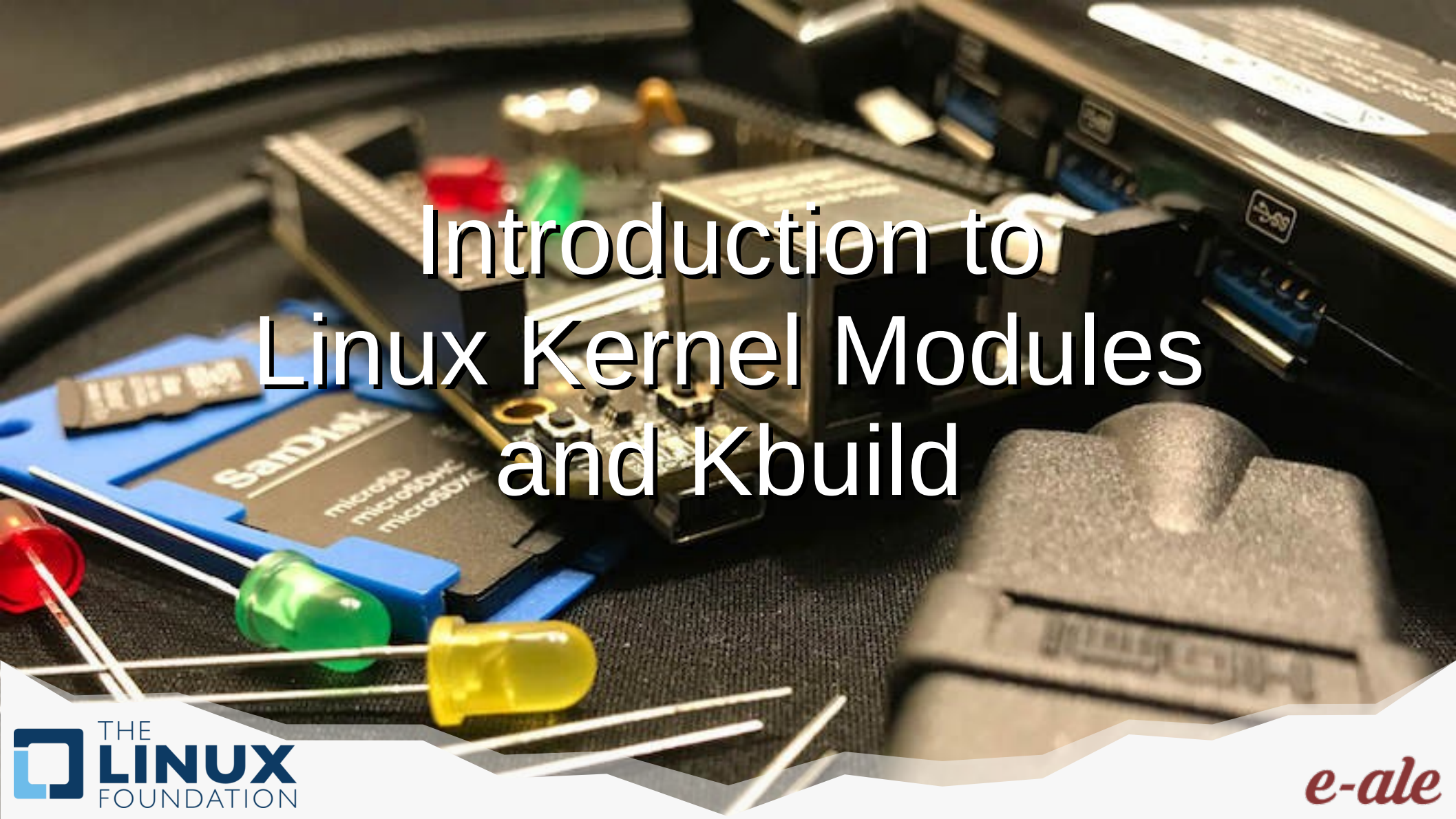

Introduction to Linux Kernel Modules and Kbuild

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e-ale

What the heck is a kernel module?

What is a kernel module?

- A way to dynamically add code (or data) to a running kernel
- Subsequently to optionally remove that same code
- A way to automatically load only the drivers we need
- A way to provide a choice between multiple modular drivers
- A way to architect kernel code in a modular way

Aren’t modules and drivers the same thing?

- While most drivers are written as modules
- Not all modules are drivers
- A kernel module is the simplest way of adding a payload of bytes to the kernel (whether code or data)
- A module can implement a driver, or library code, or a kprobe, or whatever you can dream up you want to add to a kernel...

