



BLE KEYFOB™

Hardware and Installation Guide



Version 1.0.0

SEPTEMBER 1, 2015

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Compliance Statement (Part 15.19)

The enclosed hardware device complies with the Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received including interference that may cause undesired operation.

FCC ID: APV-FOB10
IC ID: 5843C-FOB10
M/N: FOB10-BL

Manufacture: CalAmp Corp.

Warning (Part 15.21)

Changes or modifications not expressly approved by CalAmp could void the user's authority to operate the equipment. Manufacturer is not responsible for any radio or TV interference caused by unauthorized modifications to this equipment.

Compliance Statement (Part 15.105(b))

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

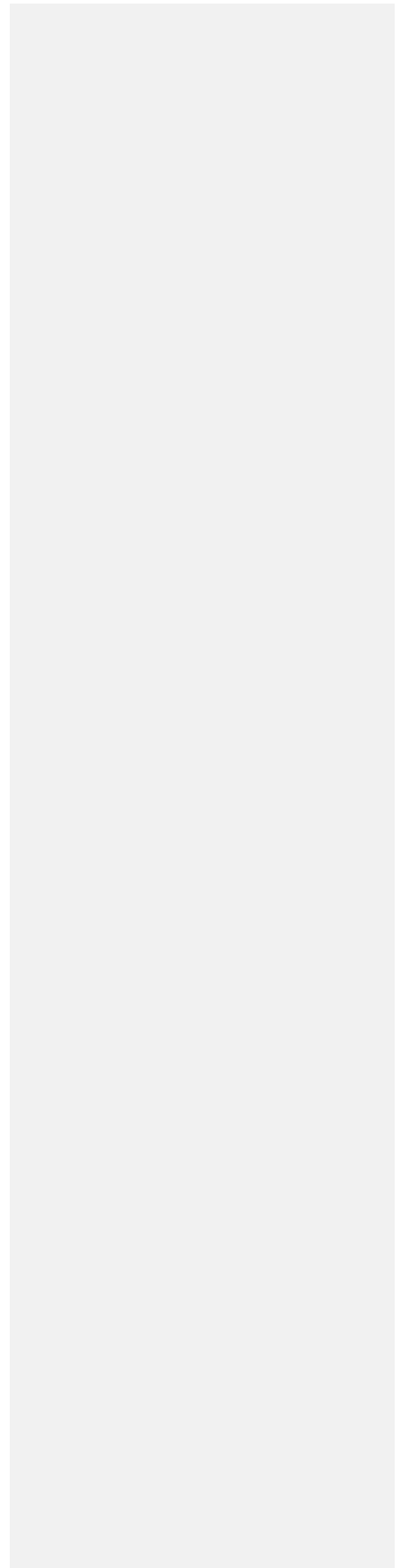
- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Industry Canada (IC) regulatory information

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement

CAN ICES-3 (B)/NMB-3(B)



Driver ID Keyfob system design

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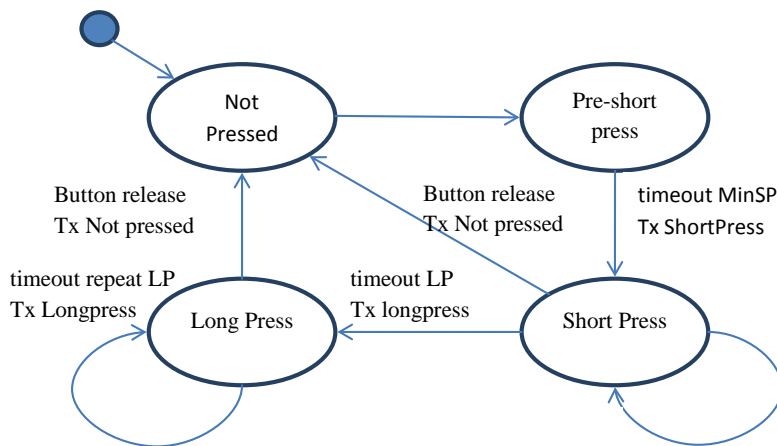
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Key Fob button pushes

Button state machine ignoring debouncing

Warning: Any key press event with time interval shorter than 1s is not going to be reliably received by LMU FOB module when LMU BT driver is operating in Scan advert mode.

The state diagram below will only work if the KeyFob is connected to BTDB.



button state coded as 2 bits

Not pressed	00
Pre-short press	01
Short Press	10
Long Press	11

The three buttons are bit coded into a single button state byte 0 0 b3 b3 b2 b2 b1 b1

Configuration for each button

configuration	units / bit	size (bytes)	default
Event Generation mask	(see below)	1	00111100 Generate events on releasing button from short press & when long pressed & keep generating long press events until button is released.

