Final Project

STATIC AND DYNAMIC DESIGN

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SPRINTS | ESW DESIGN MC

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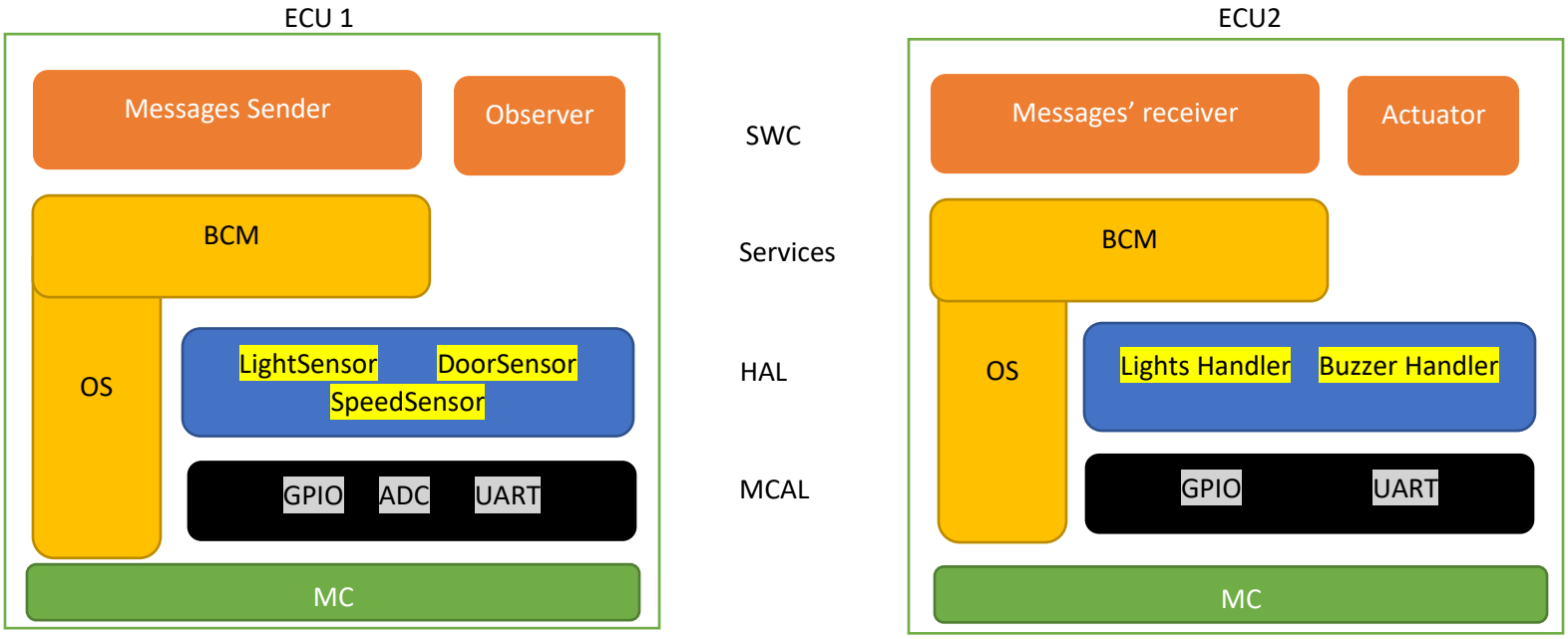
1. Project Requirements

2 ECUs communicate using BCM protocol over CAN network
ECU1 handles inputs and ECU2 handles outputs.
Inputs: Door (10 ms periodicity) / Light (20 ms periodicity) / Speed sensors (5 ms periodicity).
Outputs: Buzzer and Lights.
Sensors' data are sent in 3 CAN messages periodically.
Define SOS tasks, CPU load, and Bus load.
Application actuator requirements:

- Door open && car moving -> Buzzer on / Lights off
- Door open && car stopped -> Buzzer off / Lights on
- Door Close && lights on -> Set timer then Lights off
- Car stopped && lights on -> Buzzer on / Lights on

2. Static design

a. Layered Architecture



b. API Specification

- *DIO Module*

Data Type Table

Name	DIO_port		
Type	Enumeration		
Range	PORTA	0	Symbolic name for PortA
	PORTB	1	Symbolic name for PortB

	PORTC	2	Symbolic name for PortC
	PORTD	3	Symbolic name for PortD
Description	Define symbolic names for ports		

Name	DIO_pin	
Type	Enumeration	
Range	Pin0 ~ Pin7	Available pins on each port
Description	Define symbolic names for available pins	

Name	DIO_Level		
Type	Enumeration		
Range	STD_LOW	0	Physical pin level = 0
	STD_HIGH	1	Physical pin level = 1
Description	Digital pin value		

Name	DIO_Direction	
Type	Enumeration	
Range	Input	0
	Output	1
Description	Define DIO port pin direction	

API Design Table

Function name	Dio_InitPortPin		
Arguments	Input	DIO_port	Enumeration
		Port number / symbolic name	
		DIO_Pin	Enumeration
		Pin number / symbolic name	
		DIO_Direction	Enumeration

		Define port pin direction.
	Output	
	Input/ Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Responsible for initializing a port pin direction. Must be specified before read/write access on a pin.	

Function name	Dio_Read		
Arguments	Input	DIO_Port	Enumeration
		Port number / symbolic name	
		DIO_Pin	Enumeration
		Pin number / symbolic name	
	Output	DIO_LEVEL	Enumeration *
		Pointer to Physical level of the specified pin.	
	Input/ Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Responsible for reading the physical current value of a hardware port pin. It should be able to read the value of the pin whether it's input or output without affecting its current state. If the pin is uninitialized, the function should return an error and not do anything. For the output parameters it must check for a null pointer exception before proceeding.		

Function name	Dio_Write		
Arguments	Input	DIO_Port	Enumeration
		Port number / symbolic name	

		DIO_Pin	Enumeration
		Pin number / symbolic name	
		DIO_LEVEL	Enumeration
		Physical level to write on the specified pin.	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Responsible for writing the physical value of a hardware port pin. It should be able to write the value of the pin if it's output without. If the pin is uninitialized, the function should return an error and not do anything.		

- *ADC*

Datatype Table

Name	ADC_ChannelType	
Type	Uint8	
Range	CHANNEL1 ~ CHANNEL8	enumeration
Description	Definition of ADC channels	

Name	ADC_TriggerSrcType	
Type	Uint8	
Range	FREE_RUNNING ANALOG_COMPATRATOR EXTERNAL_INTERRUPT TMR_COMPARE_MATCH TMR_OVF	enumeration
Description	Definition of ADC channels	

Name	ADC_ConfigType
Type	Structure

Elements	ADC_IE	Boolean	0: Interrupts disabled 1: Interrupts enabled
	ADC_PreScalar	Enumeration	
	ADC_TriggerSrcType	Enumeration	
Description	Configuration parameters for timer module		

API Design Table

Function name	ADC_Init		
Arguments	Input	ADC_ConfigType	Structure
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Initialize and Enable ADC module, define interrupt usage, specify the prescalar, and trigger source		

Function name	ADC_Start		
Arguments	Input	ADC_ChannelType	Enumeration
		Channel number for the ADC to start conversion.	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for starting the work of the ADC channel specified. If the Channel passed isn't valid for ADC operation, the function should return an error and do nothing.		

Function name	ADC_Stop		
Arguments	Input	ADC_ChannelType	Enumeration

		Channel number for the ADC.
	Output	
	Input / Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Function responsible for stopping the work of the specified ADC channel. If the Channel passed isn't valid for ADC operation or isn't started, the function should return an error and do nothing.	

Function name	ADC_GetConversionResult		
Arguments	Input	ADC_ChannelType	Enumeration
		Channel number for the ADC to get conversion.	
	Output	ADC_ChannelResult	Uint16 *
		Place holder to store the latest result of the specified channel	
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for providing the latest completed conversion value for the required channel using an internal buffer storing all running channels' data.		

