SamDunk

eMMC backdoor leading to bootloader unlock on Samsung Galaxy Devices
Discovered and documented by Sean Beaupre (beaups)

Affected products

This vulnerability affects certain bootloader-locked Qualcomm based Samsung Galaxy products containing Samsung eMMC. Tested and confirmed to unlock the bootloader of the Verizon Samsung Galaxy S5. While possibly every device containing a Samsung eMMC controller is vulnerable to the attack described below, it's usefulness as a bootloader unlock is likely limited to select Samsung Galaxy devices.

Samsung's unlock mechanism

Manufacturers employ a wide variety of methods and mechanisms to determine and control a device's bootloader lock status. Motorola uses TrustZone protected fuses, HTC uses data in a write protected region of eMMC, and some LG devices use a signed blob in the boot (kernel) partition. There are likely many other methods, but the concept is the same: only allow the unlock status to be changed via a controlled and deliberate method. Additionally, when unlocking the bootloader of most devices, the user's data partition is wiped to ensure that the unlock wasn't performed in attempt to maliciously gain access to a user's data.

In some cases, like most devices built for use on the Verizon network, the ability for a user to unlock the bootloader is blocked entirely. One such device was the Galaxy S5 used for this research. The Galaxy S5 (and probably some/many other Galaxy devices) uses a unique mechanism for determining a device's unlock/dev status. **As Researched and discovered by @ryanbg (http://forum.xda-developers.com/member.php?u=766721):**

> A blob in the aboot partition image is read and decrypted. Then, the device's eMMC CID is hashed and compared to the value of the decrypted blob. If they match, the device is considered unlocked.

Basically, at some point in the manufacturing process, when a device is configured to be a "dev-edition" device, Samsung hashes the device's eMMC CID, pads it, signs (or encrypts?) it with their private key, and places that signed data in the device's aboot partition. At every boot, aboot is able to verify that the device is actually a dev-edition device.

What is an eMMC CID? According to eMMC documentation:

> **"The Device IDentification (CID) register is 128 bits wide. It contains the Device identification information used during the Device identification phase (e•MMC protocol). Every individual flash or I/O Device shall have an unique identification number. Every type of**

> **e•MMC Device shall have a unique identification number.”**

Great! We can simply change the eMMC CID to match one from a factory dev-edition device, and then flash the aboot partition (containing the hashed and signed CID blob) from the same dev-edition device. Except, elsewhere in the eMMC documentation:

> **“Programming of the Device identification register. This command shall be issued only once. The Device contains hardware to prevent this operation after the first programming. Normally this command is reserved for the manufacturer.”**

Effectively, the CID is a serial number programmed at the factory and, according to the eMMC standard, is only programmable once. What “hardware” prevents the CID from being reprogrammed? Is it really stored in some OTP region? The fact that an eMMC contains mass amounts of non-volatile reprogrammable NAND memory should make any researcher skeptical that it is truly “write-once”.

Enter vendor commands

Generally speaking, vendor commands are commands/codes/instructions that don’t appear in any official standards and allow a host/user/factory/software to interact with a device in a non-standard way. Specifically for Samsung eMMC, a special (mostly) undocumented CMD62 in conjunction with some “secret” arguments are used. Some of Samsung’s vendor commands were publicly released by Samsung due to a software defect in their eMMC controller firmware. Samsung needed the linux/android kernel to be able to patch the eMMC firmware in realtime, and thus had to release and document some of their proprietary eMMC vendor commands:

https://android.googlesource.com/kernel/omap/+/3c57a612f12b069bbc863ec0c74a26850d76a9e8%5E!

Samsung provided a critical function for enabling further research: mmc_movi_read_cmd. With a simple loop of this function, we are able to dump the entire running firmware and ram of the eMMC controller.

