ECEN 749 Lab 9 Report

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Introduction

In this lab, I combined all the knowledge and experiences I learned from previous labs, and build two built-in kernel drivers for **multiplier** and **ir demod** IP, so that they can load during boot. I also played with the Linux kernel and was able to shrink the size of the kernel image by de-select unrelated kernel module before cross-compile.

Procedure

1. Since part 1 and part 2 are quite similar, the following procedures will only cover the steps for part 2, which is a combination of two IP designs and two drivers.

2. Copy the project folder from lab 8 into lab 9.

3. Open Vivado in lab 9, and add the multiplier ip_repo in IP setting, and add multiplier IP into the current block design.

4. Run connection automation and regenerate bitstream.
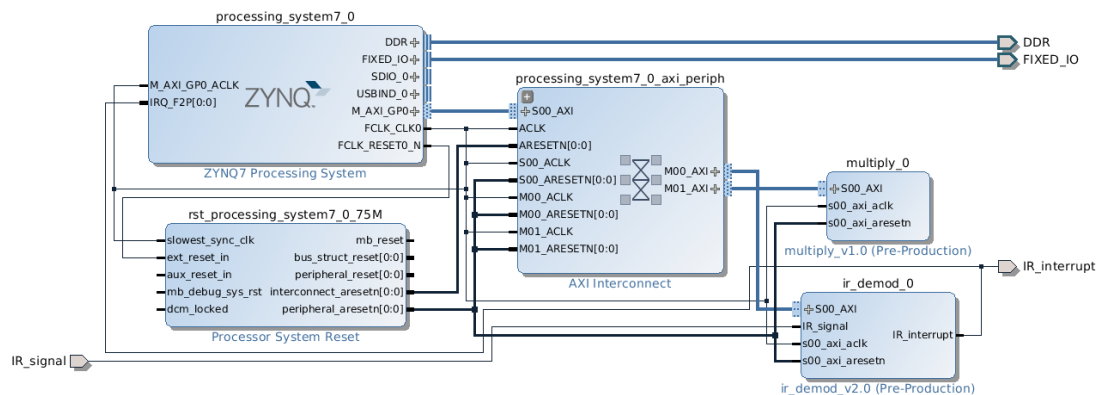
5. Export hardware and include bitstream.

6. Based on the register address in address editor, modify the device tree file:

7. Launch SDK and create a First Stage Boot Loader (FSBL).

8. Create boot image based on FSBL (as bootloader), Bitstream (as datafile), and u-boot file (as datafile).

9. Unzip the linux-3.14 folder and create folder for multiplier and ir_demod drivers.

10. Create Makefile in multiplier_driver and add the following line:

```
obj-$(CONFIG MULTIPLIER_DRIVER) += multiplier.o
```

11. Create Makefile in ir_demod_driver directory and add the following line:

```
obj-$(CONFIG IR_DEMOD_DRIVER) += ir_demod.o
```

12. Create Kconfig in multiplier_driver directory and add the following line:

```
1 config MULTIPLIER_DRIVER
2 tristate "multiplier_driver"
3 depends on ARM
4 default y if ARM
5 help
6 refer to ECEN449@TAMU
```

13. Create Kconfig in ir_demod_driver directory and add the following line:

```
1 config IR_DEMOD_DRIVER
2 tristate "ir_demod_driver"
3 depends on ARM
4 default y if ARM
5 help
6 refer to ECEN449@TAMU
```

14. Add the following lines into Makefile in Device Driver directory:

```
1 # ECEN 449
2 obj-$(CONFIG MULTIPLIER_DRIVER) += multiplier_driver/
3 obj-$(CONFIG IR_DEMOD_DRIVER) += ir_demod_driver/
```

15. Add the following lines into Kconfig file in Device Driver directory:

```
1 # ECEN 449
2 source "drivers/multiplier_driver/Kconfig"
3 source "drivers/ir_demod_driver/Kconfig"
```

16. Launch menuconfig under linux-3.14 directory and select multiplier_driver and ir_demod_driver for compile, then cross-compile the kernel image:

```
1    make ARCH=arm CROSS COMPILE=arm-xilinx-linux-gnueabi-
```

17. Set up path variable

```
1 PATH=$PATH:<directory_to_u_boot>/tools
```

18. Convert the compiled zImage into uImage.

```
1 make ARCH=arm CROSS_COMPILE=arm-xilinx-linux-gnueabi- UIMAGE_LOADADDR=0x8000
     uImage
```

19. Copy BOOT.bin, uImage, devicetree.dtb, and uramdisk.image.gz, devtest_multiplier, devtest_ir_demod (from the previous labs) into an SD card.