A Simple module

```
#include <linux/module.h>
#include <linux/init.h>

static int __init my_init(void)
{
	pr_info("Hello: module loaded at 0x%p\n", my_init);
	return 0;
}
static void __exit my_exit(void)
{
	pr_info("Bye: module unloaded from 0x%p\n", my_exit);
}

module_init(my_init);
module_exit(my_exit);

MODULE_AUTHOR("A GENIUS");
MODULE_LICENSE("GPL v2");
```

- Static functions
- Return codes
- module_init()
- module_exit()
- __init attribute
- __exit attribute

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NOTE: Output edited for brevity

The anatomy of a module (ELF file)

```
$ arm-linux-gnueabihf-objdump -x trivial.ko
1 .text         00000000  00000000  00000000  00000058  2**0
                CONTENTS, ALLOC, LOAD, READONLY, CODE
2 .init.text    00000030  00000000  00000000  00000058  2**2
                CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
3 .exit.text    00000024  00000000  00000000  00000088  2**2
                CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
9 .rodata.str1.4 00000042  00000000  00000000  00000138  2**2
                CONTENTS, ALLOC, LOAD, READONLY, DATA
11 .data        00000000  00000000  00000000  00000180  2**0
                CONTENTS, ALLOC, LOAD, DATA
```


NOTE: Output edited for brevity

__Init code and __initdata

```
static int some_data __initdata = 1 ;

void __init somefunc (void) { ... }
```

```
[0.841689] Freeing unused kernel memory: 424k freed
```


NOTE: Output edited for brevity

Modules and licensing

License	Meaning	Tainted
GPL	GNU Public License V2 or later	No
GPL v2	GNU Public License V2	No
GPL and additional rights	GNU Public License V2 rights and more	No
Dual BSD/GPL	GNU Public License V2 or BSD License	No
Dual MPL/GPL	GNU Public License V2 or MPL License	No
Dual MIT/GPL	GNU Public License V2 or MIT License	No
Proprietary	Not GPL compatible	Yes

Taint bits

```
#define TAINT_PROPRIETARY_MODULE      0
#define TAINT_FORCED_MODULE   1
#define TAINT_CPU_OUT_OF_SPEC     2
#define TAINT_FORCED_RMMOD    3
#define TAINT_MACHINE_CHECK   4
#define TAINT_BAD_PAGE    5
#define TAINT_USER    6
#define TAINT_DIE   7
#define TAINT_OVERRIDDEN_ACPI_TABLE  8
#define TAINT_WARN  9
#define TAINT_CRAP    10
#define TAINT_FIRMWARE_WORKAROUND 11
#define TAINT_OOT_MODULE12
#define TAINT_UNSIGNED_MODULE 13
#define TAINT_SOFTLOCKUP 14
#define TAINT_LIVEPATCH      15
#define TAINT_AUX     16
```

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Exporting Symbols

- The kernel has an in-kernel linker
- All symbols are considered static by default
- You must explicitly export symbols with EXPORT_SYMBOL()
- You can also elect to EXPORT_SYMBOL_GPL()
- Or use EXPORT_SYMBOL_GPL_FUTURE()
- There are also other EXPORT_SYMBOL_* macros

KBuild

- The kernel build system is called Kbuild
- Sub directories have simple Makefiles
- Simple configuration system called Kconfig
- Graphical menuconfig (and others) for Kconfig
- Most other embedded code bases use it

