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See3CAM in Jetson TK1

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Contents

1 Revision History

Rev No	Date	Major Changes	Author
1.0	December 16, 2014	Initial Draft.	Camera Dev.Team
1.1	December 22, 2014	Added See3CAM_10CUG and See3CAM_12CUNIR to the list of tested products	Camera Dev.Team

2 Introduction

The NVIDIA Jetson TK1 Development kit is the world's first mobile supercomputer for embedded systems and opens the door for embedded system designs to harness the power of GPU-accelerated computing. Some of the key features of the Tegra K1 SoC (System-on-a-Chip) architecture are:

- 4-PLUS-1 Cortex A15 "r3" CPU architecture that delivers high performance.
- Kepler GPU architecture that utilizes 192 CUDA cores to deliver advanced graphics capabilities, GPU computing with NVIDIA CUDA 6 support, breakthrough power efficiency and performance for GPU-accelerated computing applications.
- Advanced Display Engine that is capable of simultaneously driving both a 4K local display and a 4K external monitor via HDMI.

The See3CAM range of products are USB 3.0 based super speed UVC compliant cameras that are capable of streaming video at high frame rates. e-con Systems has an ever increasing range of See3CAM products that have many supported features. . The native UVC driver of Windows and Linux Operating Systems is compatible with these cameras.

3 Scope

This document is intended as a guide for developers who are interested in interfacing our See3CAM products with a Jetson TK1 Dev Kit for image processing or any computer vision application. They can use this document to jumpstart into development of their algorithms on the Jetson TK1 kit rather than working on getting the maximum throughput from our cameras.

4 Description

This document explains about the necessary steps for enabling USB 3.0 and utilizing all the features of See3CAM products on a Jetson TK1 Development Kit. This document contains information about the tested See3CAM devices on the Jetson TK1 running different versions of Linux4Tegra (L4T) available from Nvidia download center.

These data are collected by streaming the See3CAM device in all supported resolutions. During this testing only one See3CAM camera is connected to the host controller. The software used for streaming is see3camguvcview (version 1.7.2-s2.33). Also we used USB 3.0 cable of length 2-meters.

The tested devices on the Jetson TK1 Development kit are:

- **See3CAM_10CUG_M** - First See3CAM series product that uses 1.3 MP Global Shutter Monochrome Camera with 720p HD and support for trigger modes.
- **See3CAM_10CUG_C** - Bayer color version of See3CAM_10CUG range with the same functionalities.
- **See3CAM_11CUG** - Color version of See3CAM_10CUG with 720p 30 fps YUV422 preview and many additional controls.
- **See3CAM_12CUNIR** - 1.3 MP monochrome camera with amazing low light capabilities and Near IR imaging support.
- **See3CAM_CU50** - 5 MP color camera using OV5640 sensor and supporting MJPG and YUY2 output.
- **See3CAM_80** - The 8.0 MP Auto Focus USB 3.0 camera using OV8825 CMOS Image sensor from OmniVision Inc.

5 Prerequisites

5.1 Downloading the requirements

For building the kernel a cross compiler toolchain and other tools necessary for compiling are required. The default one provided in Ubuntu repositories can be used. The necessary tools can be installed by running the command on the host Linux PC:

```
sudo apt-get install gcc-arm-linux-gnueabihf build-essential
```

Download the required L4T release package and sample root file system from Nvidia website.

L4T 19.3

https://developer.nvidia.com/sites/default/files/akamai/mobile/files/L4T/Tegra124_Linux_R19.3.0_armhf.tbz2

http://developer.download.nvidia.com/mobile/tegra/l4t/r19.3.0/Tegra_Linux_Sample-Root-Filesystem_R19.3.0_armhf.tbz2

Download the corresponding kernel source code for the L4T version from the Nvidia website.

For L4T 19.3

https://developer.nvidia.com/sites/default/files/akamai/mobile/files/L4T/kernel_src.tbz2

5.2 Extracting and preparing L4T

Extract the downloaded L4T release package to get a folder with the name Linux_for_tegra, which contains the necessary tools and binaries for modifying the Jetson TK1. All the following steps should be done on the host PC itself.

```
sudo tar -xjf Tegra124_Linux_R<L4T_version>_armhf.tbz2
```

Now extract the sample file system to the rootfs directory present inside the obtained Linux_for_Tegra directory.

```
cd Linux_for_Tegra/rootfs
sudo tar -xjpf <path_to>/Tegra_Linux_Sample-Root-Filesystem_R<L4T_version>_armhf.tbz2
```

Apply the Nvidia provided libraries and binaries to the extracted file system using the following commands:

```
cd ..
export LDK_ROOTFS_DIR=<absolute path to Linux_for_Tegra>/rootfs
sudo ./apply_binaries.sh
```

6 Enabling HID support

The default kernel zImage provided by Nvidia for the Jetson TK1 does not support hidraw device support. Hidraw support is necessary for accessing the extra controls present in each See3CAM device. To enable hidraw in Jetson, the kernel binary needs to be rebuilt after configuring and enabling HID device support.