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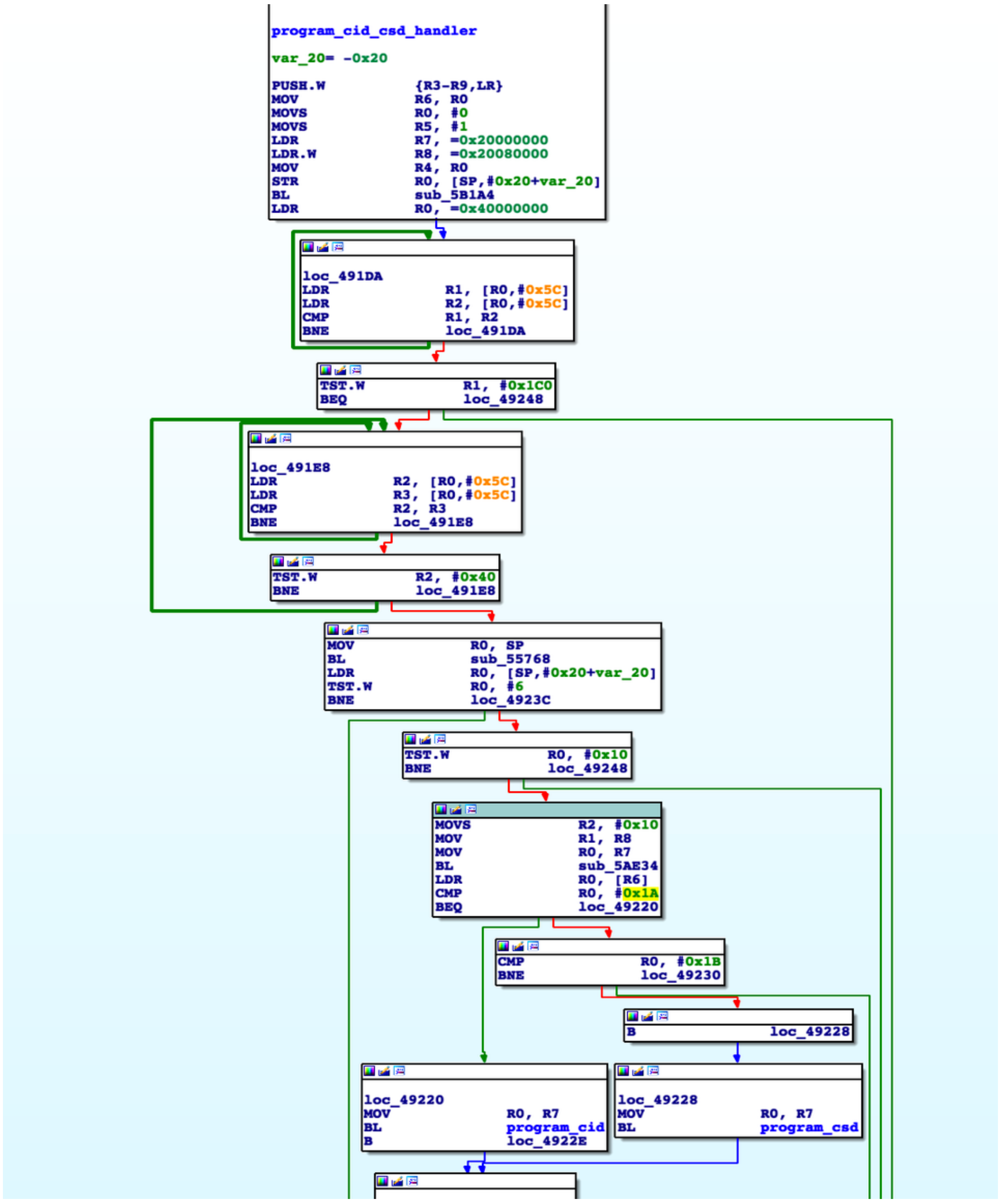
Finding something useful