- *PWM*

Datatype Table

Name	PWM_Config		
Type	Structure		
Elements	TMR_Channel	enumeration	
	TMR_CLK	Enumeration	
	TMR_Operation_Mode	Boolean	0: PWM 1: Fast PWM

Description	Configuration parameters for timer module

API Design Table

Function name	PWM_Init		
Arguments	Input	PWM_Config	structure
		Pointer to structure address holding pwm configuration parameters.	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing a timer channel for PWM operation according to configuration parameters. This function isn't supposed to handle other timer modes. Function must be initialized before using Start/Stop functions Function return E_NOT_OK when: • If a nullptr detected • If the TMR_Channel isn't valid		

Function name	PWM_Start		
Arguments	Input	TMR_Channel	Enumeration
		Channel number for the pwm to start.	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for starting the work of the pwm specified. If the TMR_Channel passed isn't available for PWM operation, the function should return an error and do nothing.		

Function name	PWM_Stop

Arguments	Input	TMR_Channel	Enumeration
		Channel number for the pwm to stop.	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for stopping the work of the pwm specified. If the TMR_Channel passed isn't available for PWM operation, the function should return an error and do nothing.		

- *UART*

Datatype Table

Name	UART_ChannelType	
Type	Enumeration	
Range	1 - 3	
Description	Define available UART channel values: UART1_CHANNEL UART2_CHANNEL UART3_CHANNEL	

Name	UART_BaudRateType
Type	Enumeration
Range	BPS_4800 BPS_9600 BPS_19200 BPS_57600 BPS_115200
Description	Define available UART baud rate values:

Name	UART_ConfigType

Type	Structure		
Elements	Parity	Boolean	0: No Parity 1: Even Parity
	BaudRate	UART_BaudRateType	
	UART_Channel	UART_ChannelType	
Description	Configuration parameters for UART module		

API Design Table

Function name	UART_init		
Arguments	Input	ConfigPtr	UART_ConfigType *
		Pointer to channel configuration struct	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Initialize the specified UART channel for Receive and Transmit according to configuration parameters. The function should return an error on invalid parameters.		

Function name	UART_Transmit		
Arguments	Input	Channel	UART_ChannelType
		a channel to send data	
		DataPtr	uint8 *
		Pointer to data array to send	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function to perform asynchronous transmit of an array of data.		

Function name	UART_Recieve		
Arguments	Input	Channel	UART_ChannelType
		a channel to send data	
		DataPtr	uint8 *
		Pointer to store received data	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function to perform asynchronous receive of an array of data using external buffer.		

- *Light Sensor*

Datatype Table

Name	LightSensorClassType	
Type	Structure	
Elements	DataValue	Uint8
	SensorPort	DIO_PORT
	SensorPin	DIO_PIN
Description	Pointer to a new sensor instance to be used with the Sensor interface	

API Design Table

Function name	LightSensor_Create		
Arguments	Input	me	LightSensorClassType *
		Pointer to configuration structure holding DIO information of one instance of the sensor	
	Output		
	Input / Output		
Return	E_OK	1	

	E_NOT_OK	0	
Description	Function responsible for initializing the Sensor DIO pins and assigning sensor readings to the dedicated data variable.		

Function name	LightSensor_Main		
Arguments	Input	me	LightSensorClassType *
		Pointer to the sensor object (instance)	
	output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Periodic function to get the physical meaning of the average of the latest 10 readings of the sensor and store in the data variable		

Function name	LightSensor_SetUpdateFrequency		
Arguments	Input	me	LightSensorClassType *
		Pointer to the sensor object (instance)	
		Frequency	uint
		Define the periodic update interval in ms	
	output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function to set the update criteria for the sensor		

Function name	LightSensor_ReadValue		
Arguments	Input	me	LightSensorClassType *
		Pointer to the sensor object (instance)	

	output	
	Input / Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Return the value stored in the data variable of the associated instance / object	

- *Door Sensor*

Datatype Table

Name	DoorSensorClassType	
Type	Structure	
Elements	DataValue	Uint8
	SensorPort	DIO_PORT
	SensorPin	DIO_PIN
Description	Pointer to a new sensor instance to be used with the Sensor interface	

API Design Table

Function name	DoorSensor_Create		
Arguments	Input	me	DoorSensorClassType *
		Pointer to the sensor object (instance)	
	output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Create a new instance of the Sensor DIO pins and assigning sensor readings to the dedicated data variable.		

Function name	DoorSensor_Main		
Arguments	Input	me	DoorSensorClassType *

		Pointer to the sensor object (instance)
	output	
	Input / Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Periodic function to get the physical meaning of the average of the latest 10 readings of the sensor and store in the data variable	

Function name	DoorSensor_SetUpdateFrequency		
Arguments	Input	me	DoorSensorClassType *
		Pointer to the sensor object (instance)	
		Frequency	uint
		Define the periodic update interval in ms	
	output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function to set the update criteria for the sensor		

Function name	DoorSensor_ReadValue		
Arguments	Input	me	DoorSensorClassType *
		Pointer to the sensor object (instance)	
	output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Return the value stored in the data variable of the associated instance / object		

- *Speed Sensor*

Datatype Table

API Design Table

Function name	SpeedSensor_Init		
Arguments	Input	ADC_ChannelType	Enumeration
		ADC channel to which the Sensor is assigned	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing the Sensor and starting the associated ADC channel conversion.		

Function name	SpeedSensor_main		
Arguments	Input		
	Output	Speed_KMH	Uint16 *
		Return the physical meaning of ADC conversion result in actual speed	
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Main function to get the avg and physical meaning of the last 10 ADC readings.		

- *Light Actuator*

Datatype Table

Name	LightActuatorClassType	
Type	Structure	
Elements	DataValue	Uint8

	SensorPort	DIO_PORT
	SensorPin	DIO_PIN
Description	Pointer to a new instance to be used with the actuator interface	

API Design Table

Function name	LightActuator_Create		
Arguments	Input	me	LightActuatorClassType *
		Pointer to configuration structure holding DIO information of one instance of the light actuator	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing the DIO pins.		

Function name	LightActuator_SetValue		
Arguments	Input	me	LightActuatorClassType *
		Pointer to one instance of the light actuator	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for setting the DIO pins values.		

Function name	LightActuator_GetValue		
Arguments	Input	me	LightActuatorClassType *
		Pointer to one instance of the light actuator	
	Output		

	Input / Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Function responsible for getting the DIO pins values.	

- *Buzzer Actuator*

Datatype Table

API Design Table

Function name	Buzzer_Init		
Arguments	Input	pin	DIO_PIN
		port	DIO_PORT
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing the Buzzer pin.		

Function name	Buzzer_SetValue		
Arguments	Input		
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for setting the Buzzer pin value.		

Function name	Buzzer_GetValue		
Arguments	Input		
	Output		

	Input / Output	
Return	E_OK	1
	E_NOT_OK	0
Description	Function responsible for getting the Buzzer pin value.	

- *BCM*

Datatype Table

Name	COM_ChannelType	
Type	Enumeration	
Range	Enumeration	
Description	Define available com channel values: CAN1_Channel CAN2_Channel UART_Channel I2C_Channel	

API Design Table

Function name	BCM_init		
Arguments	Input		
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	This function is responsible for initializing the different communication modules used in the system, internal or external.		

Function name	BCM_RxInit		
Arguments	Input	comChannel	COM_ChannelType
		Define which communication channel to setup receive sequence	

	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing Rx sequence for the specified Communication channel		

Function name	BCM_TxInit		
Arguments	Input	comChannel	COM_ChannelType
		Define which communication channel to setup transmit sequence	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for initializing Tx sequence for the specified Communication channel.		

Function name	BCM_RxDispatcher		
Arguments	Input	comChannel	COM_ChannelType
		Define which communication channel to Create receive event.	
	Output	funcPtr	Void *
		Pointer to call back function to be executed when the RX event occur	
	Input / Output		
Return			
Description	Main receive periodic function to start the receive sequence.		