6.1 Extracting and configuring the kernel

Extract the source code to any path on the host Linux PC.

```
tar -xjf <path_to>/kernel_src.tbz2
cd kernel/
```

ARCH=arm make tegra12_defconfig
ARCH=arm make menuconfig

Now enable hidraw support in the kernel by enabling the option given below.

"**Device Drivers -> HID support -> /dev/hidraw raw HID device support**".

Now save and exit from the menu.

6.2 Building and installing the kernel

Run the following commands in the host PC to build and install the kernel and drivers.

ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- make zImage
ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- make modules
sudo ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- make modules_install INSTALL_MOD_PATH=$LDK_ROOTFS_DIR

sudo cp arch/arm/boot/zImage $LDK_ROOTFS_DIR/boot
sudo cp arch/arm/boot/zImage <path_to>/Linux_for_Tegra/kernel/zImage

NOTE: Alternatively, the Grinch kernel (>=19.3.1) can be used which has support for hidraw devices. Refer to the Nvidia developer forums for more information.

7 Enabling USB 3.0 support

By default, the USB 3.0 port in the Jetson TK1 dev kit works only in USB 2.0 mode. So connecting any USB 3.0 device to that port is not sufficient to utilize the maximum performance that USB 3.0 offers. The following are the steps required to enable USB 3.0 in Jetson TK1 depending upon the version of L4T used.

For L4T 19.3

The default bootloader in this version of L4T is fastboot. For enabling USB 3.0 using this boot loader, the ODMDATA value needs to be changed in the file "jetson-tk1.conf" in Linux_for_Tegra directory and a re-flash is required.

cd Linux_for_Tegra/

Open the file jetson-tk1.conf. Modify the value **ODMDATA=0x6009C000** to **ODMDATA=0x6209C000** and save the file. Now follow the steps for Flashing the Jetson TK1 (Section 7.1) to enable USB 3.0.

If U-boot is used as bootloader, the file extlinux.conf needs to be modified to get USB 3.0 working. For changing the bootloader to U-boot, refer to section 7.2. The following steps are **not required** otherwise.

After successfully booting the device, edit the file extlinux.conf in /boot and make the following changes on the Jetson device itself.

The second occurrence of **usb_port_owner_info=0** should be changed to **usb_port_owner_info=2**.

Example extlinux.conf file

TIMEOUT 30
DEFAULT primary

MENU TITLE Jetson-TK1 eMMC boot options

```
LABEL primary
    MENU LABEL primary kernel
    LINUX zImage
    FDT tegra124-pm375.dtb
    APPEND console=ttyS0,115200n8 console=tty1 no_console_suspend=1 lp0_vec=2064@0xf46ff000
video=tegrafb mem=1862M@2048M memtype=255 ddr_die=2048M@2048M section=256M
pmuboard=0x0177:0x0000:0x02:0x43:0x00 vpr=151M@3945M tsec=32M@3913M
otf_key=c75e5bb91eb3bd947560357b64422f85 usbcore.old_scheme_first=1 core_edp_mv=1150
core_edp_ma=4000 tegraid=40.1.1.0.0 debug_uartport=lsport,3 power_supply=Adapter
audio_codec=rt5640 modem_id=0 android.kerneltype=normal usb_port_owner_info=0 fbcon=map:1
commchip_id=0 usb_port_owner_info=2 lane_owner_info=6 emc_max_dvfs=0 touch_id=0@0
tegra_fbmem=32899072@0xad012000 board_info=0x0177:0x0000:0x02:0x43:0x00
root=/dev/mmcblk0p1 rw rootwait tegraboot=sdmmc gpt
```

Now reboot the device. The blue colored USB port will work in USB 3.0 mode after the reboot.

7.1 Flashing the Jetson TK1

Connect the USB cable between the host PC and Jetson TK1 dev kit. Put the board in recovery mode by holding down the RECOVERY button and pressing the RESET button once. If the board is successfully changed to recovery mode, the jetson will be enumerated as an USB device to the host PC.

```
lsusb
Bus 003 Device 006: ID 0955:7140 NVidia Corp
```

Now flash the Jetson TK1 kit using the flash.sh script from your Host PC.

```
sudo ./flash.sh jetson-tk1 mmcblk0p1
```

Now reboot the device. The blue colored USB port will work in USB 3.0 mode after the reboot.