20. Insert SD card on FPGA, push Reset button, and then use picocom to monitor USB1 port and check the printout.

21. Disable the support for networking, multimedia, and sound, and recompile the kernel:

```
1 [lvtongtom305@lin13-424cvlb linux-3.14]$ make ARCH=arm CROSS_COMPILE=arm-xilinx-
     linux-gnueabi-
2 scripts/kconfig/conf --silentoldconfig Kconfig
3 #
4 # configuration written to .config
5 #
6   CHK     include/config/kernel.release
7   CHK     include/generated/uapi/linux/version.h
8   CHK     include/generated/utsrelease.h
```

```
 9 make[1]: `include/generated/mach-types.h' is up to date.
10   CALL    scripts/checksyscalls.sh
11   CHK     include/generated/compile.h
12   UPD     include/generated/compile.h
13   CC      init/version.o
14   CC      init/do_mounts.o
15   LD      init/mounts.o
16   LD      init/built-in.o
17   CC      kernel/sysctl.o
18   CC      kernel/sysctl_binary.o
19   GZIP    kernel/config_data.gz
20   CHK     kernel/config_data.h
21   UPD     kernel/config_data.h
22   CC      kernel/configs.o
23   LD      kernel/built-in.o
24   CC      mm/slab.o
25   LD      mm/built-in.o
26   CC      fs/select.o
27   CC      fs/lockd/clntlock.o
28   CC      fs/lockd/clntproc.o
29   CC      fs/lockd/clntxdr.o
30   CC      fs/lockd/host.o
31   CC      fs/lockd/svc.o
32   CC      fs/lockd/svclock.o
33   CC      fs/lockd/svcshare.o
34   CC      fs/lockd/svcproc.o
35   CC      fs/lockd/svcsubs.o
36   CC      fs/lockd/mon.o
37   CC      fs/lockd/xdr.o
38   CC      fs/lockd/clnt4xdr.o
39   CC      fs/lockd/xdr4.o
40   CC      fs/lockd/svc4proc.o
41   LD      fs/lockd/lockd.o
42   LD      fs/lockd/built-in.o
43   CC      fs/nfs/client.o
44   CC      fs/nfs/dir.o
45   CC      fs/nfs/file.o
46   CC      fs/nfs/getroot.o
47   CC      fs/nfs/inode.o
48   CC      fs/nfs/super.o
49   CC      fs/nfs/direct.o
50   CC      fs/nfs/pagelist.o
51   CC      fs/nfs/read.o
52   CC      fs/nfs/symlink.o
53   CC      fs/nfs/unlink.o
54   CC      fs/nfs/write.o
55   CC      fs/nfs/namespace.o
56   CC      fs/nfs/mount_clnt.o
57   CC      fs/nfs/nfstrace.o
58   CC      fs/nfs/nfsroot.o
59   CC      fs/nfs/sysctl.o
60   LD      fs/nfs/nfs.o
61   CC      fs/nfs/nfs2super.o
62   CC      fs/nfs/proc.o
63   CC      fs/nfs/nfs2xdr.o
64   LD      fs/nfs/nfsv2.o
65   CC      fs/nfs/nfs3super.o
66   CC      fs/nfs/nfs3client.o
67   CC      fs/nfs/nfs3proc.o
```

```
68   CC        fs/nfs/nfs3xdr.o
69   LD        fs/nfs/nfsv3.o
70   LD        fs/nfs/built-in.o
71   LD        fs/built-in.o
72   CC        crypto/algapi.o
73   LD        crypto/crypto_algapi.o
74   LD        crypto/built-in.o
75   CC        drivers/base/core.o
76   LD        drivers/base/regmap/built-in.o
77   LD        drivers/base/built-in.o
78   CC        drivers/connector/cn_queue.o
79   CC        drivers/connector/connector.o
80   LD        drivers/connector/cn.o
81   CC        drivers/connector/cn_proc.o
82   LD        drivers/connector/built-in.o
83   LD        drivers/gpu/drm/i2c/built-in.o
84   LD        drivers/gpu/drm/built-in.o
85   LD        drivers/gpu/built-in.o
86   LD        drivers/media/i2c/built-in.o
87   LD        drivers/media/platform/built-in.o
88   LD        drivers/media/built-in.o
89   CC        drivers/net/Space.o
90   CC        drivers/net/loopback.o
91   CC        drivers/net/can/dev.o
92   LD        drivers/net/can/can-dev.o
93   CC        drivers/net/can/xilinx_can.o
94   LD        drivers/net/can/built-in.o
95   LD        drivers/net/built-in.o
96   LD        drivers/of/built-in.o
97   LD        drivers/built-in.o
98   LD        sound/built-in.o
99   CC        net/socket.o
100  CC        net/8021q/vlan_core.o
101  LD        net/8021q/built-in.o
102  CC  [M]   net/8021q/vlan.o