Function name	BCM_TxData		
Arguments	Input	comChannel	COM_ChannelType
		Define which communication channel to setup transmit sequence	
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Function responsible for transmitting data over the specified Communication channel. The function should return an error if the channel is not initialized as Tx or an invalid parameter is passed.		

- *SOS*

Datatype Table

Name	TaskConfigType	
Type	Structure	
Elements	pFunc	Void *
	Pointer to function to execute when the task is ready	
	Delay	Uint8
	The amount of time in ms to wait before first task ttriggering	
	Period	Uint8
	The frequency in ms at which the task will be ready to execute.	
Description	Pointer to a new task.	

API Design Table

Function name	SOS_init		
Arguments	Input		
	Output		
	Input / Output		

Return	E_OK	1
	E_NOT_OK	0
Description	This function is responsible for initializing the system Timer configurations.	

Function name	SOS_CreateTask		
Arguments	Input	TaskPtr	TaskConfigType *
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	This function is responsible for creating a new task and reserving its place in stack/memory.		

Function name	SOS_DeleteTask		
Arguments	Input	TaskPtr	TaskConfigType *
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	This function is responsible for deleting an existing task and freeing its place in stack/memory.		

Function name	SOS_Run	
Arguments	Input	
	Output	
	Input / Output	
Return	E_OK	1

	E_NOT_OK	0
Description	Main periodic function. responsible for dispatching and running the tasks in queue according to priority and ready flag.	

- *SWC Message Sender*

Datatype Table

API Design Table

Function name	MS_GetData		
Arguments	Input	sensorID	Uint8
	Output	sensorData	Uint8 *
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Request data of a specific sensor from the Sensor Observer Server.		

Function name	MS_SendMsg		
Arguments	Input	MsgID	Uint8
		Data	Uint8
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Send Msg over BCM		

Function name	MS_Main		
Arguments	Input		
	Output		
	Input / Output		
Return	E_OK	1	

	E_NOT_OK	0
Description	Periodic function to send sensors data on intervals configured by systems requirements	

- *SWC Observer*

Datatype Table

Name	SensorObserverType	
Type	Structure	
Elements	SensorID	Enumeration
	Id of the sensor instance to be used with the specified sensor module	
	SensorData	Uint8
	Reading of the sensor	
	NotificationHandler[]	Void()*
	Array of subscription list.	
Description	Used to add a new instance to the observer server	

API Design Table

Function name	SensorObserver_init		
Arguments	Input	me	SensorObserverType *
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Constructor for the sensor instance		

Function name	SensorObserver_CleanUp		
Arguments	Input	me	SensorObserverType *
	Output		
	Input / Output		

Return	E_OK	1
	E_NOT_OK	0
Description	DeConstructor for the sensor instance	

Function name	SensorObserver_subscripe		
Arguments	Input	me	SensorObserverType *
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Add a new client to the subscription list		

Function name	SensorObserver_unsubscripe		
Arguments	Input	me	SensorObserverType *
	Output		
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Remove a client from the subscription list		

- *SWC Message Receiver*

Datatype Table

API Design Table

Function name	MR_CallBack		
Arguments	Input		
	Output		
	Input / Output		
Return	E_OK	1	

	E_NOT_OK	0
Description	Function passed to the BCM to be executed on data reception complete event. It should store the new commands in hared global variables for the Actuator to use later	

Function name	MR_GetBuzzerCMD		
Arguments	Input		
	Output	BuzzerLevel	Uint8 *
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Get the latest value assigned to the buzzer.		

Function name	MR_GetLightCMD		
Arguments	Input		
	Output	lightLevel	Uint8 *
	Input / Output		
Return	E_OK	1	
	E_NOT_OK	0	
Description	Get the latest command for the light actuator		

- *SWC Actuator*

Datatype Table

API Design Table

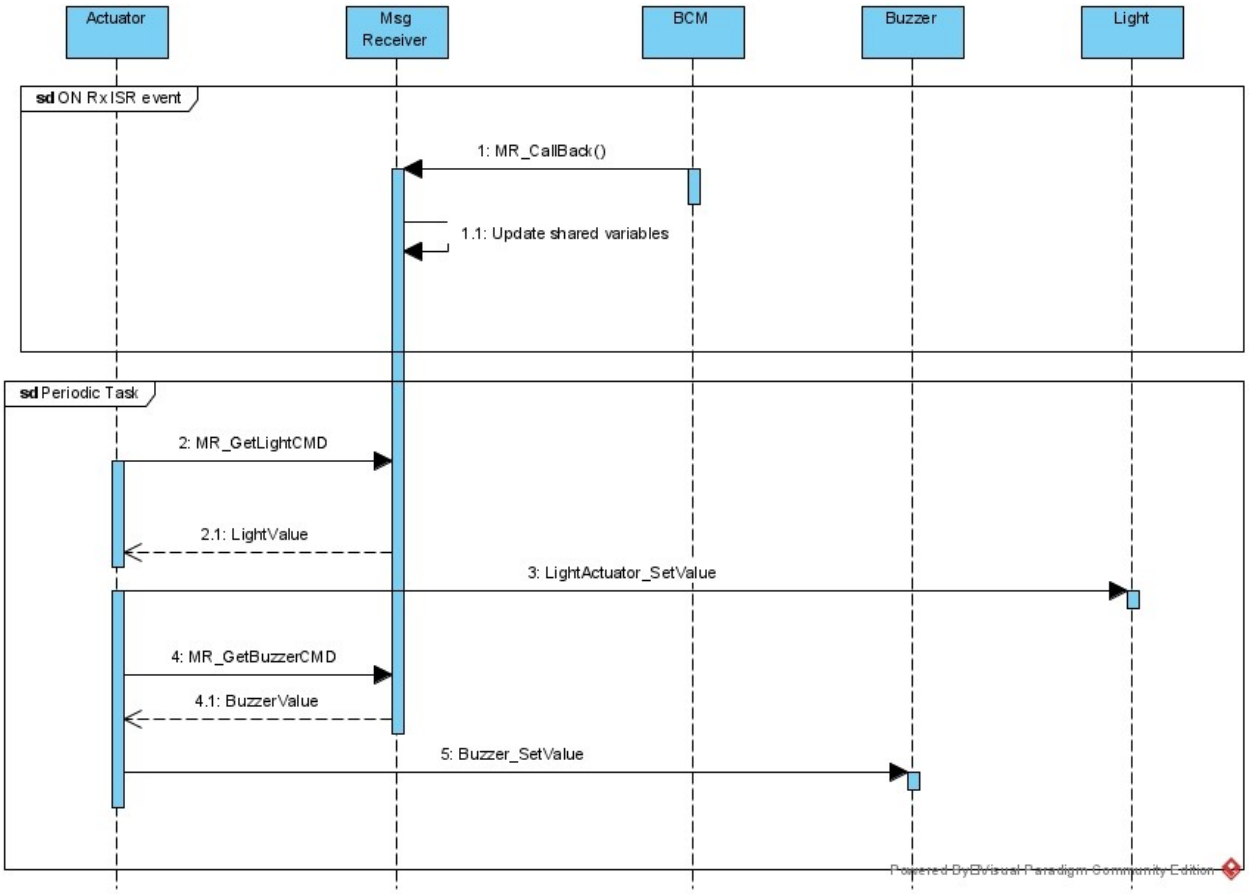
Function name	ACT_main		
Arguments	Input		
	Output		
	Input / Output		
Return	E_OK	1	

	E_NOT_OK	0
Description	Periodic function used to update the status of the buzzer and light actuators based on the readings from MR_GetLightCMD && MR_GetBuzzerCMD.	