Event generation mask for each button coded as 1 byte

description	mask (top 2 bits are reserved)
generate message on min short press timeout	00xxxxx1
generate message on short press repeat timeout	00xxxx1x
generate message on short press release	00xxx1xx
generate message on long press timeout	00xx1xxx
generate message on long press repeat timeout	00x1xxxx
generate message on long press release	001xxxxx

Keyfob configuration

Stored on individual Keyfobs.

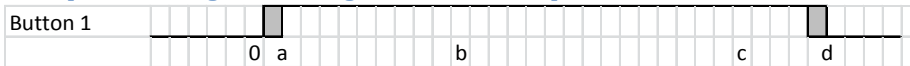
	units / bit	size (bytes)	default
Short Press minimum	100ms	1	2
Short Press Repeat	100ms	1	2
Long Press time	100ms	1	15
Long Press Repeat	100ms	1	5
beacon interval	1ms	1	8750
beacon duration after keypress	1s	1	0 (always and forever)
CID	n/a	2	0xFFFF (0xFFFF is special case and is always processed) otherwise this CID must match the CID in the LMU
Tx power	db	1	0
Low Battery LED blink %	%	1	20
Button push LED blink	n/a	1	0x07 all 3 buttons cause blink when pressed (0x0f if 4 buttons)
Config button 1 (see above)	n/a	1	0x3c
Config button 2 (see above)	n/a	1	0x3c
Config button 3 (see above)	n/a	1	0x3c
reserved (for 4 th button)	n/a	1	0x00

OTP (factory set configuration)

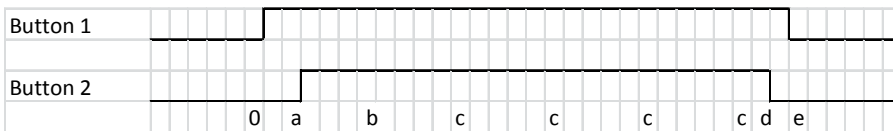
Description	size (bytes)	default
Cal Id	2	0xca1a (** to be confirmed by BT SIG)
tx power calibration	4 (1 for each available power level)	measured during ATE

Keyfob button timing diagrams for common scenarios.

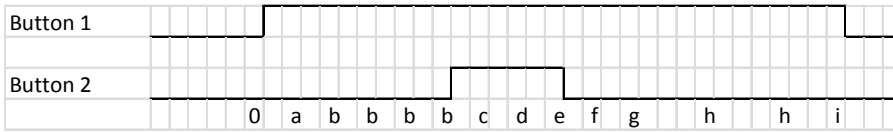
Short press showing de-bouncing other buttons not pressed.



- 0) Button is pushed at time zero.
- a) After de-bouncing button is determined as pressed but no message is generated.
- b) After 'short press minimum time' a short press event is generated and if configured a message is broadcast with button state 0b00000010 and reason code 0b00010001.
- c) After 'short press repeat time' a short press repeat event is generated and if configured a message is generated with button state 0b00000010 and reason code 0b00010001.
- d) After Button is released and de-bounced a button release event is generated and if configured a message is generated with button state 0b00000000 and reason code 0b00110001



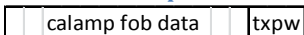
- 0) Button 1 is pushed
- a) Button 2 is pushed before 'short press minimum time' for button 1. Because button 2 is pushed before 'short press minimum time' Buttons 1 and 2 are now considered as grouped for the purposes of the reason code.
- b) Short press minimum time elapses on both button 1 and 2 if configured a message is broadcast with button state 0b00010010 and a reason code of 0b00010011
- c) The short press repeat time passes for buttons 1 and 2; if configured a message is generated with button state 0b00001010 and a reason code of 0b00010011.
- d) button 2 is released if configured a message is generated with button state 0b00000010 and reason code 0b00110010
- e) Button 1 is released if configured a message is generated with button state 0b00000000 and reason code 0b00110001