7.2 Changing bootloader to U-boot

The bootloader can be changed to U-boot also. This step is not mandatory but explains how to change the default bootloader to U-boot in L4T 19.3. A u-boot binary is provided in the Nvidia provided release package. It is present in Linux_for_Tegra/bootloader/u-boot.bin. The command given below will change the bootloader of the Jetson TK1 dev kit to U-boot.

```
sudo ./flash.sh -L <full path to u-boot.bin> jetson-tk1 mmcblk0p1
```

8 Improving performance of CPU

After flashing the kernel and modules, the board can be successfully booted with full support for hidraw and USB 3.0. The default CPU governor on the Jetson TK1 is ondemand. Changing the CPU governor to performance provides better overall performance of the system and also improves rendering at high frame rates as well. The following commands should be run on the target device.

```
sudo su
echo performance > /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor
exit
```

9 See3camguvcview

See3camguvcview is our linux application to demonstrate all the features of See3CAM USB 3.0 devices. This software is available to anyone who purchases any of our See3CAM devices. Contact sales@e-consystems.com or visit our website www.e-consystems.com for more info.

9.1 Dependencies

1. libavutil-dev
2. libavcodec-dev
3. libusb-1.0-0-dev
4. libv4l-dev
5. libgtk-3-dev
6. libsdl1.2-dev
7. portaudio19-dev
8. libudev-dev
9. intltool

Install them all by running the following command on the Jetson TK1 dev kit:

sudo apt-get update && sudo apt-get install intltool libudev-dev libsdl1.2-dev libgtk-3-dev libv4l-dev libusb-1.0-0-dev portaudio19-dev libavcodec-dev

9.2 Installing see3camguvcview from source code

The source code of the see3camguvcview application can be obtained from e-con systems when you buy any See3CAM device.

1. Extract the source code using

   tar -xvzf <path to tar file>/See3CAM_LINUX_REL_Package_xxxx.tar.gz

2. Enter in to the source directory by the command

   cd See3CAM_LINUX_REL_Package_xxxx/src/See3CAM_guvcview-src-1.7.2/

3. Now run the following commands in order to install see3camguvcview.

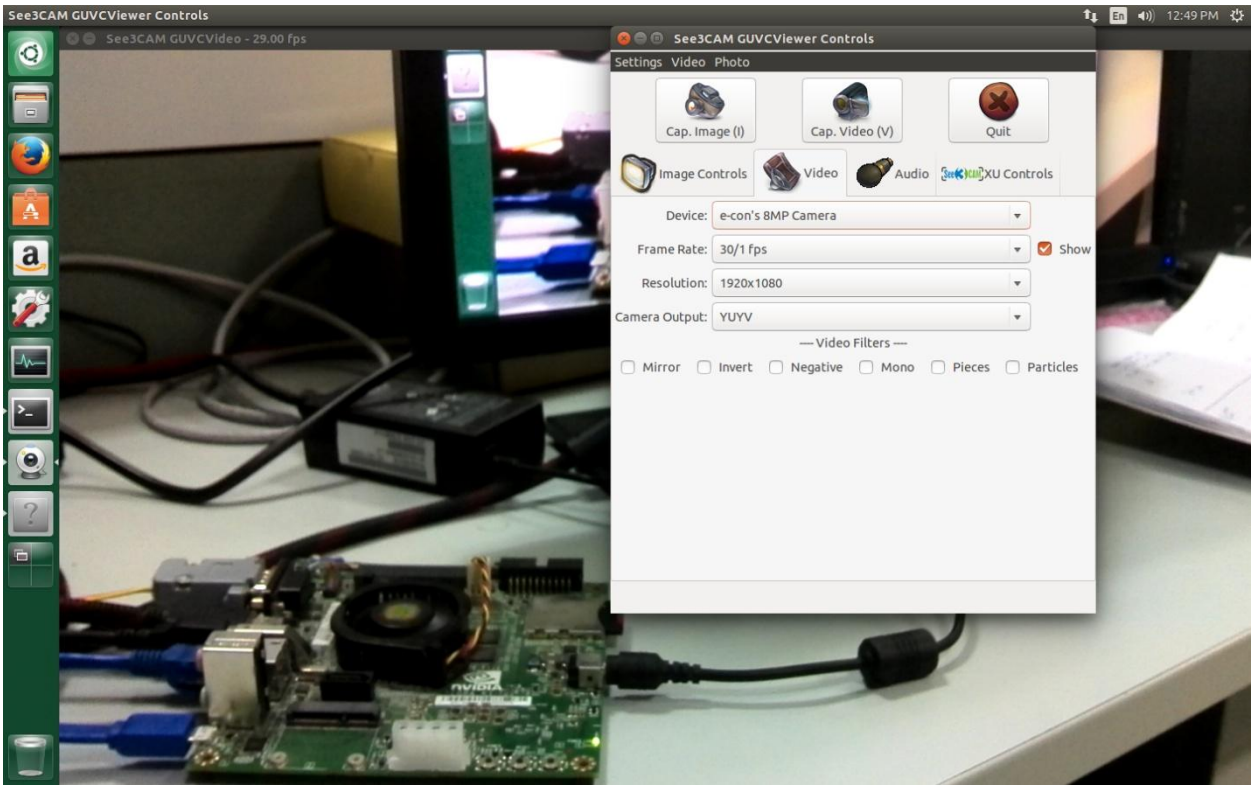
   ./configure && make && sudo make install