The first step was to find what function in Samsung's firmware handled a host's PROGRAM_CID request. A quick (and quite lucky, as most eMMC commands use a function pointer table) search for the immediate value 26 (eMMC command 26 is PROGRAM_CID) reveals this:



```
program_cid_csd_handler

var_20= -0x20

PUSH.W          {R3-R9,LR}
MOV             R6, R0
MOVS            R0, #0
MOVS            R5, #1
LDR             R7, =0x20000000
LDR.W           R8, =0x20080000
MOV             R4, R0
STR             R0, [SP,#0x20+var_20]
BL              sub_5B1A4
LDR             R0, =0x40000000
```

```
loc_491DA
LDR             R1, [R0,#0x5C]
LDR             R2, [R0,#0x5C]
CMP             R1, R2
BNE             loc_491DA
```

```
TST.W           R1, #0x1C0
BEQ             loc_49248
```

```
loc_491E8
LDR             R2, [R0,#0x5C]
LDR             R3, [R0,#0x5C]
CMP             R2, R3
BNE             loc_491E8
```

```
TST.W           R2, #0x40
BNE             loc_491E8
```

```
MOV             R0, SP
BL              sub_55768
LDR             R0, [SP,#0x20+var_20]
TST.W           R0, #6
BNE             loc_4923C
```

```
TST.W           R0, #0x10
BNE             loc_49248
```

```
MOVS            R2, #0x10
MOV             R1, R8
MOV             R0, R7
BL              sub_5AE34
LDR             R0, [R6]
CMP             R0, #0x1A
BEQ             loc_49220
```

```
CMP             R0, #0x1B
BNE             loc_49230
```

```
B               loc_49228
```

```
loc_49220
MOV             R0, R7
BL              program_cid
B               loc_4922E
```

```
loc_49228
MOV             R0, R7
BL              program_csd
```

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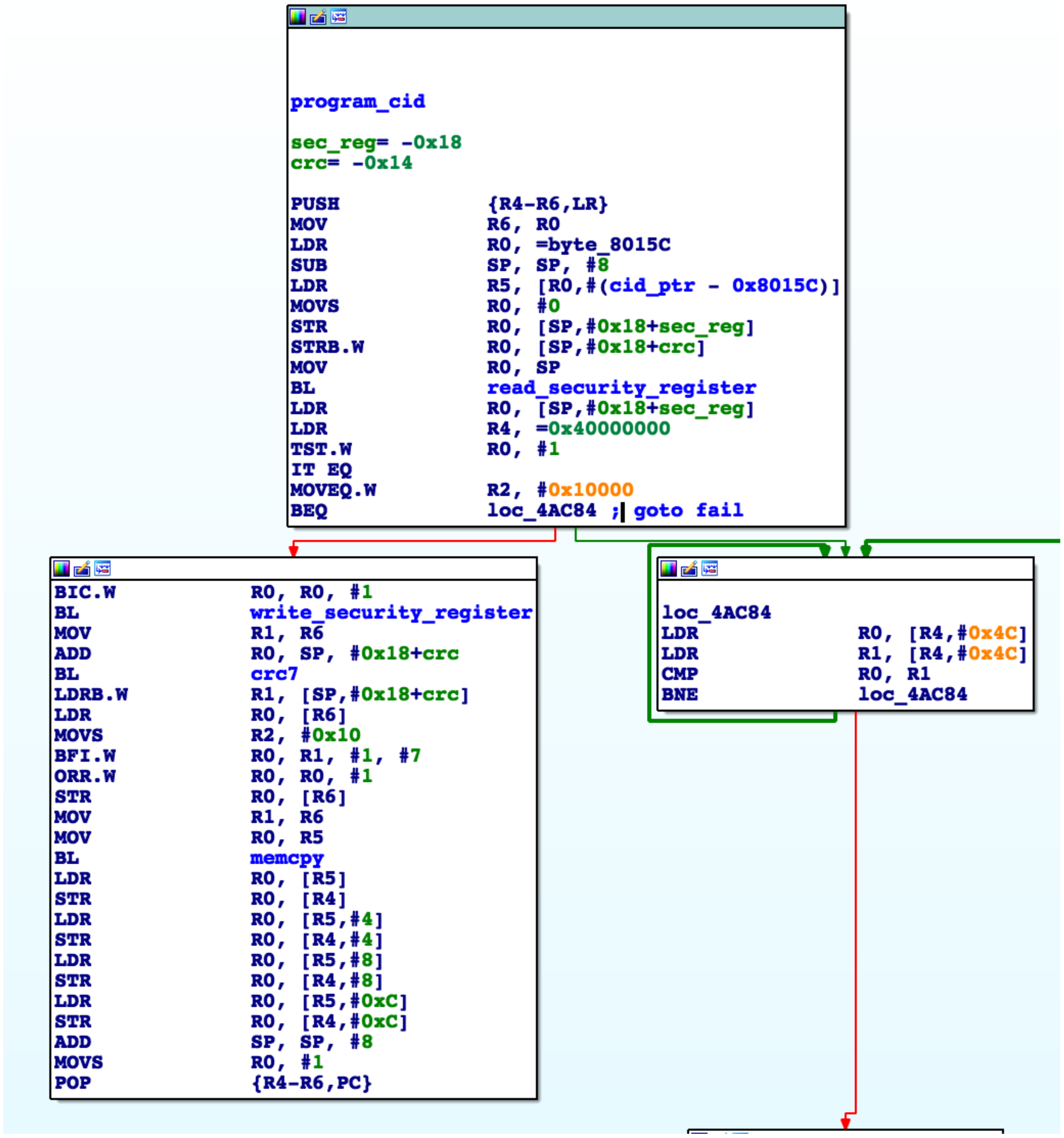
Some basic setup is done, then the opcode is checked to decide whether or not the host is trying to program the CSD register or the CID register. Since we are trying to reprogram the CID register, let's look at the program_cid function called when R0 = 0x1A (26):



```
program_cid

sec_reg= -0x18
crc= -0x14

PUSH                {R4-R6,LR}
MOV                 R6, R0
LDR                 R0, =byte_8015C
SUB                 SP, SP, #8
LDR                 R5, [R0,#(cid_ptr - 0x8015C)]
MOVS                R0, #0
STR                 R0, [SP,#0x18+sec_reg]
STRB.W              R0, [SP,#0x18+crc]
MOV                 R0, SP
BL                  read_security_register
LDR                 R0, [SP,#0x18+sec_reg]
LDR                 R4, =0x40000000
TST.W               R0, #1
IT EQ
MOVEQ.W             R2, #0x10000
BEQ                 loc_4AC84 ; goto fail
```

```
BIC.W               R0, R0, #1
BL                  write_security_register
MOV                 R1, R6
ADD                 R0, SP, #0x18+crc
BL                  crc7
LDRB.W              R1, [SP,#0x18+crc]
LDR                 R0, [R6]
MOVS                R2, #0x10
BFI.W               R0, R1, #1, #7
ORR.W               R0, R0, #1
STR                 R0, [R6]
MOV                 R1, R6
MOV                 R0, R5
BL                  memcpy
LDR                 R0, [R5]
STR                 R0, [R4]
LDR                 R0, [R5,#4]
STR                 R0, [R4,#4]
LDR                 R0, [R5,#8]
STR                 R0, [R4,#8]
LDR                 R0, [R5,#0xC]
STR                 R0, [R4,#0xC]
ADD                 SP, SP, #8
MOVS                R0, #1
POP                 {R4-R6,PC}
```

```
loc_4AC84
LDR                 R0, [R4,#0x4C]
LDR                 R1, [R4,#0x4C]
CMP                 R0, R1
BNE                 loc_4AC84
```