- o) Button 1 is pushed
- a) Button 1 'short press minimum time'; a short press event is generated and if configured a message is broadcast with button state 0b00000010 and reason code 0b00010001.
- b) Button 1 'short press repeat time'; a short press repeat event is generated and if configured a message is generated with button state 0b00000010 and reason code 0b00010001.
- c) Button 2 'short press minimum time'; a short press event is generated and if configured a message is broadcast with button state 0b00001010 and reason code 0b00010010.
- d) Button 1+2 'short press repeat time'; a short press repeat event is generated and if configured a message is generated with button state 0b00001010 and reason code 0b00010011.
- e) Button 2 'released'; a button release event is generated and if configured a message is generated with button state 0b00000010 and reason code 0b00110010
- f) Button 1 'short press repeat time'; a short press repeat event is generated and if configured a message is generated with button state 0b00000010 and reason code 0b00010001.
- g) Button 1 'long press time'; a long press event is generated and if configured a message is generated with button state 0b00000011 and reason code 0b00100001.
- h) Button 1 'long press repeat time'; a long press repeat event is generated and if configured a message is generated with button state 0b00000011 and reason code 0b00100001.
- i) Button 1 'released'; a button release event is generated and if configured a message is generated with button state 0b00000000 and reason code 0b00110000.

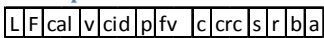
LMU-FOB comms

Advertisement packet contents



The advertisement consists of at least 2 parts from GAP specification, Manufacturer Specific Data called 'calamp fob data'; and Tx Power Level called txpw.

Calamp Fob data contents



note: now using the MAC address as the fob ID.

	size (bytes)	Description	default
L	1	length of this data	0x10
F	1	Manufacturer Specific Data as defined in GAP	0xff
cal	2	Calamp manufacturer ID set by us to distinguish our devices	0xca1a (big endian) TBC

v	1	version of this message	0x01
cid	2	Set by customer/provisioning to allow a single customer to differentiate their devices from the mass.	0x0000
p	1	App id;for the keyfob this is 0x01	0x01
fv	2	Version of keyfob firmware running on the keyfob.	0xnnbb (big endian) nn coded as packed binary coded decimal bb is version letter and running area (see below) 0x1308 is version "1.3e" running from low area
c	1	configuration version	
crc	2	crc of the keyfob configuration (defined above) that will include CID, button config etc . Actual crc polynomial TBD . This is to be used to determine if the configuration is as expected.	N/A
s	1	button state (see above)	0x00 no buttons pressed
r	1	advertisement old button state captured in previous time slot(see above)	0x00 beacon
b	1	battery state (%)	0x64 100%
a	1	RSSI @ 1 metre taking into account tx power level	n/a

Version letter encoding

version letter	bb for low area	bb for high area
'a'	0x00	0x01
'b'	0x02	0x03
'c'	0x04	0x05
'd'	0x06	0x07
.....		
'y'	0x30	0x31
'z'	0x32	0x33

txpw contents

L|P|p

	size (bytes)	Description	default
L	1	length of this data	2
P	1	Tx power as defined in GAP	0x0a
p	1	transmitted power of this	0xf6 (-10dB) **TBD

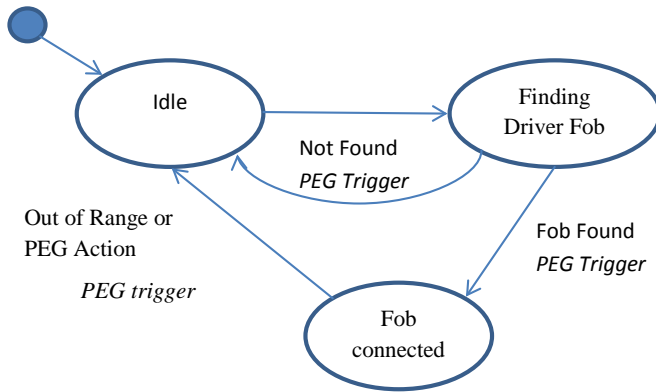
		advertisement (db)	
--	--	--------------------	--

Scan response packet contents

May contain uuids of services, name and any other static data.

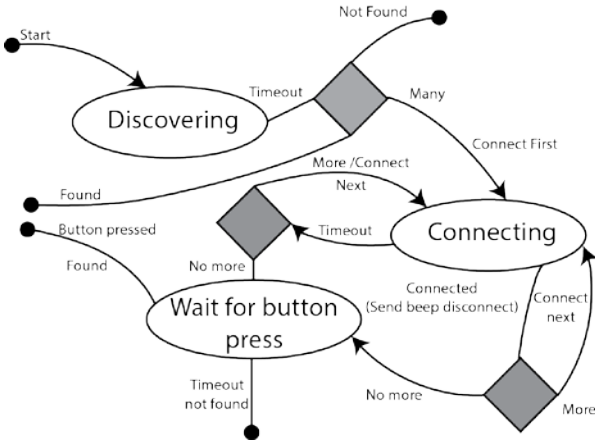
Overview of Bluetooth Automatic Driver ID process

State Machine for driver ID discovery



To mitigate contention where a FOB is in range of several LMUs the LMU will only look for FOBs when the PEG script executes PEG action.