KBuild

.config

CONFIG_FOO=m ← Configure foo as module

Makefile

obj-$(CONFIG_FOO) += foo.o ← module/builtin

obj-y += bar.o ← builtin

obj-$(CONFIG_BLAH) += blah/ ← Subdirectory

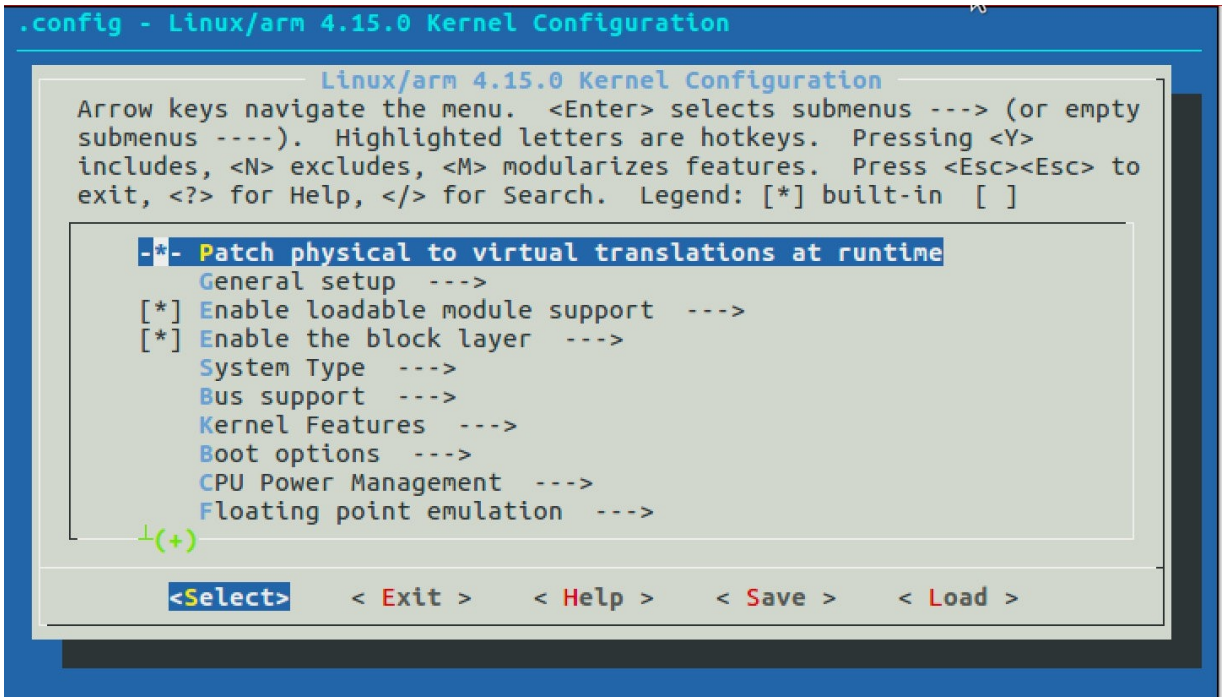
KConfig

- A language to describe configuration options for Kbuild
- Attributes of type, defaults, help, dependencies, selects, conditionals

KConfig

```
config FOO
        tristate “one line description of config option”
        default m
        depends BLAH
        select FLOOP
        select BAR if !BAZ
        help
            This is a multiline long help.
```

menuconfig



Menuconfig

- Up/Down moves through selections
- Left/Right moves through bottom selections
- Enter goes into “→” subdirectories
- Space toggles values
- Y/N/M allows you to choose values
- “/” allows to search options by name

Bulding a module in tree

- Add your code into the tree
- Add yourself to Kconfig
- Add configuration to .config with menuconfig
- make will then build the kernel and your module

Bulding a module out-of-tree

- KROOT=/path/to/relevant/kernel/headers
- make -C $KROOT M=$(pwd) modules
- Use the make system in $KROOT
- Build the modules in the local directory

Cross compiling a module

- Set ARCH to the architecture you want to build
- Set CROSS_COMPILE to the compiler triplet

```
make -C $ROOT M=$(pwd) ARCH=arm \
        CROSS_COMPILE=arm-linux-gnueabihf- modules
```

Installing a module

- Copies a module to /usr/modules/$(uname -r)

```
make -C $ROOT M=$(pwd) ARCH=arm modules_install
```

insmod

- Insert a module into a running kernel
- Invokes the in-kernel linker to link the module into the kernel using the kernel symbol table

$ sudo insmod /path/to/modulename.ko <options>

- Modules are files with the modulename ending in .ko

lsmod

- List currently loaded modules
- Top module was most recently loaded
- Lists size, reference count, and optional dependencies

```
debian@beaglebone:~$ lsmod
Module                  Size  Used by
Evdev                   13811  1
uio_pdrv_genirq         4205  0
uio                     11036  1 uio_pdrv_genirq
usb_f_mass_storage      51462  2
```

rmmod

- Remove a module by name (not filename)
- You can remove more than one module at a time, but the order matters if there are dependencies

$ rmmod foo

$ rmmod bar blah

depmod

- Builds dependency files for all modules used by modprobe

```
$ ls -1 /lib/modules/$(uname -r)
modules.alias
modules.builtin
modules.dep
modules.order
modules.symbols
```

modprobe

- A “smart” insmod
- Will load module pre-dependencies
- Allows you to set persistent options (and more)
- Uses /etc/modprobe.conf and /etc/modprobe.d
- Used by udevd to load drivers

Modprobe configuration

/etc/modprobe.d/foo.conf

```
blacklist bar
options blah option1=value option2=value …
alias genericname foo
```

modinfo

- Shows module metadata

```
root@beaglebone:~# modinfo uio
filename:     /lib/modules/4.9.82-ti-r102/kernel/drivers/uio/uio.ko
license:      GPL v2
depends:
intree:       Y
vermagic:   4.9.82-ti-r102 SMP preempt mod_unload \
                modversions ARMv7 p2v8
```

dmesg

- dmesg shows kernel in-memory log buffer.
- Using the “-w” option does a “tail” of the log

root@beaglebone:~# dmesg -w


Questions?
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Thank you!
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