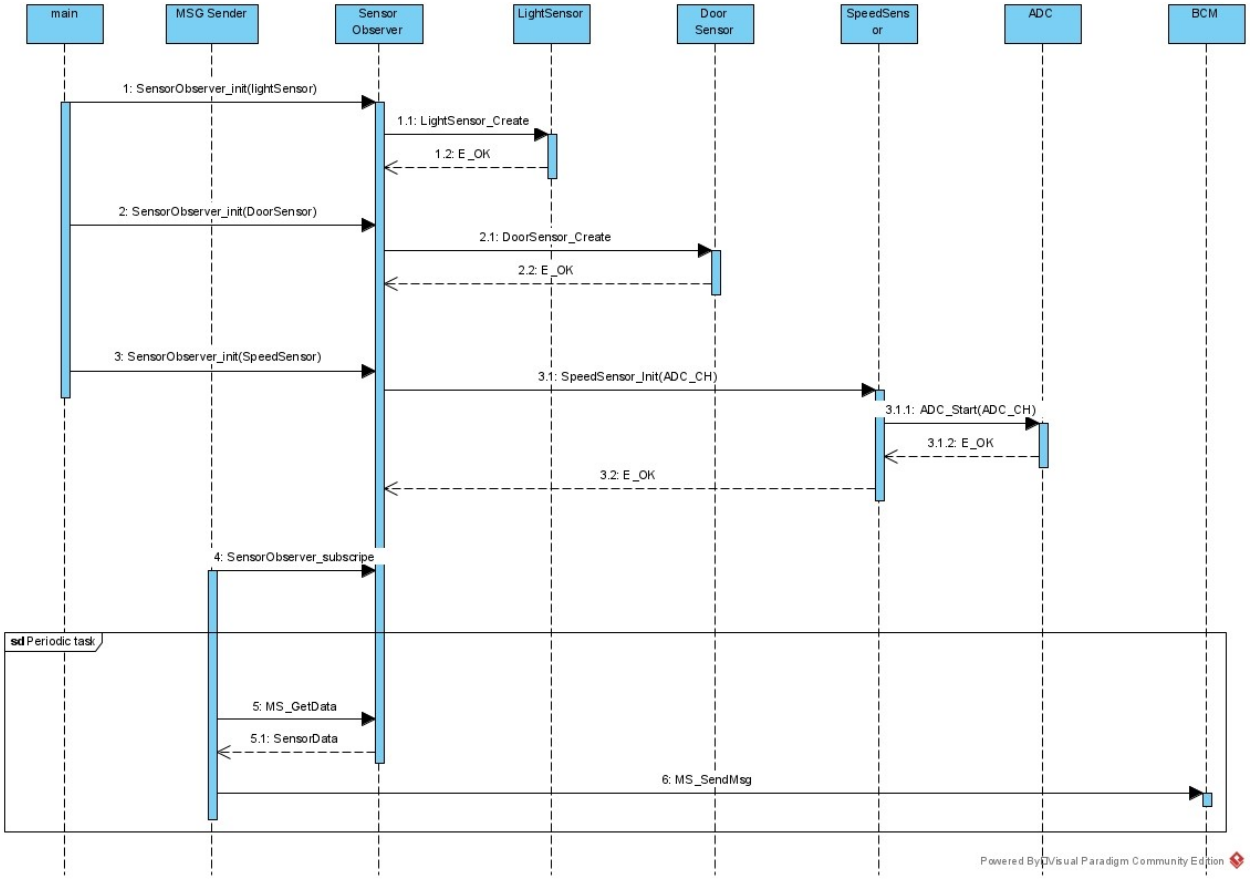
3. Dynamic design

a. Sequence diagrams

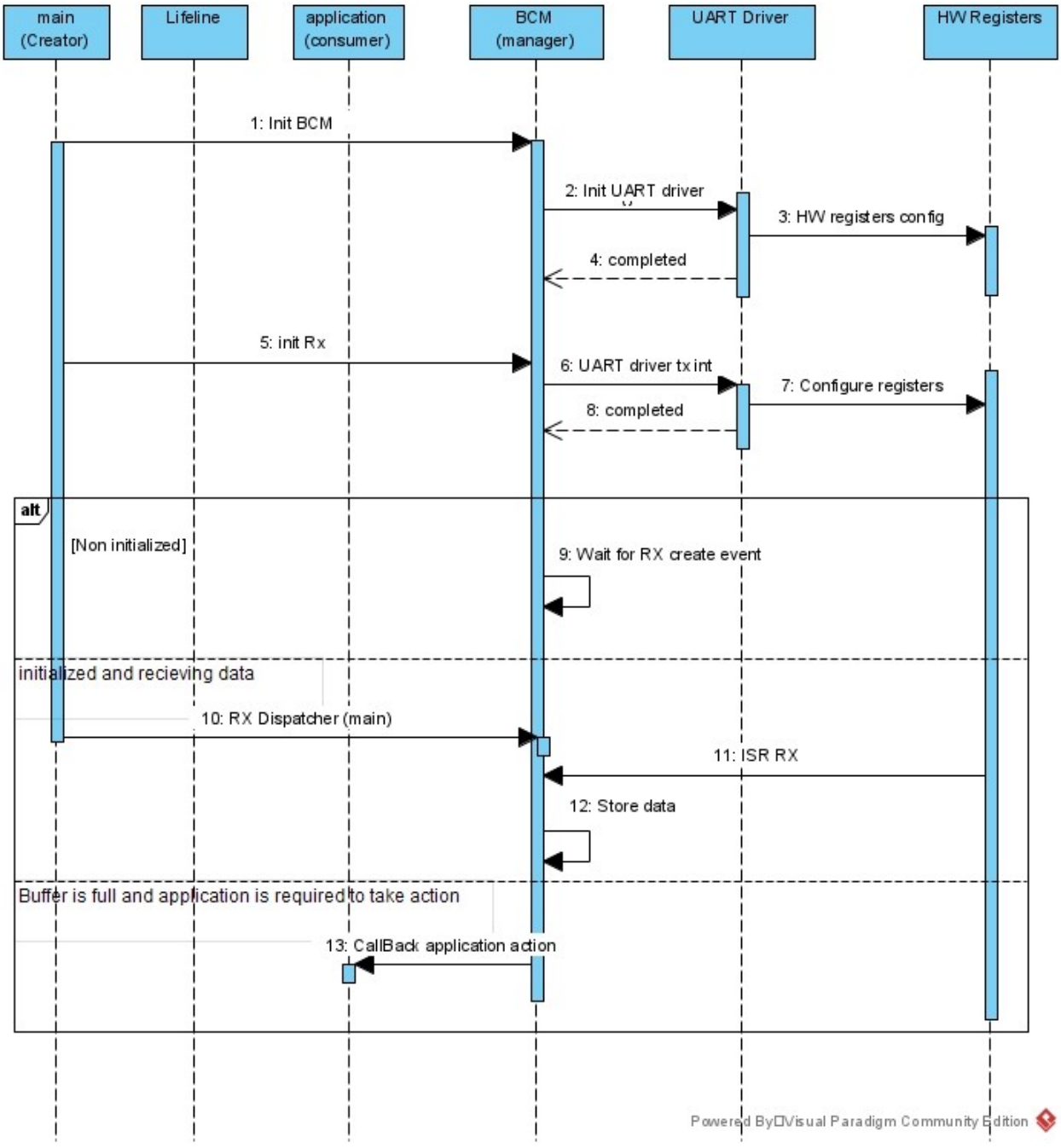
- *Actuator / Receiver sequence*



- *Observer / Sender sequence*



- *BCM RX*


main
(Creator)
Lifeline
application
(consumer)
BCM
(manager)
UART Driver
HW Registers
1: Init BCM
2: Init UART driver
3: HW registers config
4: completed
5: init Rx
6: UART driver tx int