103  CC  [M]   net/8021q/vlan_dev.o
104  CC  [M]   net/8021q/vlan_netlink.o
105  CC  [M]   net/8021q/vlanproc.o
106  LD  [M]   net/8021q/8021q.o
107  CC        net/can/af_can.o
108  CC        net/can/proc.o
109  LD        net/can/can.o
110  CC        net/can/raw.o
111  LD        net/can/can-raw.o
112  CC        net/can/bcm.o
113  LD        net/can/can-bcm.o
114  CC        net/can/gw.o
115  LD        net/can/can-gw.o
116  LD        net/can/built-in.o
117  CC        net/core/sock.o
118  CC        net/core/request_sock.o
119  CC        net/core/skbuff.o
120  CC        net/core/iovec.o
121  CC        net/core/datagram.o
122  CC        net/core/stream.o
123  CC        net/core/scm.o
124  CC        net/core/gen_stats.o
125  CC        net/core/gen_estimator.o
126  CC        net/core/net_namespace.o
```

```
127  CC      net/core/flow_dissector.o
128  CC      net/core/sysctl_net_core.o
129  CC      net/core/dev.o
130  CC      net/core/ethtool.o
131  CC      net/core/dev_addr_lists.o
132  CC      net/core/dst.o
133  CC      net/core/netevent.o
134  CC      net/core/neighbour.o
135  CC      net/core/rtnetlink.o
136  CC      net/core/utils.o
137  CC      net/core/link_watch.o
138  CC      net/core/filter.o
139  CC      net/core/sock_diag.o
140  CC      net/core/dev_ioctl.o
141  CC      net/core/tso.o
142  CC      net/core/net-sysfs.o
143  CC      net/core/net-procfs.o
144  LD      net/core/built-in.o
145  CC      net/ethernet/eth.o
146  LD      net/ethernet/built-in.o
147  CC      net/ipv4/route.o
148  CC      net/ipv4/inetpeer.o
149  CC      net/ipv4/protocol.o
150  CC      net/ipv4/ip_input.o
151  CC      net/ipv4/ip_fragment.o
152  CC      net/ipv4/ip_forward.o
153  CC      net/ipv4/ip_options.o
154  CC      net/ipv4/ip_output.o
155  CC      net/ipv4/ip_sockglue.o
156  CC      net/ipv4/inet_hashtables.o
157  CC      net/ipv4/inet_timewait_sock.o
158  CC      net/ipv4/inet_connection_sock.o
159  CC      net/ipv4/tcp.o
160  CC      net/ipv4/tcp_input.o
161  CC      net/ipv4/tcp_output.o
162  CC      net/ipv4/tcp_timer.o
163  CC      net/ipv4/tcp_ipv4.o
164  CC      net/ipv4/tcp_minisocks.o
165  CC      net/ipv4/tcp_cong.o
166  CC      net/ipv4/tcp_metrics.o
167  CC      net/ipv4/tcp_fastopen.o
168  CC      net/ipv4/tcp_offload.o
169  CC      net/ipv4/datagram.o
170  CC      net/ipv4/raw.o
171  CC      net/ipv4/udp.o
172  CC      net/ipv4/udplite.o
173  CC      net/ipv4/udp_offload.o
174  CC      net/ipv4/arp.o
175  CC      net/ipv4/icmp.o
176  CC      net/ipv4/devinet.o
177  CC      net/ipv4/af_inet.o
178  CC      net/ipv4/igmp.o
179  CC      net/ipv4/fib_frontend.o
180  CC      net/ipv4/fib_semantics.o
181  CC      net/ipv4/fib_trie.o
182  CC      net/ipv4/inet_fragment.o
183  CC      net/ipv4/ping.o
184  CC      net/ipv4/ip_tunnel_core.o
185  CC      net/ipv4/gre_offload.o
```

```
186  CC        net/ipv4/sysctl_net_ipv4.o
187  CC        net/ipv4/proc.o
188  CC        net/ipv4/xfrm4_mode_beet.o
189  CC        net/ipv4/inet_lro.o
190  CC        net/ipv4/xfrm4_mode_transport.o
191  CC        net/ipv4/xfrm4_mode_tunnel.o
192  CC        net/ipv4/ipconfig.o
193  CC        net/ipv4/inet_diag.o
194  CC        net/ipv4/tcp_diag.o
195  CC        net/ipv4/tcp_cubic.o
196  CC        net/ipv4/xfrm4_policy.o
197  CC        net/ipv4/xfrm4_state.o
198  CC        net/ipv4/xfrm4_input.o
199  CC        net/ipv4/xfrm4_output.o
200  CC        net/ipv4/xfrm4_protocol.o
201  LD        net/ipv4/built-in.o
202  CC [M]    net/ipv4/ip_tunnel.o
203  CC [M]    net/ipv4/ipip.o
204  CC [M]    net/ipv4/tunnel4.o
205  CC        net/ipv6/addrconf_core.o
206  CC        net/ipv6/exthdrs_core.o
207  CC        net/ipv6/ip6_checksum.o
208  CC        net/ipv6/ip6_icmp.o
209  CC        net/ipv6/output_core.o