State Machine for Finding Fobs using Beeps and Buttons



Description

- LMU is asleep saving power
- Key Fob(s) transmitting beacons (advertisement packets) every 10 seconds.
- Driver turns key in ignition (and wakes LMU)

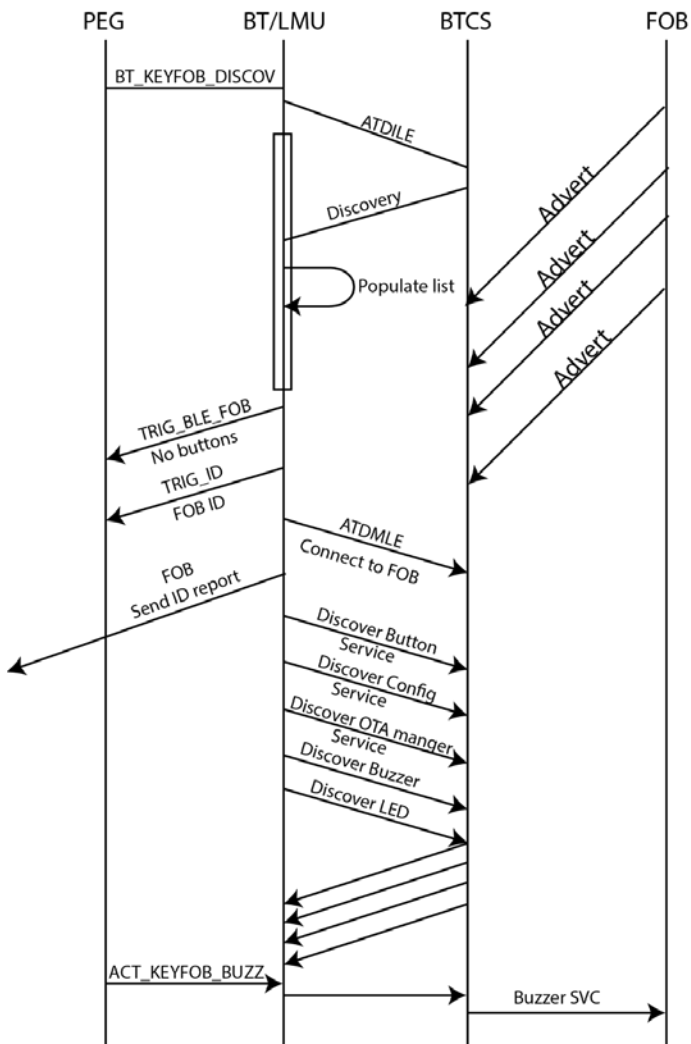
- Peg ignition trigger causes Peg BT_KEYFOB_DISCOVER action (TBD) for BT_KEYFOB_DISCOVER_TIME (configurable TBD) time.
- BT middleware starts discovery
- BT middleware populates discovered devices list including FOB ID and RSSI and TxPwr for all calamp keyfobs that match the BT_KEYFOB_CID (configurable 0-FFFE standard CID, FFFF is special case).
- BT middleware stops discovery after BT_KEYFOB_DISCOVER_TIME timeout
- BT middleware calculates path attenuation for all discovered keyfobs based on RSSI and TxPwr.
 - If a single KeyFob has (config TBD) smaller path attenuation [BT_KEYFOB_PATHATT] than all others, that key fob is selected as the driver's fob.
 - If a single KeyFob has advertised a button push that key fob is selected as the driver's fob.
 - Otherwise a set of candidate fobs is created from those fobs within BT_KEYFOB_PATHATT of the least attenuated.
 - if configured with BT_KEYFOB_USE_FOB_RSSI (config TBD) BT middleware connects in turn to each candidate fob and uses a config/control service to measure the RSSI at the fob
 - If a single KeyFob measures the RSSI with a 6dB/BT_KEYFOB_PATHATT less than all the rest this fob is selected as the driver's fob.
 - otherwise if configured with BT_KEYFOB_USE_FOB_BUTT (config TBD) BT Middleware connects to each candidate fob and requests the buzzer to sound for TBD on bench, start with 200 ms. BT middleware waits for BT_KEYFOB_QUERY_DRIVER_TIMEOUT (config TBD) for a button press response from the driver.
 - if button defined in BT_KEYFOB_USE_FOB_BUTT is received from a single fob, this fob is selected as the drivers fob
 - otherwise the driver's fob is set to null.
- if driver's fob is non null
 - BT Middleware invokes PEG TRIG_BLE_FOB (already used) trigger with a button code (TBD) as the modifier; having populated (config TBD) ACC_BLE_RSSI_HILO (already used) accumulator with RSSI and ACC_BLE_FOB_BATT (config TBD) (already used) with battery status.
 - BT Middleware invokes DID_DriverId_Event()(already used) with FOB ID (not MAC address) as the driver's ID
 - BT Middleware connects to Drivers fob and connects to the 'button notification' service; the 'LED' service; the 'Buzzer' service; and the 'Configuration' service.
 - button notification service provides the button state and reason codes as per advertisement packet.
 - while connected PEG actions ACT_KEYFOB_BUZZ (config TBD) cause BT-middleware to connect to the buzzer service(TBD) and sound the buzzer according to the modifier (TBD)