7: Configure registers
8: completed
alt
[Non initialized]
9: Wait for RX create event
initialized and recieving data
10: RX Dispatcher (main)
11: ISR RX
12: Store data
Buffer is full and application is required to take action
13: CallBack application action
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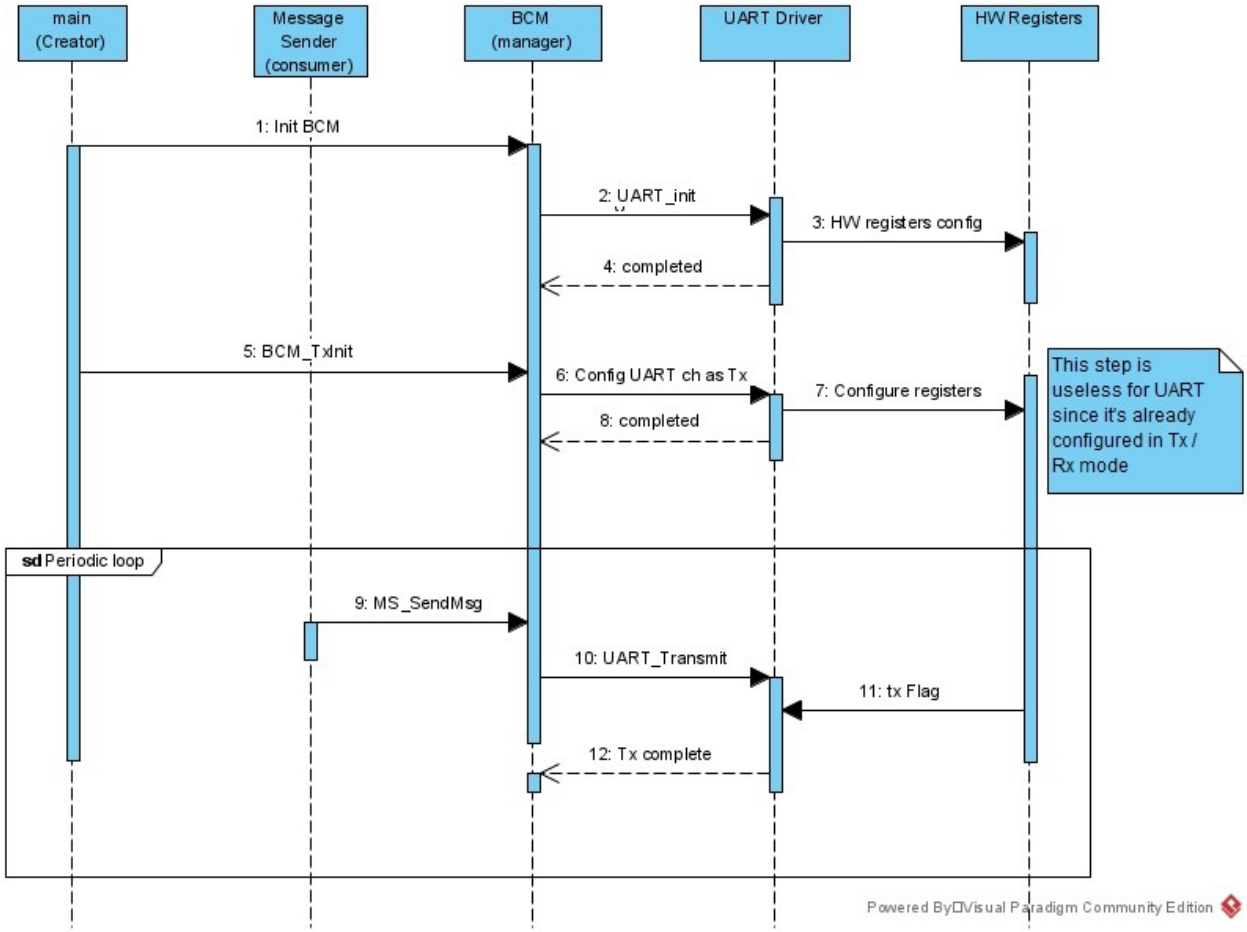
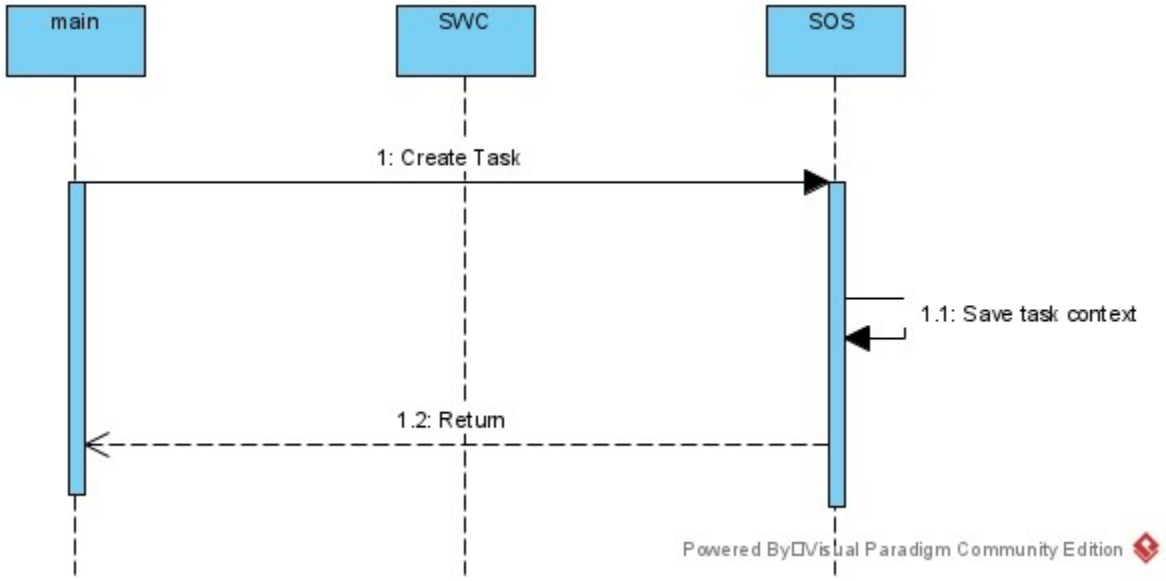
- *BCM Tx*