210  CC        net/ipv6/protocol.o
211  CC        net/ipv6/ip6_offload.o
212  CC        net/ipv6/tcpv6_offload.o
213  CC        net/ipv6/udp_offload.o
214  CC        net/ipv6/exthdrs_offload.o
215  CC        net/ipv6/inet6_hashtables.o
216  LD        net/ipv6/built-in.o
217  CC [M]    net/ipv6/af_inet6.o
218  CC [M]    net/ipv6/anycast.o
219  CC [M]    net/ipv6/ip6_output.o
220  CC [M]    net/ipv6/ip6_input.o
221  CC [M]    net/ipv6/addrconf.o
222  CC [M]    net/ipv6/addrlabel.o
223  CC [M]    net/ipv6/route.o
224  CC [M]    net/ipv6/ip6_fib.o
225  CC [M]    net/ipv6/ipv6_sockglue.o
226  CC [M]    net/ipv6/ndisc.o
227  CC [M]    net/ipv6/udp.o
228  CC [M]    net/ipv6/udplite.o
229  CC [M]    net/ipv6/raw.o
230  CC [M]    net/ipv6/icmp.o
231  CC [M]    net/ipv6/mcast.o
232  CC [M]    net/ipv6/reassembly.o
233  CC [M]    net/ipv6/tcp_ipv6.o
234  CC [M]    net/ipv6/ping.o
235  CC [M]    net/ipv6/exthdrs.o
236  CC [M]    net/ipv6/datagram.o
237  CC [M]    net/ipv6/ip6_flowlabel.o
238  CC [M]    net/ipv6/inet6_connection_sock.o
239  CC [M]    net/ipv6/sysctl_net_ipv6.o
240  CC [M]    net/ipv6/xfrm6_policy.o
241  CC [M]    net/ipv6/xfrm6_state.o
242  CC [M]    net/ipv6/xfrm6_input.o
243  CC [M]    net/ipv6/xfrm6_output.o
244  CC [M]    net/ipv6/xfrm6_protocol.o
```

```
245  CC [M]  net/ipv6/proc.o
246  LD [M]  net/ipv6/ipv6.o
247  CC [M]  net/ipv6/xfrm6_mode_transport.o
248  CC [M]  net/ipv6/xfrm6_mode_tunnel.o
249  CC [M]  net/ipv6/xfrm6_mode_beet.o
250  CC [M]  net/ipv6/sit.o
251  CC      net/netlink/af_netlink.o
252  CC      net/netlink/genetlink.o
253  LD      net/netlink/built-in.o
254  CC      net/packet/af_packet.o
255  LD      net/packet/built-in.o
256  CC      net/sched/sch_generic.o
257  CC      net/sched/sch_mq.o
258  LD      net/sched/built-in.o
259  CC      net/sunrpc/clnt.o
260  CC      net/sunrpc/xprt.o
261  CC      net/sunrpc/socklib.o
262  CC      net/sunrpc/xprtsock.o
263  CC      net/sunrpc/sched.o
264  CC      net/sunrpc/auth.o
265  CC      net/sunrpc/auth_null.o
266  CC      net/sunrpc/auth_unix.o
267  CC      net/sunrpc/auth_generic.o
268  CC      net/sunrpc/svc.o
269  CC      net/sunrpc/svcsock.o
270  CC      net/sunrpc/svcauth_unix.o
271  CC      net/sunrpc/addr.o
272  CC      net/sunrpc/rpcb_clnt.o
273  CC      net/sunrpc/timer.o
274  CC      net/sunrpc/sunrpc_syms.o
275  CC      net/sunrpc/rpc_pipe.o
276  CC      net/sunrpc/svc_xprt.o
277  CC      net/sunrpc/stats.o
278  LD      net/sunrpc/sunrpc.o
279  LD      net/sunrpc/built-in.o
280  CC      net/unix/af_unix.o
281  CC      net/unix/garbage.o
282  CC      net/unix/sysctl_net_unix.o
283  LD      net/unix/unix.o
284  LD      net/unix/built-in.o
285  CC      net/xfrm/xfrm_policy.o
286  CC      net/xfrm/xfrm_state.o
287  CC      net/xfrm/xfrm_input.o
288  CC      net/xfrm/xfrm_output.o
289  CC      net/xfrm/xfrm_sysctl.o
290  CC      net/xfrm/xfrm_replay.o
291  LD      net/xfrm/built-in.o
292  CC      net/sysctl_net.o
293  LD      net/built-in.o
294  CC      lib/nlattr.o
295  LD      lib/built-in.o
296  CC      lib/kobject_uevent.o
297  CC      lib/vsprintf.o
298  AR      lib/lib.a
299  LINK    vmlinux
300  LD      vmlinux.o
301  MODPOST vmlinux.o
302  GEN     .version
303  CHK     include/generated/compile.h
```

```
304    UPD      include/generated/compile.h
305    CC       init/version.o
306    LD       init/built-in.o
307    KSYM     .tmp_kallsyms1.o
308    KSYM     .tmp_kallsyms2.o
309    LD       vmlinux
310    SORTEX   vmlinux
311    SYSMAP   System.map
312    OBJCOPY  arch/arm/boot/Image
313    Kernel: arch/arm/boot/Image is ready
314    GZIP     arch/arm/boot/compressed/piggy.gzip
315    AS       arch/arm/boot/compressed/piggy.gzip.o
316    LD       arch/arm/boot/compressed/vmlinux