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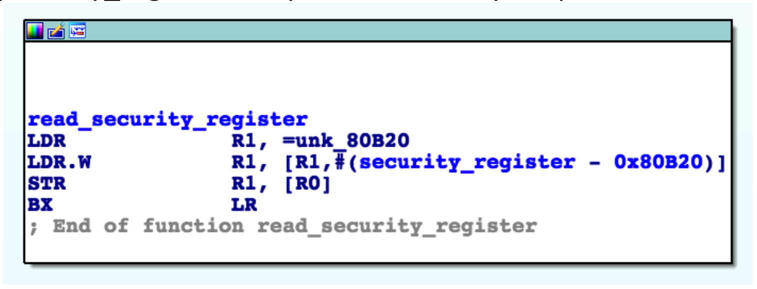
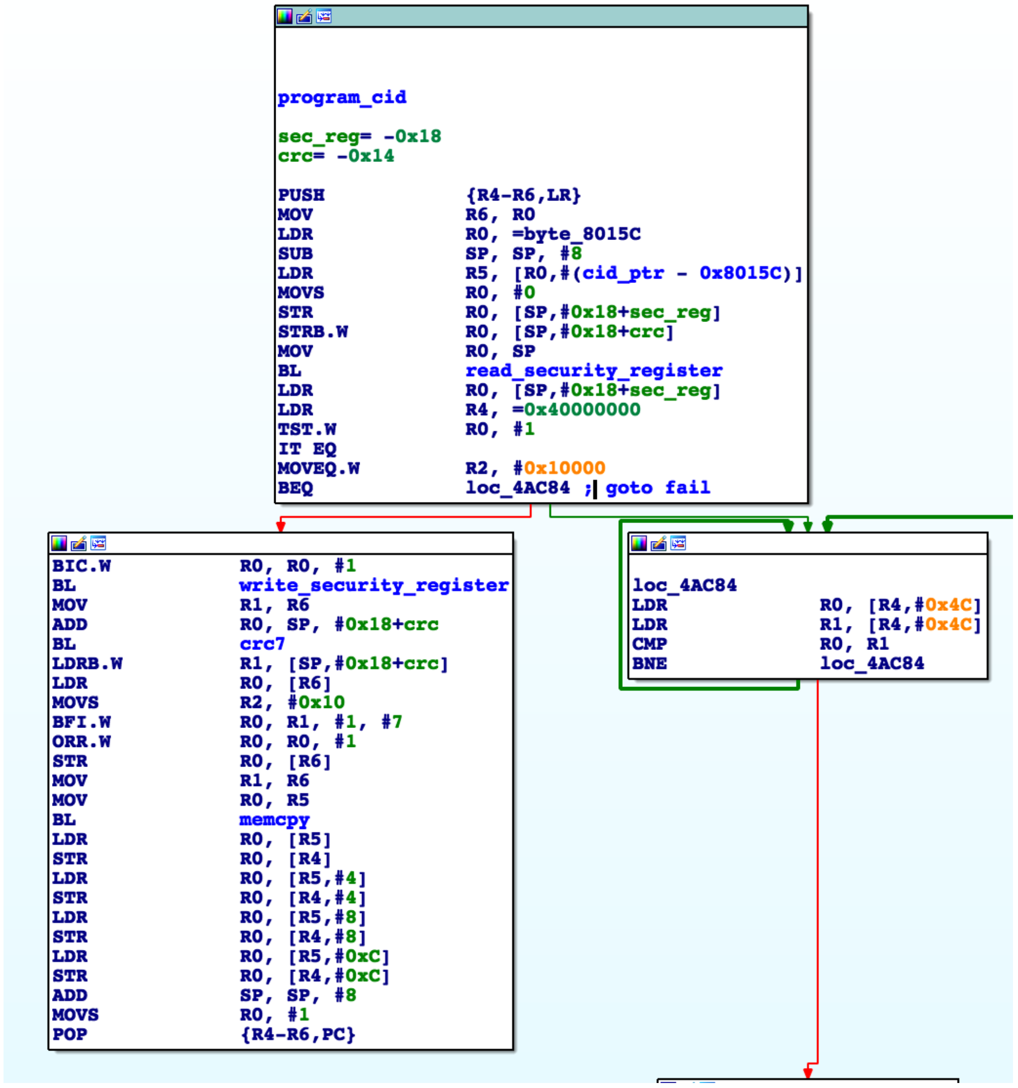
The function read_security_register is important and very simple:



```
read_security_register
LDR             R1, =unk_80B20
LDR.W           R1, [R1,#(security_register - 0x80B20)]
STR             R1, [R0]
BX              LR
; End of function read_security_register
```