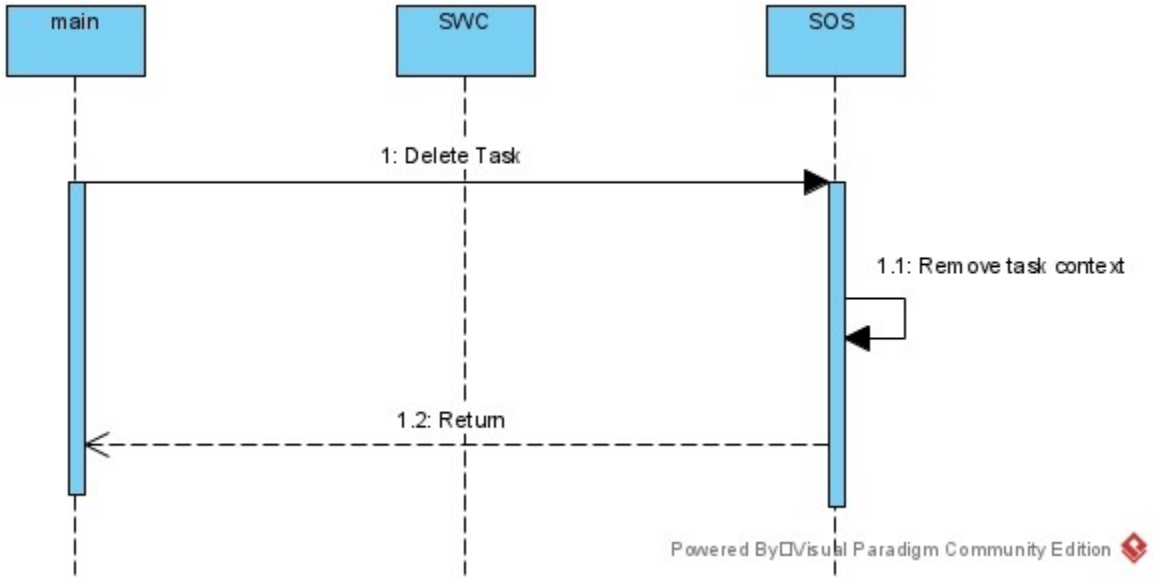


- *SO*S

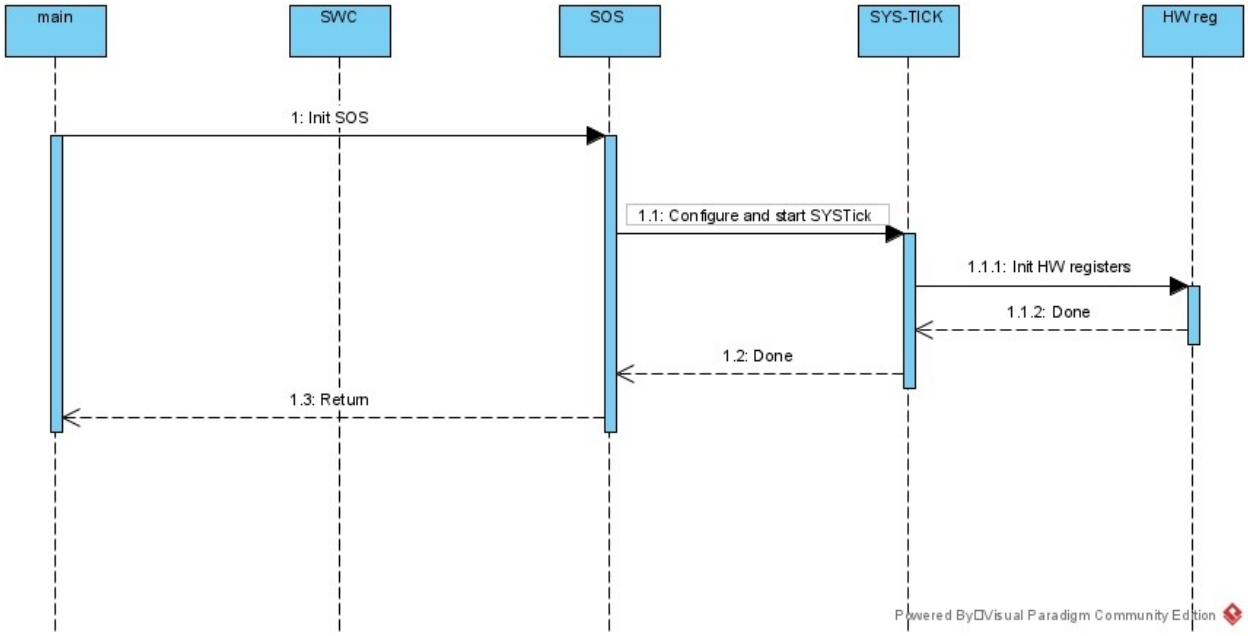
SOS Create Task



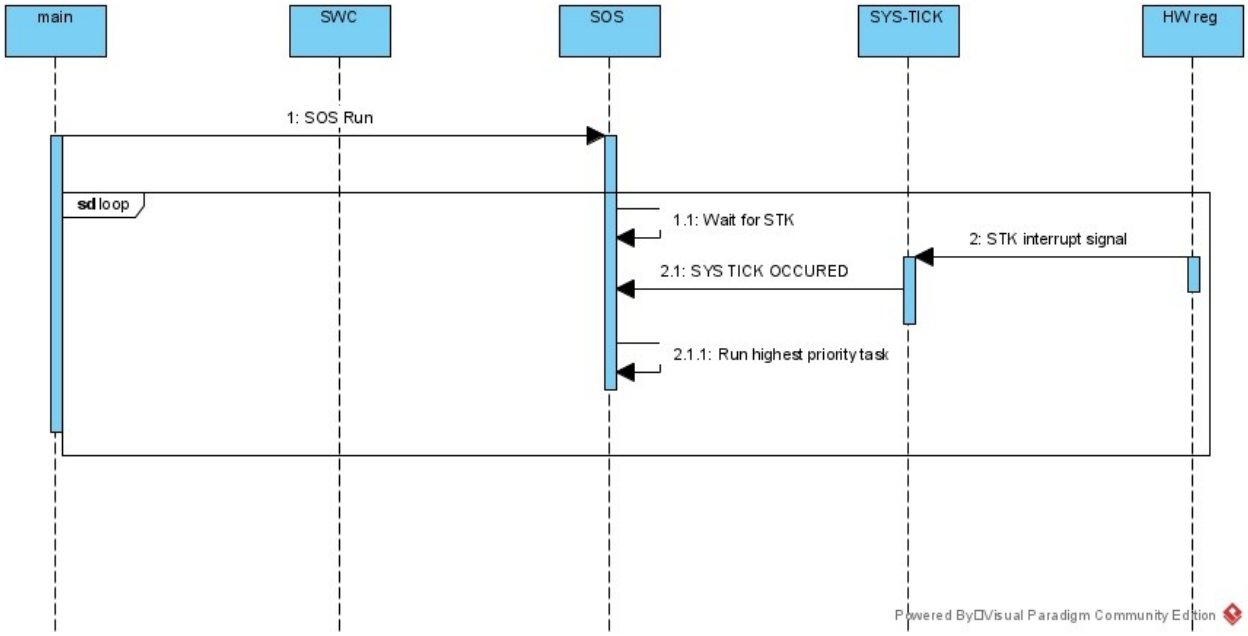
SOS Delete Task



SOS init



SOS Run


main
SWC
SOS
SYS-TICK
HW reg
1: SOS Run
sd loop
1.1: Wait for STK
2: STK interrupt signal
2.1: SYS TICK OCCURED
2.1.1: Run highest priority task
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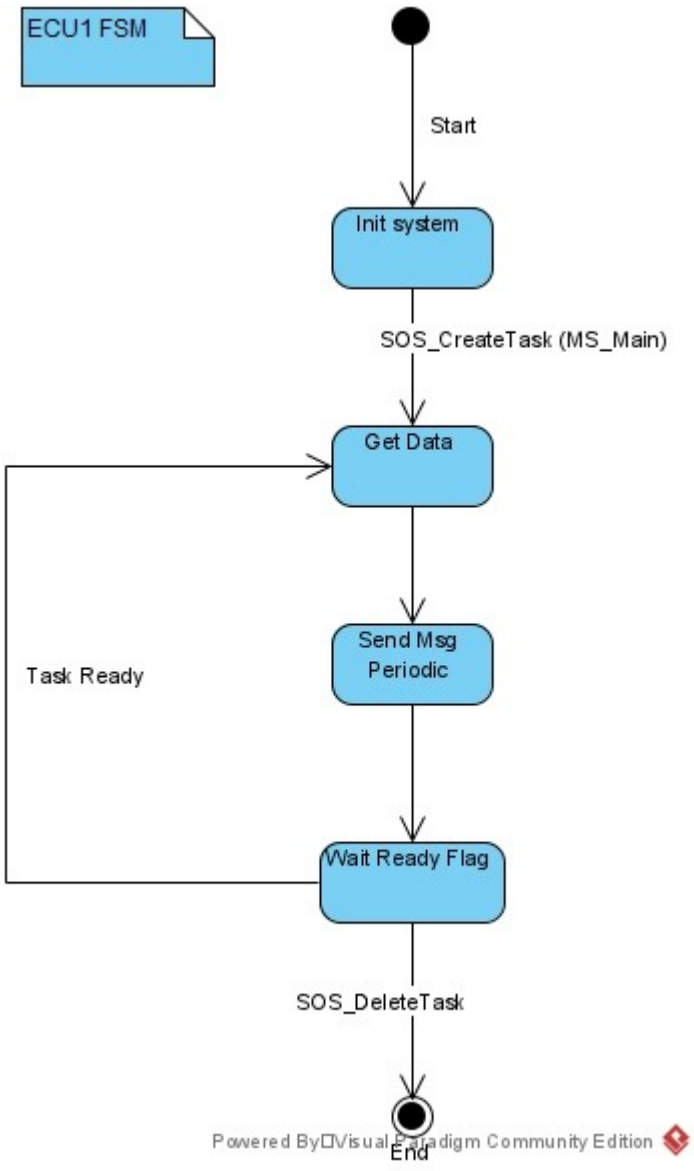
b. FSM