317    OBJCOPY  arch/arm/boot/zImage
318    Kernel: arch/arm/boot/zImage is ready
319    Building modules, stage 2.
320    MODPOST 22 modules
321    CC       crypto/ansi_cprng.mod.o
322    LD [M]   crypto/ansi_cprng.ko
323    CC       crypto/krng.mod.o
324    LD [M]   crypto/krng.ko
325    CC       crypto/rng.mod.o
326    LD [M]   crypto/rng.ko
327    CC       drivers/remoteproc/mb_remoteproc.mod.o
328    LD [M]   drivers/remoteproc/mb_remoteproc.ko
329    CC       drivers/remoteproc/remoteproc.mod.o
330    LD [M]   drivers/remoteproc/remoteproc.ko
331    CC       drivers/remoteproc/zynq_remoteproc.mod.o
332    LD [M]   drivers/remoteproc/zynq_remoteproc.ko
333    CC       drivers/rpmsg/virtio_rpmsg_bus.mod.o
334    LD [M]   drivers/rpmsg/virtio_rpmsg_bus.ko
335    CC       drivers/usb/gadget/function/usb_f_ss_lb.mod.o
336    LD [M]   drivers/usb/gadget/function/usb_f_ss_lb.ko
337    CC       drivers/usb/gadget/legacy/g_zero.mod.o
338    LD [M]   drivers/usb/gadget/legacy/g_zero.ko
339    CC       drivers/usb/gadget/libcomposite.mod.o
340    LD [M]   drivers/usb/gadget/libcomposite.ko
341    CC       drivers/virtio/virtio.mod.o
342    LD [M]   drivers/virtio/virtio.ko
343    CC       drivers/virtio/virtio_ring.mod.o
344    LD [M]   drivers/virtio/virtio_ring.ko
345    CC       net/8021q/8021q.mod.o
346    LD [M]   net/8021q/8021q.ko
347    CC       net/ipv4/ip_tunnel.mod.o
348    LD [M]   net/ipv4/ip_tunnel.ko
349    CC       net/ipv4/ipip.mod.o
350    LD [M]   net/ipv4/ipip.ko
351    CC       net/ipv4/tunnel4.mod.o
352    LD [M]   net/ipv4/tunnel4.ko
353    CC       net/ipv6/ipv6.mod.o
354    LD [M]   net/ipv6/ipv6.ko
355    CC       net/ipv6/sit.mod.o
356    LD [M]   net/ipv6/sit.ko
357    CC       net/ipv6/xfrm6_mode_beet.mod.o
358    LD [M]   net/ipv6/xfrm6_mode_beet.ko
359    CC       net/ipv6/xfrm6_mode_transport.mod.o
360    LD [M]   net/ipv6/xfrm6_mode_transport.ko
361    CC       net/ipv6/xfrm6_mode_tunnel.mod.o
362    LD [M]   net/ipv6/xfrm6_mode_tunnel.ko
```

```
363 [lvtongtom305@lin13-424cvlb linux-3.14]$ PATH=$PATH:~/ecen749/lab4/u-boot/t
364 test/  tools/
365 [lvtongtom305@lin13-424cvlb linux-3.14]$ PATH=$PATH:~/ecen749/lab4/u-boot/tools/
366 [lvtongtom305@lin13-424cvlb linux-3.14]$ make ARCH=arm CROSS_COMPILE=arm-xilinx-
        linux-gnueabi- UIMAGE_LOADADDR=0x8000
367   CHK     include/config/kernel.release
368   CHK     include/generated/uapi/linux/version.h
369   CHK     include/generated/utsrelease.h
370 make[1]: `include/generated/mach-types.h' is up to date.
371   CALL    scripts/checksyscalls.sh
372   CHK     include/generated/compile.h
373   CHK     kernel/config_data.h
374 ^Cmake[2]: *** [drivers/i2c/busses] Interrupt
375 make[1]: *** [drivers/i2c] Interrupt
376 make: *** [drivers] Interrupt
377
378 [lvtongtom305@lin13-424cvlb linux-3.14]$ make ARCH=arm CROSS_COMPILE=arm-xilinx-
        linux-gnueabi- UIMAGE_LOADADDR=0x8000 uImage
379   CHK     include/config/kernel.release
380   CHK     include/generated/uapi/linux/version.h
381   CHK     include/generated/utsrelease.h
382 make[1]: `include/generated/mach-types.h' is up to date.
383   CALL    scripts/checksyscalls.sh
384   CHK     include/generated/compile.h
385   CHK     kernel/config_data.h
386   Kernel: arch/arm/boot/Image is ready
387   Kernel: arch/arm/boot/zImage is ready
388   UIMAGE  arch/arm/boot/uImage
389 Image Name:   Linux-3.18.0-xilinx
390 Created:      Fri Nov 16 09:11:22 2018
391 Image Type:   ARM Linux Kernel Image (uncompressed)
392 Data Size:    3107912 Bytes = 3035.07 kB = 2.96 MB
393 Load Address: 00008000
394 Entry Point:  00008000
395   Image arch/arm/boot/uImage is ready
```
<div align="center">src/compile_new_kernel_printout</div>