Comment [n1]: Optional for phase 2

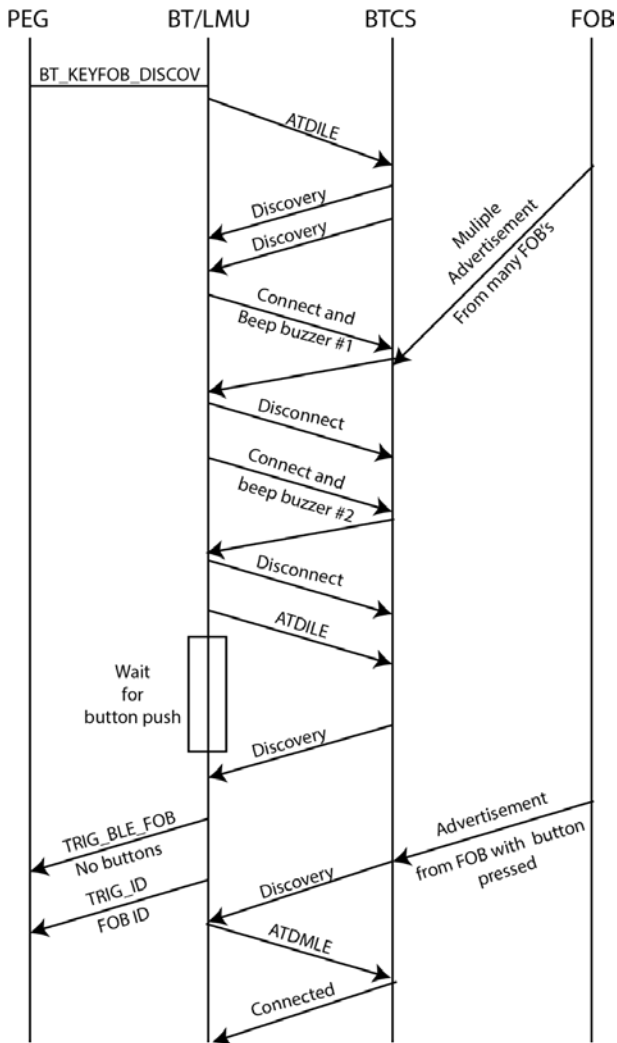
- while connected PEG actions ACT_KEYFOB_LED (config TBD) cause BT-middleware to connect to the led service(TBD) and sound the buzzer according to the modifier (TBD)
- While connected BT-middleware connects to config service(config TBD) and ota management service(config TBD) and constructs a PULS ID report with the fob id as the unique identifier and the LMU id as an agent(TBD).
- If required LMU will download new config or firmware for fob.
 - the BT-middleware will contact the config service to update the config as necessary
 - the BT-middleware will contact the OTA service and update firmware as necessary
 - the BT-middleware will restart the fob firmware using the keyfob control(TBD) service
 - Note: no settings changes take effect without reset. Reset drops the connection.
- BT-Middleware monitors the connection. If the connection drops BT-middleware invokes PEG TRIG_BLE_FOB (already used) trigger and DID_DriverId_Event()(already used)