ECU1 FSM
Start
Init system
SOS_CreateTask (MS_Main)
Get Data
Send Msg
Periodic
Task Ready
Wait Ready Flag
SOS_DeleteTask
End
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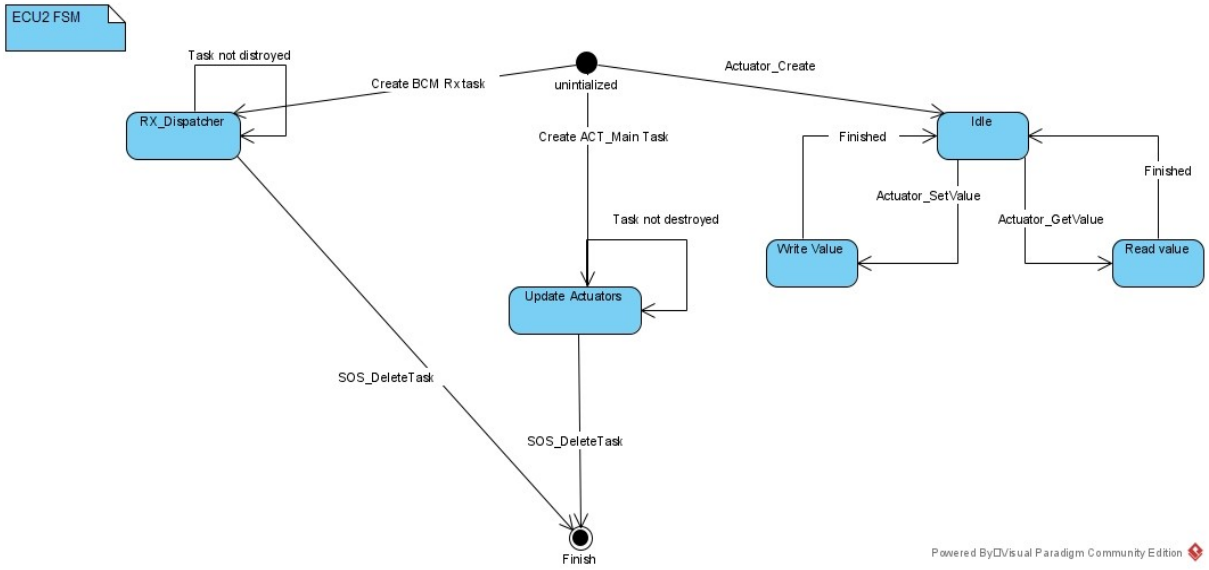
- ECU1

- ECU2


ECU2 FSM
Task not distroyed
Create BCM Rx task
unintialized
Actuator_Create
RX_Dispatcher
Create ACT_Main Task
Finished
Idle
Finished
Actuator_SetValue
Actuator_GetValue
Task not destroyed
Write Value
Read value
Update Actuators
SOS_DeleteTask
SOS_DeleteTask
Finish
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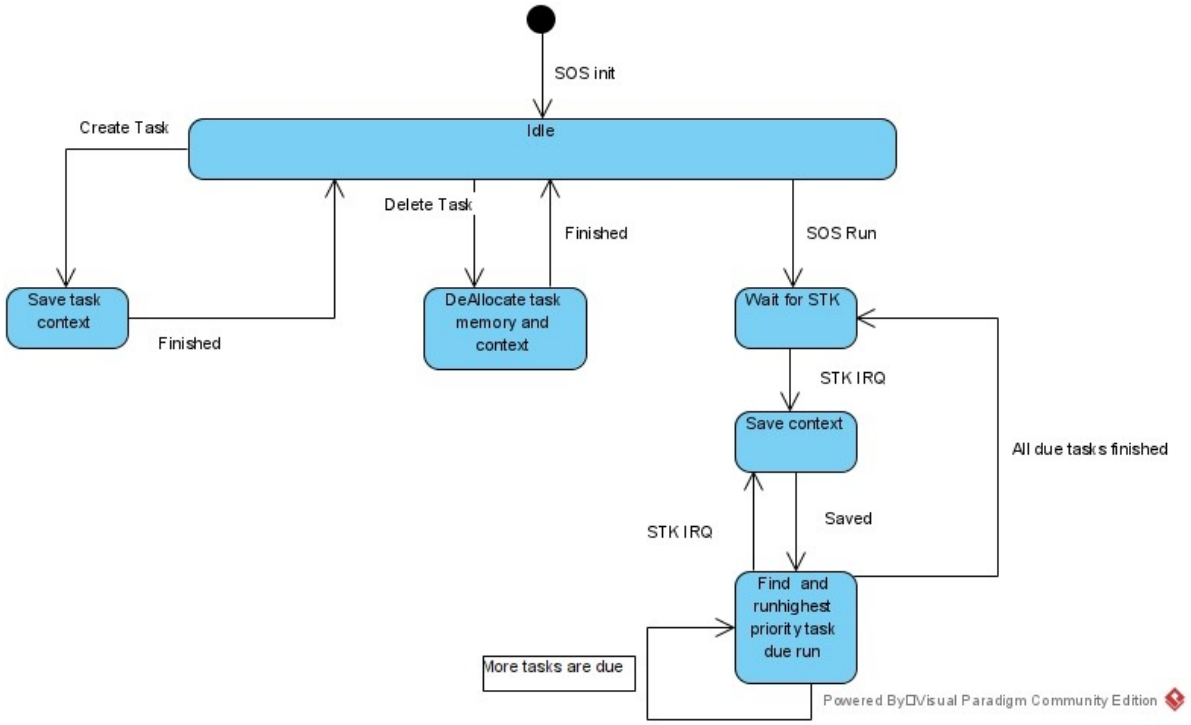
- SOS