22. **As shown above, the size of the new kernel image is 2.95MB, whereas the previous kernel module size was 3.56MB. It is clear that disabling the three modules do shrink the size of the kernel.**

Result

All the programs was finished and demonstrated to TA. The programs are working well and meet all the requirement on lab manual.

Printout for built-in kernel drivers are at line 155-line160, the successful result of multiplier is at the end:

```
1  3693174 bytes read in 323 ms (10.9 MiB/s)
2  ## Booting kernel from Legacy Image at 03000000 ...
3     Image Name:   Linux-3.18.0-xilinx
4     Image Type:   ARM Linux Kernel Image (uncompressed)
5     Data Size:    3450432 Bytes = 3.3 MiB
6     Load Address: 00008000
7     Entry Point:  00008000
8     Verifying Checksum ... OK
9  ## Loading init Ramdisk from Legacy Image at 02000000 ...
10    Image Name:
11    Image Type:   ARM Linux RAMDisk Image (gzip compressed)
12    Data Size:    3693110 Bytes = 3.5 MiB
13    Load Address: 00000000
14    Entry Point:  00000000
15    Verifying Checksum ... OK
16 ## Flattened Device Tree blob at 02a00000
17    Booting using the fdt blob at 0x2a00000
18    Loading Kernel Image ... OK
19    Loading Ramdisk to 1f7aa000, end 1fb2fa36 ... OK
20    Loading Device Tree to 1f7a5000, end 1f7a9d85 ... OK
21
22 Starting kernel ...
23
24 Booting Linux on physical CPU 0x0
25 Linux version 3.18.0-xilinx (lvtongtom305@lin04-424cvlb.ece.tamu.edu) (gcc version
      4.9.1 (Sourcery CodeBench Lite 2014.11-30) ) #4 SMP PREEMPT Wed Nov 14 23:12:35 CST
      2018
26 CPU: ARMv7 Processor [413fc090] revision 0 (ARMv7), cr=18c5387d
27 CPU: PIPT / VIPT nonaliasing data cache, VIPT aliasing instruction cache
28 Machine model: Xilinx Zynq
29 cma: Reserved 16 MiB at 0x1e400000
30 Memory policy: Data cache writealloc
31 PERCPU: Embedded 10 pages/cpu @5fbd3000 s8768 r8192 d24000 u40960
32 Built 1 zonelists in Zone order, mobility grouping on.  Total pages: 130048
33 Kernel command line: console=ttyPS0,115200 root=/dev/ram rw earlyprintk
34 PID hash table entries: 2048 (order: 1, 8192 bytes)
35 Dentry cache hash table entries: 65536 (order: 6, 262144 bytes)
36 Inode-cache hash table entries: 32768 (order: 5, 131072 bytes)
37 Memory: 492632K/524288K available (4650K kernel code, 259K rwdata, 1616K rodata, 212K
      init, 219K bss, 31656K reserved, 0K highmem)
38 Virtual kernel memory layout:
39    vector  : 0xffff0000 - 0xffff1000   (   4 kB)
40    fixmap  : 0xffc00000 - 0xffe00000   (2048 kB)
41    vmalloc : 0x60800000 - 0xff000000   (2536 MB)
42    lowmem  : 0x40000000 - 0x60000000   ( 512 MB)
43    pkmap   : 0x3fe00000 - 0x40000000   (   2 MB)
44    modules : 0x3f000000 - 0x3fe00000   (  14 MB)
45      .text : 0x40008000 - 0x40626bf0   (6267 kB)
46      .init : 0x40627000 - 0x4065c000   ( 212 kB)
47      .data : 0x4065c000 - 0x4069cc60   ( 260 kB)
48       .bss : 0x4069cc60 - 0x406d3bb8   ( 220 kB)
49 Preemptible hierarchical RCU implementation.
50    Dump stacks of tasks blocking RCU-preempt GP.
```

```
51     RCU restricting CPUs from NR_CPUS=4 to nr_cpu_ids=2.
52  RCU: Adjusting geometry for rcu_fanout_leaf=16, nr_cpu_ids=2
53  NR_IRQS:16 nr_irqs:16 16
54  L2C-310 erratum 769419 enabled
55  L2C-310 enabling early BRESP for Cortex-A9
56  L2C-310 full line of zeros enabled for Cortex-A9
57  L2C-310 ID prefetch enabled, offset 1 lines
58  L2C-310 dynamic clock gating enabled, standby mode enabled
59  L2C-310 cache controller enabled, 8 ways, 512 kB
60  L2C-310: CACHE_ID 0x410000c8, AUX_CTRL 0x76360001
61  ps7-slcr mapped to 60804000
62  zynq_clock_init: clkc starts at 60804100
63  Zynq clock init
64  sched_clock: 64 bits at 325MHz, resolution 3ns, wraps every 3383112499200ns
65  ps7-ttc #0 at 60806000, irq=43
66  Console: colour dummy device 80x30
67  Calibrating delay loop... 1292.69 BogoMIPS (lpj=6463488)
68  pid_max: default: 32768 minimum: 301
69  Mount-cache hash table entries: 1024 (order: 0, 4096 bytes)
70  Mountpoint-cache hash table entries: 1024 (order: 0, 4096 bytes)
71  CPU: Testing write buffer coherency: ok
72  CPU0: thread -1, cpu 0, socket 0, mpidr 80000000