Sequence diagram of discovery of driver id when only one fob in range

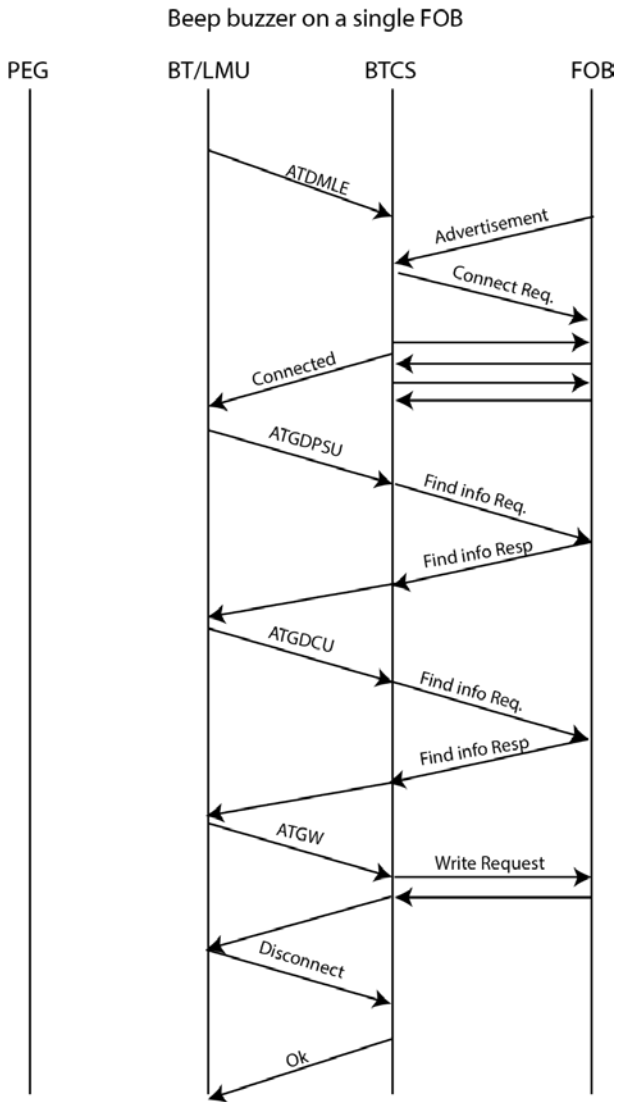
Discovery one FOB in range or one FOB has much less attention



Sequence Diagram of discovery of driver ID using buzzer and button
 Discovery FOB using buzzer and button push



Sequence diagram of connecting to a single fob to sound buzzer during driver id discovery



Bluetooth LE services

Service Name	Attribute Name	r/w	size (bytes)	notes
LED				New custom primary service
	pattern	r/w	3	Characteristic that defines the blink pattern 1 st byte on time; 2 nd byte off time; 3 rd byte blink pattern least significant bit first is shifted to the LED; bit 1 implies on; LED turned off at end of pattern
Buzzer				New custom primary service
	pattern	r/w	3	as above
Button				New custom primary service
	button	r	2	1 st byte is the button state; 2 nd byte is the reason code identical to the advertisement packet
Config/control				New custom primary service
	Config	r/w	16	read write fob configuration
	reset	w	1	write to reset keyfob
	RSSI	r	8	RSSI of connection to LMU
OverAir download				existing TI service
	TBC			

New PEG triggers

Trigger	Modifier	Description
PEG TRIG_BLE_FOB	PEG_MOD_FOB_BUTTON	Existing trigger new modifier

New Trigger modifiers

Modifier	Description
PEG_MOD_FOB_BUTTON	TBD probably the reason code from advertisement with extra for 'fob out-of-range' value

New PEG actions

Action	Modifier	Description
ACT_BT_KEYFOB	0 – DISCOVER/CONNECT 1 – HUP	Start discovery for a period of time
ACT_BT_LISTSEND	0NONE	send list of discovered keyfobs to server in an app message
ACT_KEYFOB_OUTPUT	B7-b6: Output Dest 0 – LED 1 – BUZZER B5-b4: Pattern 0 – Slow 1Hz 1 – Fast 5Hz B3-b0: count	beep buzzer count (up to 4) times
	None	disconnect FOB

Params

	size (bits)	Desc
BT_KEYFOB_DISCOVER_TIME	16	Discovery time period (30)
BT_KEYFOB_CID	16	filter for customer's keyfobs default (0x0000)
BT_KEYFOB_PATHATT	8	a single keyfob needs to have a greater RSSI than all other discovered keyfobs; exceeding by at least this configured amount
BT_KEYFOB_MODE	8	9 = USE_FOB_RSSI 10 = USE_FOB_BUTT
BT_KEYFOB_QUERY_DRIVER_TIMEOUT	8	1s/bit wait for this long to see button press
BT_KEYFOB_USE_FOB_BUTT	8	0-3 configures which button on the fob is designated as the driver's response button
ACC_BLE_RSSI_HILO	8	configure which accumulator holds RSSI of driver's fob
ACC_BLE_FOB_BATT	8	configure which accumulator holds battery status of driver's fob

Comment [n2]: Use Existing Bluetooth Mode configuration and have two enumerations for FOB use, 1 for Use FOB RSSI and 1 for Use FOB BUTT

Comment [n3]: NF check understanding. Should have new accumulator type BLE_RSSI.