SOS init
Idle
Create Task
Delete Task
Finished
SOS Run
Save task context
Finished
DeAllocate task memory and context
Wait for STK
STK IRQ
Save context
All due tasks finished
Saved
STK IRQ
Find and runhighest priority task due run
More tasks are due
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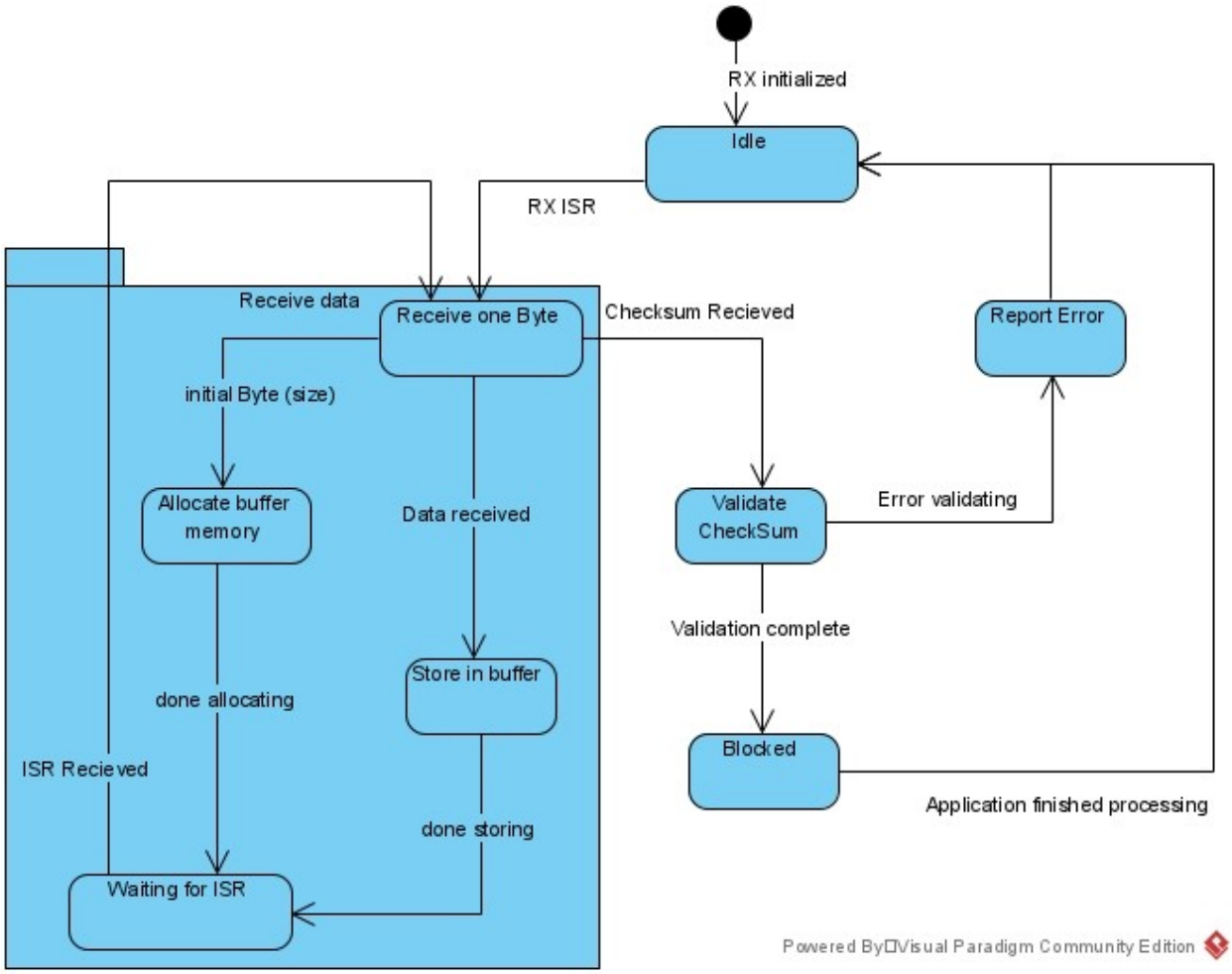
- BCM Receiver



c. Folder Structure

- *ECU1*

- Documentation
- SW
  - BSW
    - MCAL
      - DIO
      - UART
      - ADC
    - ECUAL
      - LightSensor
      - SpeedSensor
      - DoorSensor
    - Services
      - SOS
      - BCM
  - COMMON

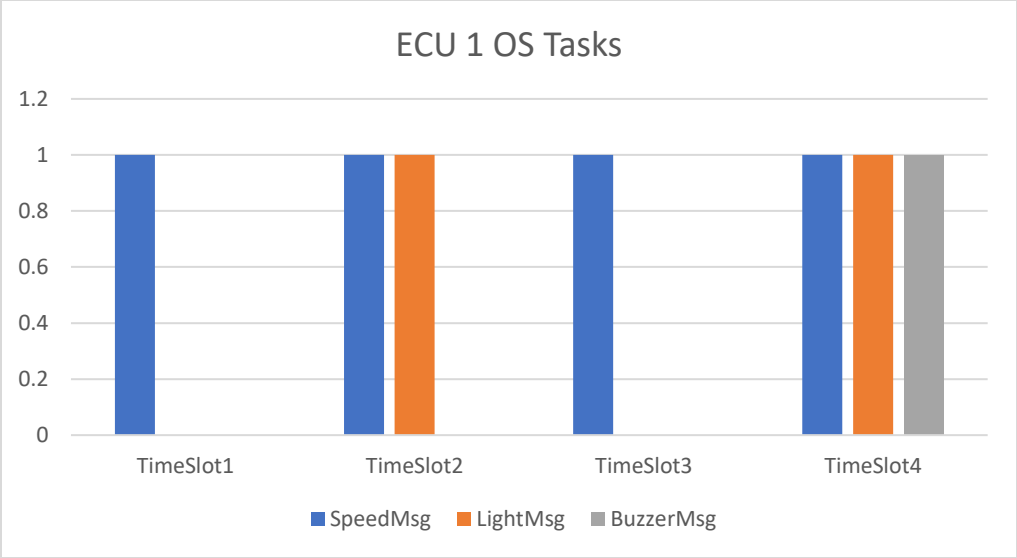
        - STD_Types
        - Bit_Math
        - CompilerAbstraction
        - PlatformTypes
    - SWC
        - MessageSender
        - Observer
- Build
    - MakeFile

- *ECU2*
- Documentation
- SW
    - BSW
        - MCAL
            - DIO
            - UART
        - ECUAL
            - LightsHandler
            - BuzzerHandler
        - Services
            - SOS
            - BCM
    - COMMON
        - STD_Types
        - Bit_Math
        - CompilerAbstraction
        - PlatformTypes
    - SWC
        - MessageReceiver
        - Actuator
- Build
    - MakeFile

d. CPU Load and Bus Load

i. ECU1

According to system requirements ECU1 will send at least one message every 5ms Time slots can be represented as follow given that a system tick = 5ms

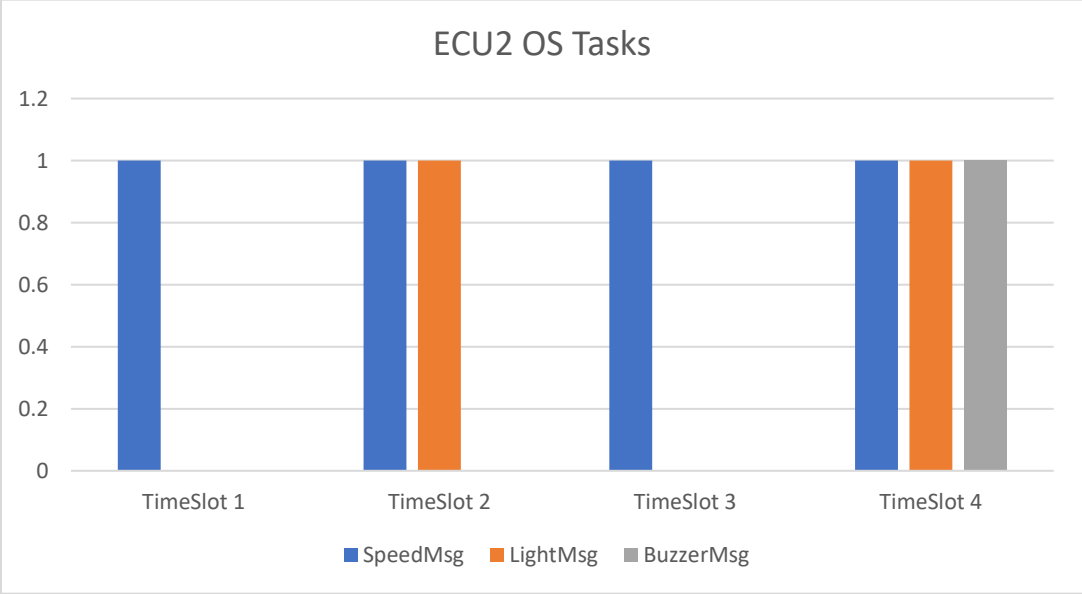


Assuming that each msg is processed in 100 us and sent over UART network in 100us. The Cpu utilization over repetitive 4 time slots = ((200 + 400 + 200 + 600) us /20 ms)* 100 % = 7% not considering wakeup and sleep events.

And Bus load will only equal the propagation time of messages
= ((100+200+100+300) us / 20 ms)*100% = 3.5%

ii. ECU2

According to system requirements ECU2 will receive a message at least every 5 ms thus it can be represented as follows:



It only processes the messages just like ECU1 so the load on CPU and bus is almost the same.