73  Setting up static identity map for 0x467e38 - 0x467e90
74  CPU1: Booted secondary processor
75  CPU1: thread -1, cpu 1, socket 0, mpidr 80000001
76  Brought up 2 CPUs
77  SMP: Total of 2 processors activated.
78  CPU: All CPU(s) started in SVC mode.
79  devtmpfs: initialized
80  VFP support v0.3: implementor 41 architecture 3 part 30 variant 9 rev 4
81  regulator-dummy: no parameters
82  NET: Registered protocol family 16
83  DMA: preallocated 256 KiB pool for atomic coherent allocations
84  cpuidle: using governor ladder
85  cpuidle: using governor menu
86  hw-breakpoint: found 5 (+1 reserved) breakpoint and 1 watchpoint registers.
87  hw-breakpoint: maximum watchpoint size is 4 bytes.
88  zynq-ocm f800c000.ps7-ocmc: ZYNQ OCM pool: 256 KiB @ 0x60880000
89  vgaarb: loaded
90  SCSI subsystem initialized
91  usbcore: registered new interface driver usbfs
92  usbcore: registered new interface driver hub
93  usbcore: registered new device driver usb
94  media: Linux media interface: v0.10
95  Linux video capture interface: v2.00
96  pps_core: LinuxPPS API ver. 1 registered
97  pps_core: Software ver. 5.3.6 - Copyright 2005-2007 Rodolfo Giometti <giometti@linux.
        it>
98  PTP clock support registered
99  EDAC MC: Ver: 3.0.0
100 Advanced Linux Sound Architecture Driver Initialized.
101 Switched to clocksource arm_global_timer
102 NET: Registered protocol family 2
103 TCP established hash table entries: 4096 (order: 2, 16384 bytes)
104 TCP bind hash table entries: 4096 (order: 3, 32768 bytes)
105 TCP: Hash tables configured (established 4096 bind 4096)
106 TCP: reno registered
107 UDP hash table entries: 256 (order: 1, 8192 bytes)
108 UDP-Lite hash table entries: 256 (order: 1, 8192 bytes)
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109  NET: Registered protocol family 1
110  RPC: Registered named UNIX socket transport module.
111  RPC: Registered udp transport module.
112  RPC: Registered tcp transport module.
113  RPC: Registered tcp NFSv4.1 backchannel transport module.
114  Trying to unpack rootfs image as initramfs...
115  rootfs image is not initramfs (no cpio magic); looks like an initrd
116  Freeing initrd memory: 3608K (5f7aa000 - 5fb30000)
117  hw perfevents: enabled with armv7_cortex_a9 PMU driver, 7 counters available
118  futex hash table entries: 512 (order: 3, 32768 bytes)
119  jffs2: version 2.2. (NAND) (SUMMARY)  © 2001-2006 Red Hat, Inc.
120  msgmni has been set to 1001
121  io scheduler noop registered
122  io scheduler deadline registered
123  io scheduler cfq registered (default)
124  dma-pl330 f8003000.ps7-dma: Loaded driver for PL330 DMAC-241330
125  dma-pl330 f8003000.ps7-dma:     DBUFF-128x8bytes Num_Chans-8 Num_Peri-4 Num_Events-16
126  xuartps e0001000.serial: ttyPS0 at MMIO 0xe0001000 (irq = 82, base_baud = 3125000) is
          a xuartps
127  console [ttyPS0] enabled
128  xdevcfg f8007000.ps7-dev-cfg: ioremap 0xf8007000 to 6086c000
129  [drm] Initialized drm 1.1.0 20060810
130  brd: module loaded
131  loop: module loaded
132  CAN device driver interface
133  e1000e: Intel(R) PRO/1000 Network Driver - 2.3.2-k
134  e1000e: Copyright(c) 1999 - 2014 Intel Corporation.
135  libphy: XEMACPS mii bus: probed
136  xemacps e000b000.ps7-ethernet: invalid address, use random
137  xemacps e000b000.ps7-ethernet: MAC updated 82:e5:2e:19:6e:06
138  xemacps e000b000.ps7-ethernet: pdev->id -1, baseaddr 0xe000b000, irq 54
139  ehci_hcd: USB 2.0 'Enhanced' Host Controller (EHCI) Driver
140  ehci-pci: EHCI PCI platform driver
141  zynq-dr e0002000.ps7-usb: Unable to init USB phy, missing?
142  usbcore: registered new interface driver usb-storage
143  mousedev: PS/2 mouse device common for all mice
144  i2c /dev entries driver
145  Xilinx Zynq CpuIdle Driver started
146  sdhci: Secure Digital Host Controller Interface driver
147  sdhci: Copyright(c) Pierre Ossman
148  sdhci-pltfm: SDHCI platform and OF driver helper
149  sdhci-arasan e0100000.ps7-sdio: No vmmc regulator found
150  sdhci-arasan e0100000.ps7-sdio: No vqmmc regulator found
151  mmc0: SDHCI controller on e0100000.ps7-sdio [e0100000.ps7-sdio] using ADMA