Comment [n4]: As per comment above.

Driver's FOB Out-of-Range

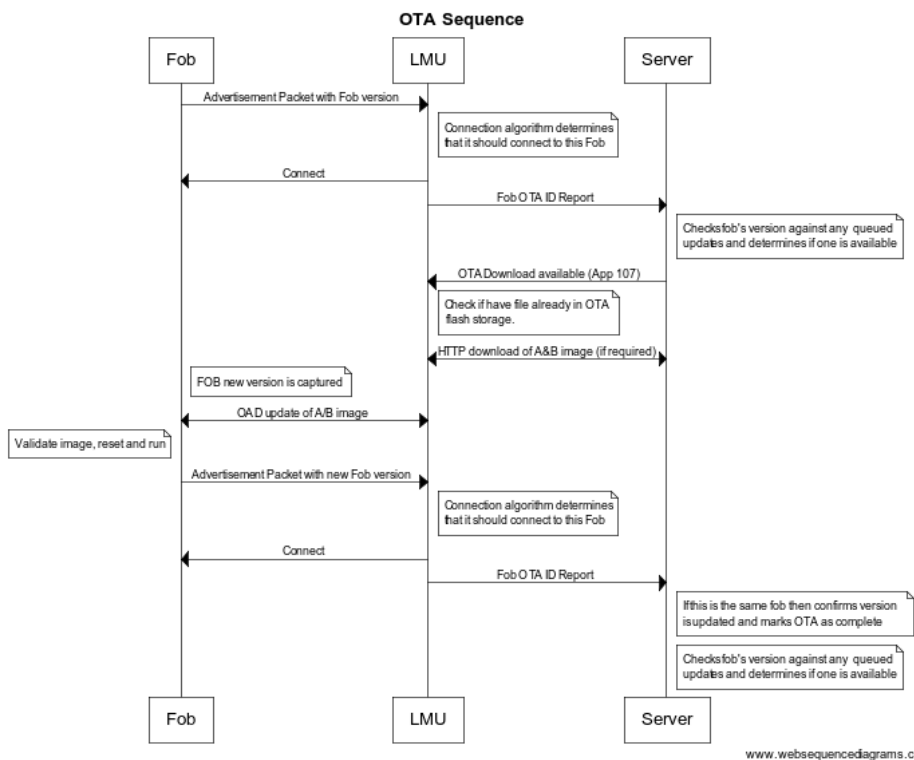
'Disconnect' from BTCS is used to signal to LMU that driver's ID is no longer valid.

option 1) New/existing Peg trigger to allow peg to decide to rescan () and send a logoff message to server.

option 2) If Ignition is still on, rescan automatically and follow driver ID discovery process.

option 3) Both of the above

Over the Air Update



Note that it is possible that a different fob could be connected after an OTA upgrade, and so the next ID report for the upgraded fob will not be until the next time it is used.

Generated (<https://www.websequencediagrams.com/#>):

For Style: use "Plain UML" style.

title OTA Sequence

Fob->LMU: Advertisement Packet with Fob version

note right of LMU: Connection algorithm determines that it should connect to this Fob

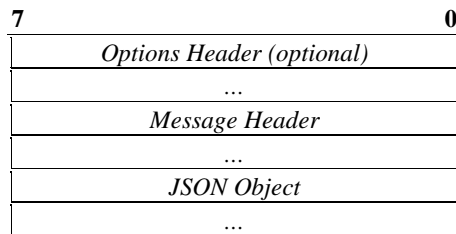
LMU->Fob: Connect

LMU->Server: Fob OTA ID Report
 note right of Server: Checks fob's version against any queued\nupdates and determines if one is available
 Server->LMU: OTA Download available (App 107)
 note right of LMU: Check if have file already in OTA\n flash storage.
 LMU->Server: HTTP download of A&B image (if required)
 note right of Fob: FOB new version is captured
 LMU->Fob: OAD update of A/B image
 note left of Fob: Validate image, reset and run
 Fob->LMU: Advertisement Packet with new Fob version
 note right of LMU: Connection algorithm determines\nthat it should connect to this Fob
 LMU->Fob: Connect
 LMU->Server: Fob OTA ID Report
 note right of Server: If this is the same fob then confirms version\nis updated and marks OTA as complete
 note right of Server: Checks fob's version against any queued\nupdates and determines if one is available

Format of Fob OTA ID report

This is the LM Direct ID report for the Bluetooth fob that is sent from the LMU to PULS.