It simply reads a value from ram, stores it in the caller's pointer, and returns. Back to the program_cid function:



```
program_cid

sec_reg= -0x18
crc= -0x14

PUSH            {R4-R6,LR}
MOV             R6, R0
LDR             R0, =byte_8015C
SUB             SP, SP, #8
LDR             R5, [R0,#(cid_ptr - 0x8015C)]
MOVS            R0, #0
STR             R0, [SP,#0x18+sec_reg]
STRB.W          R0, [SP,#0x18+crc]
MOV             R0, SP
BL              read_security_register
LDR             R0, [SP,#0x18+sec_reg]
LDR             R4, =0x40000000
TST.W           R0, #1
IT EQ
MOVEQ.W         R2, #0x10000
BEQ             loc_4AC84 ; goto fail
```

```
BIC.W           R0, R0, #1
BL              write_security_register
MOV             R1, R6
ADD             R0, SP, #0x18+crc
BL              crc7
LDRB.W          R1, [SP,#0x18+crc]
LDR             R0, [R6]
MOVS            R2, #0x10
BFI.W           R0, R1, #1, #7
ORR.W           R0, R0, #1
STR             R0, [R6]
MOV             R1, R6
MOV             R0, R5
BL              memcpy
LDR             R0, [R5]
STR             R0, [R4]
LDR             R0, [R5,#4]
STR             R0, [R4,#4]
LDR             R0, [R5,#8]
STR             R0, [R4,#8]
LDR             R0, [R5,#0xC]
STR             R0, [R4,#0xC]
ADD             SP, SP, #8
MOVS            R0, #1
POP             {R4-R6,PC}
```

```
loc_4AC84
LDR             R0, [R4,#0x4C]
LDR             R1, [R4,#0x4C]
CMP             R0, R1
BNE             loc_4AC84
```