9.3 Running see3camguvcview

Connect any See3CAM device to the USB 3.0 port of the Jetson TK1 Development Kit and run the following command in a terminal window.

sudo see3camguvcview

The following image shows see3camguvcview running in the Jetson TK1 development Kit. The preview is from e-con's See3CAM_80 camera connected in USB 3.0 streaming 1080p at 30fps.



9.4 Test results

The following table summarizes the performance of tested See3CAM devices on the Jetson TK1 dev kit.

Device Name	Mode	Format	Resolution	Actual fps	Observed fps
See3CAM_10CUG_M	USB 3.0	YUYV	1280x960	45	45
			1280x720	60	58
			640x480	45	45
	USB 2.0	YUYV	1280x960	9	9
			1280x720	12	12
			640x480	30	30
	USB 3.0	GREY	1280x960	45	45
			1280x720	60	60
			640x480	45	45
	USB 2.0	GREY	1280x960	9	9
			1280x720	12	12
			640x480	30	30

Device Name	Mode	Format	Resolution	Actual fps	Observed fps
See3CAM_10CUG_C	USB 3.0	BA81	1280x960	45	20
			1280x720	60	25
			640x480	45	45
	USB 2.0	BA81	1280x960	9	9
			1280x720	12	12
			640x480	30	30
See3CAM_11CUG	USB 3.0	YUYV	1280x960	20	20
			1280x720	30	30
			640x480 (Binned)	30	30
			640x480 (Cropped)	60	60
	USB 2.0	YUYV	1280x960	8	8
			1280x720	12	12
			640x480 (Binned)	30	30
			640x480 (Cropped)	30	30
See3CAM_12CUNIR	USB 3.0	Y16	1280x960	45	35-40
			1280x720	60	55
			640x480 (Binned)	45	45
			640x480 (Cropped)	60	60
	USB 2.0	Y16	1280x960	9	9
			1280x720	12	12
			640x480 (Binned)	30	30
			640x480 (Cropped)	30	30
See3CAM_CU50	USB 3.0	YUYV	2592x1944	8	8
			1920x1080	15	15
			1280x720	30	30
			640x480	30	30
	USB 3.0	MJPG	2592x1944	15	15
			1920x1080	30	30
			1280x720	60	60
			640x480	60	60

Device Name	Mode	Format	Resolution	Actual fps	Observed fps
See3CAM_80	USB 3.0	YUYV	3264x2448	11	11 (preview is distorted)
			1920x1080	30	30
			1280x720	30	30
			640x480	30	30
	USB 2.0	YUYV	1280x720	10	10
			3264x2448	1.5	1.5

10 Known Issues

- See3CAM_CU50 does not work in USB 2.0 mode on the Jetson for now.
- Frame rates at higher resolutions of See3CAM_10CUG_C are low because of Bayer interpolation processing which is done in CPU.
- Frame rates in See3CAM_12CUNIR drops a little bit at high resolutions due to custom conversion from Y16 to YUYV.
- 8 MP streaming using See3CAM_80 in USB 3.0 is corrupt due to lot of frames being dropped by the uvcvideo driver. This could be due to bandwidth issues in the Tegra K1 USB 3.0 host controller.
- Currently see3camguvciew does not work in L4T_R21.1 and L4T_R21.2 due to missing firmware nvavp_aud_ucode.bin which causes issues with portaudio. Portaudio is required for see3camguvcview to work. We are working with Nvidia to solve this issue. Common gstreamer commands can be used instead to view the camera preview.

11 Conclusion

This document explains about the requirements for interfacing the See3CAM devices with a Jetson TK1 development kit and the performance achieved using the See3CAM devices on the Jetson TK1.