152  ledtrig-cpu: registered to indicate activity on CPUs
153  usbcore: registered new interface driver usbhid
154  usbhid: USB HID core driver
155  Registered a device with dynamic Major number of 245
156  Create a device file for this device with this command:
157  'mknod /dev/multiplier c 245 0'.
158  Registered a device with dynamic Major number of 244
159  Create a device file for this device with this command:
160  'mknod /dev/ir_demod c 244 0'.
161  TCP: cubic registered
162  NET: Registered protocol family 17
163  can: controller area network core (rev 20120528 abi 9)
164  NET: Registered protocol family 29
165  can: raw protocol (rev 20120528)
166  can: broadcast manager protocol (rev 20120528 t)
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167  can: netlink gateway (rev 20130117) max_hops=1
168  zynq_pm_ioremap: no compatible node found for 'xlnx,zynq-ddrc-a05'
169  zynq_pm_late_init: Unable to map DDRC IO memory.
170  Registering SWP/SWPB emulation handler
171  drivers/rtc/hctosys.c: unable to open rtc device (rtc0)
172  ALSA device list:
173    No soundcards found.
174  RAMDISK: gzip image found at block 0
175  mmc0: new high speed SDHC card at address aaaa
176  mmcblk0: mmc0:aaaa SS08G 7.40 GiB
177   mmcblk0: p1
178  EXT2-fs (ram0): warning: mounting unchecked fs, running e2fsck is recommended
179  VFS: Mounted root (ext2 filesystem) on device 1:0.
180  devtmpfs: mounted
181  Freeing unused kernel memory: 212K (40627000 - 4065c000)
182  Starting rcS...
183  ++ Mounting filesystem
184  ++ Setting up mdev
185  ++ Starting telnet daemon
186  ++ Starting http daemon
187  ++ Starting ftp daemon
188  ++ Starting dropbear (ssh) daemon
189  random: dropbear urandom read with 1 bits of entropy available
190  rcS Complete
191  zynq> mknod /dev/ir_demod c 244 0
192  zynq> mount dev/mmcblk0p1
193  .ash_history  lib/          mnt/          sbin/          var/
194  bin/          licenses/     opt/          sys/
195  dev/          linuxrc       proc/         tmp/
196  etc/          lost+found/   root/         usr/
197  zynq> mount dev/mmcblk0p1 mnt/
198  FAT-fs (mmcblk0p1): Volume was not properly unmounted. Some data may be corrupt.
        Please run fsck.
199  zynq> ./mnt/devtest_ir_demod
200  message Reading...
201  Enter number of message you want to read:1th interrupt: raw_data = c90
202  2th interrupt: raw_data = c90
203  3th interrupt: raw_data = c90
204  4th interrupt: raw_data = c90
205  5th interrupt: raw_data = c90
206  6th interrupt: raw_data = c90
207  7th interrupt: raw_data = c90
208  8th interrupt: raw_data = c90
209  9th interrupt: raw_data = c90
210  10th interrupt: raw_data = c90
211  5
212  message Reading...
213  message 1 = 0xc90
214  message 2 = 0xc90
215  message 3 = 0xc90
216  message 4 = 0xc90
217  message 5 = 0xc90
218  Enter number of message you want to read:5
219  message Reading...
220  message 1 = 0xc90
221  message 2 = 0xc90
222  message 3 = 0xc90
223  message 4 = 0xc90
224  message 5 = 0xc90
```

```
225  Enter number of message you want to read:9
226  message Reading...
227  Enter number of message you want to read:
```

<div align="center">src/console_printout</div>

Conclusion

This is the last lab for this class. To finish this lab, I went back to previous lab manuals and refresh my knowledge. It feels great when the correct result shows up. Thanks to the helps of our TA, I was able to finish all the labs successfully. The knowledge I learned from these labs are very beneficial to me, and now I can really feel the power of hardware design and FPGA programming.

Answer to Questions

(a) **What are the advantage and disadvantages of loadable kernel modules and built-in modules?**

	Loadable Kernel Modules	Built-in Kernel Modules
Advantages	1. Configurable Modules can be easily load/unload. 2. Kernel image can maintain a smaller size and shorter booting time.	1. Easy to use, no extra loading steps are needed after booting
Disadvantages	1. Users need to apply extra steps for loading/unloading the kernel modules.	1. Adding new built-in module requires recompiling the kernel. 2. Larger kernel Image, size and longer booting time