The PULS ID report for the Bluetooth fob will use LM Direct Message type 13 which is a Device Version Report Message. This message type was created for the Android MDT but can be reused by changing the device type in the message body.



Device Version Report Message Format

The message body (following the Message Header) consists of a single JavaScript Object Notation (JSON) object, which for the fob will contain three JSON structures. The names and contents of each structure are summarized in the table below:

Name	JSON type	Contents
"ids"	array	Device type for Bluetooth fob (13), Hardware version (key fob app id = 1), MAC ID, Firmware file type (0), Firmware version

Name	JSON type	Contents
"extensions"	object	"OTA": "<protocols> <device type>;<supported file types>", "OTASTAT": "<OTA ID>,<device type>,<file type>,<state code>,<diagnostic code>,<additional status>"
"which"	array	The number of this message (starting from 1), the number of messages in the report

The OTA ID field in the OTASTAT value is initialised to 00000000 and updated when any App 107 message is received.

The OTASTAT value will be reset to "00000000,13,0,0,0," at initialisation and for any fob ID report to PULS where the MAC ID does not match the previous (if any) fob ID report to PULS.

An example of the JSON object is:

```
{ "ids": [ 13, 1, "D05FB80DE12F", 0, "1.0a" ], "extensions": { "OTA": "1|13;0", "OTASTAT": "00000000,13,0,0,0," }, "which": [ 1, 1 ] }
```

Note that the order within JSON arrays is fixed, but the order in JSON objects is not fixed, and so for example the "ids" member is not necessarily the first member, and within the "extensions" object the "OTASTAT" name/value pair may precede the "OTA" name/value pair.

The example above decodes as follows:

Structure	Type	Value or Name:Value	Explanation
ids	array	13	Device type for Bluetooth fob
		1	Hardware version is the key fob app id
		"D05FB80DE12F"	MAC ID
		0	Firmware file type
		"1.0a"	Firmware version
extensions	object	"OTA": "1 13;0"	OTA attributes: supported protocols = 1 (HTTP) Device type = 13 (Bluetooth fob) Supported file types = 0 (Firmware)
		OTASTAT: "00000000,13,0,0,0,"	OTA status: OTAID = 00000000 (timestamp) Device type = 13 (Bluetooth fob) File type = 0 (Firmware) State code = 0 Diag code = 0 Additional status = "" (none)
which	array	1	This is message 1
		1	Number of messages in report is 1

Work Breakdown

Build Process

Firmware Version

Make sure that the build process automatically names the final binaries correctly and that there is exactly one place in the project that sets the version information.

Keyfob

Keyfob Over the air service

we are currently working on this.

Keyfob Advertisement packet

Fully populate with at least static data

Keyfob Button push advertisement

This includes different advertisement timing; detection of button states; and reason coding.

Keyfob configuration storage (done?? or only ATE)

Keyfob Config service

Keyfob measure rssi service/characteristic

This is measuring the rssi of the LMU/BTCS transmissions on the keyfob

Keyfob LED service

Keyfob Buzzer service

This should be implemented as a carbon copy of LED service reusing code as much as possible.

BTCS

ATDILE

ATDMLE

ATGDCU

LMU

LMU Over the air BT Client

??? what is needed ???

LMU Modified interaction with Puls new FOB_ID message

Includes designing the contents of this message and pretty documentation

LMU Modified 'file' Handling to allow LMU to 'cache' file.

LMU Keyfob config ??? Puls or params?

LMU passive scan for strongest keyfob

Includes creating a list of 'seen' keyfobs; adding parameters BT_KEYFOB_CID, BT_KEYFOB_DISCOVER_TIME; adding PEG action ACT_BT_KEYFOB_DISCOVER.

LMU report of 'seen keyfobs'

Includes PEG action ACT_BT_KEYFOB_LISTSEND to generate the report and pretty documentation of the report contents.

LMU selection of keyfob by measuring rssi on the key fob

Includes state machine to connect to each candidate keyfob and request RSSI measurement.

LMU selection of keyfob by beep and button on the key fob

Includes state machine to connect to each candidate keyfob and beep buzzer then wait for response.

LMU PEG trigger PEG TRIG_BLE_FOB

Trigger is done make needs to be integrated with new feature; add new button modifier.

LMU PEG action ACT_KEYFOB_BUZZ

Add new peg action

LMU PEG action ACT_KEYFOB_LED

Add new peg action

LMU PEG action ACT_BT_KEYFOB_HUP

Add new peg action to disconnect from current driver's fob