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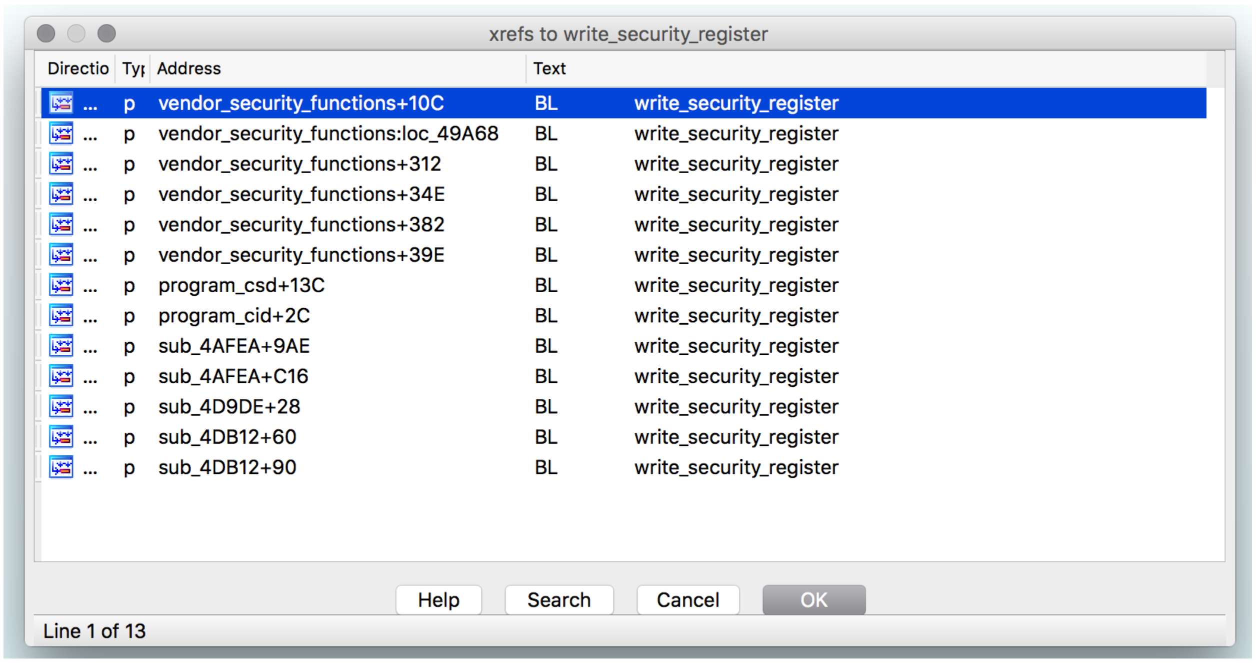
The security register is read and bit 0 is tested. If bit 0 is clear, a branch is taken to loc_4AC84, and ultimately the CID programming fails. If bit 0 == 1, the function continues:

1.) Bit 0 is cleared, and the security register is updated with the new value
2.) The CID is programmed

Surely this "security_register" can't be the "hardware to prevent this operation after the first programming" as described in the eMMC spcifications; it is simply a dword in the controller's RAM. How can we get bit 0 set in the security_register? A quick refs search to write_security_register answers this question quickly:

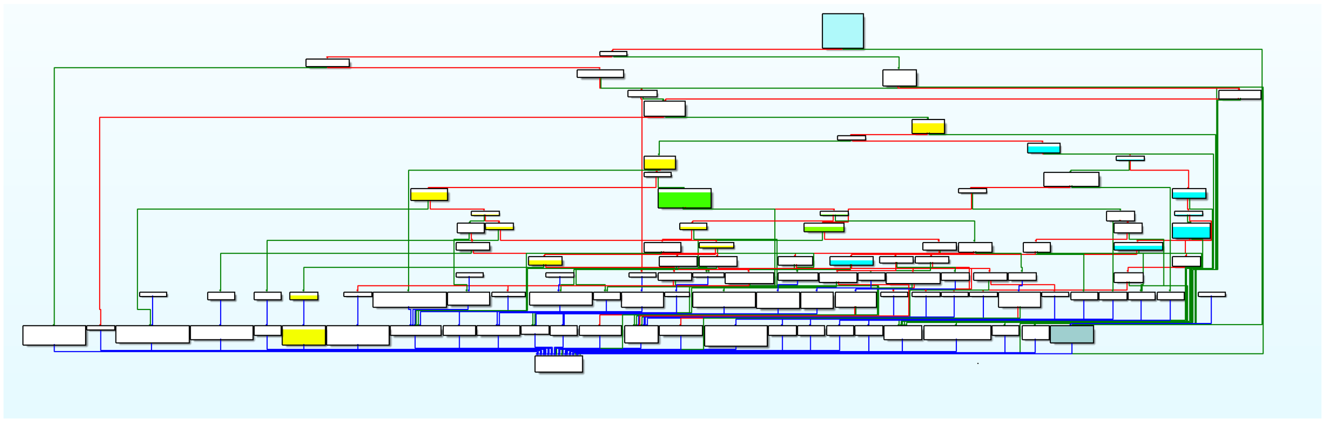


xrefs to write_security_register

Directio	Tyı	Address	Text	
...	p	vendor_security_functions+10C	BL	write_security_register
...	p	vendor_security_functions:loc_49A68	BL	write_security_register
...	p	vendor_security_functions+312	BL	write_security_register
...	p	vendor_security_functions+34E	BL	write_security_register
...	p	vendor_security_functions+382	BL	write_security_register
...	p	vendor_security_functions+39E	BL	write_security_register
...	p	program_csd+13C	BL	write_security_register
...	p	program_cid+2C	BL	write_security_register
...	p	sub_4AFEA+9AE	BL	write_security_register
...	p	sub_4AFEA+C16	BL	write_security_register
...	p	sub_4D9DE+28	BL	write_security_register
...	p	sub_4DB12+60	BL	write_security_register
...	p	sub_4DB12+90	BL	write_security_register

Line 1 of 13

vendor_security_functions() is a real mess:



