Las entradas y salidas del sistema se comportan basado en la información mostrada en la tabla de verdad.

De acuerdo a la tabla, siempre y cuando el indicador del nivel de la cisterna se encuentre apagado, el sistema debe funcionar normalmente.

| Inputs | | | | | Ouputs | |
|---|---|---|---|---|---|---|
| Cistern | Thermal Sensor | Water Tank | Alarm1 | Alarm2 | Water Pump | Irrigation |
| OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| OFF | OFF | OFF | OFF | ON | OFF | ON |
| OFF | OFF | OFF | ON | OFF | OFF | ON |
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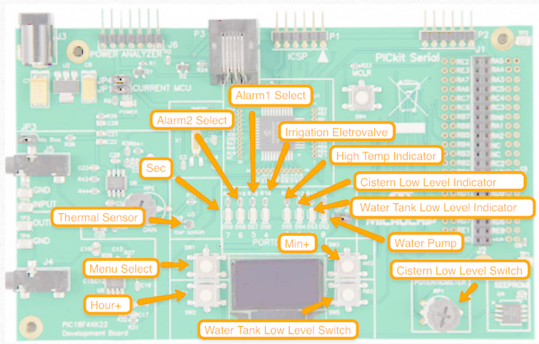
# Distribución en la Tarjeta de Desarrollo




# Conclusión

- Con el sistema implementado, se mejora el uso del agua, así como la efectividad en el riego.
- Al no permitir el sistema el riego cuando existe alta temperatura, se minimiza el riesgo de dañar la siembra, así como el desperdiciarla por no tener mayor beneficio.
- El sistema de detección de bajo nivel en la cisterna nos ayuda a alertar al usuario, sin quedar sin suministro de agua. Tendrá suficiente agua para uso común, optimizando el uso de la reserva.
- Al no permitir el consumo completo de la reserva de agua, también se protege a las tuberías de agua de introducir aire, el cual podría disminuir la presión en la misma.