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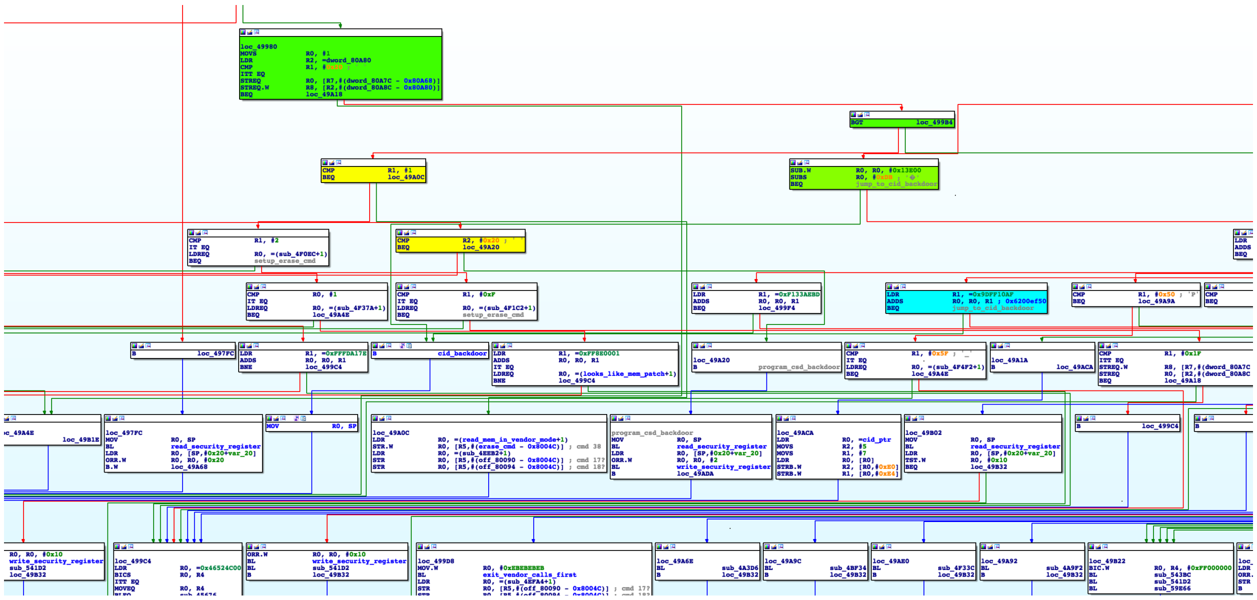
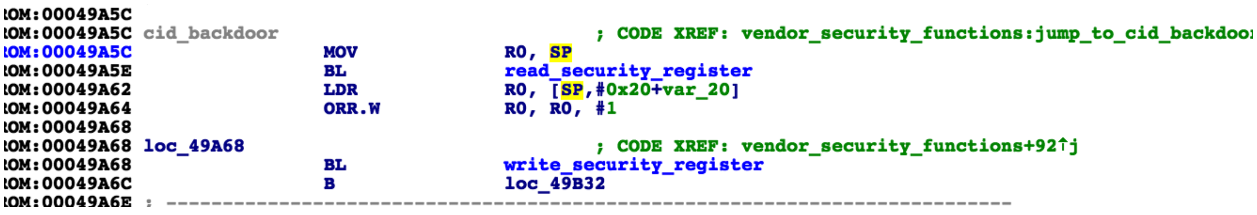
We need to find a call to write_security_register with a value of 1, to allow us to reprogram the CID. Zooming in:



Bingo:



```
ROM:00049A5C
ROM:00049A5C cid_backdoor                              ; CODE XREF: vendor_security_functions:jump_to_cid_backdoo
ROM:00049A5C                 MOV             R0, SP
ROM:00049A5E                 BL              read_security_register
ROM:00049A62                 LDR             R0, [SP,#0x20+var_20]
ROM:00049A64                 ORR.W           R0, R0, #1
ROM:00049A68
ROM:00049A68 loc_49A68                                 ; CODE XREF: vendor_security_functions+92↑j
ROM:00049A68                 BL              write_security_register
ROM:00049A6C                 B               loc_49B32
ROM:00049A6E ; ---------------------------------------------------------------------------
```

You can see very clearly, the security register is read, bit 0 is set, and the security register is updated, enabling programming of the CID.

Working backwards through the ~100 argument calculations in the vendor command handler, I'll simply state that the arg value that needs to be passed with the CMD62 is **0xEF50. Issuing the vendor command with argument 0xEFAC62EC followed by the vendor command with argument 0xEF50 is Samsung's backdoor to allow reprogramming of the eMMC CID.**

Doing the deed

I've pushed code to github to change the CID in Samsung eMMC using the backdoor described above: https://github.com/beaups/SamsungCID

Caveats (important):

1.) **It is generally a bad idea to do much with Samsung vendor codes from userspace, as you can not take a lock on the eMMC. The program_cid backdoor appears to be quite safe, but do NOT try to update the code to do operations such as reading/writing controller memory. You'll want to do that with a kernel module. You've been warned.**

2.) **While the code will change the device's CID, you will need to check (after reboot) to see that the CID changed "perfectly". In some instances, a few bits are kept from the original CID. If that happens, you will need to write a kernel module, dump the controller memory, find the current CID in the controller's memory, patch it to 0, and program the CID again.**

3.) **I have not researched what else Samsung/Android/bootloaders/apps/etc. might use the device's CID for. Change your CID at your own risk.**

4.) **If your goal is to turn your device into a dev-edition device, YOU will need to find the dev-edition aboot image and the corresponding CID. Further, you should only attempt to flash any aboot through ODIN. If ODIN rejects the flash, you've done something wrong.**

5.) **Only UID 0 has write access to mmcblk0, which is needed to issue the necessary IOCTLs.**

6.) **Do not PM, email, call, or otherwise stalk me looking for support, supporting files, or anything else.**