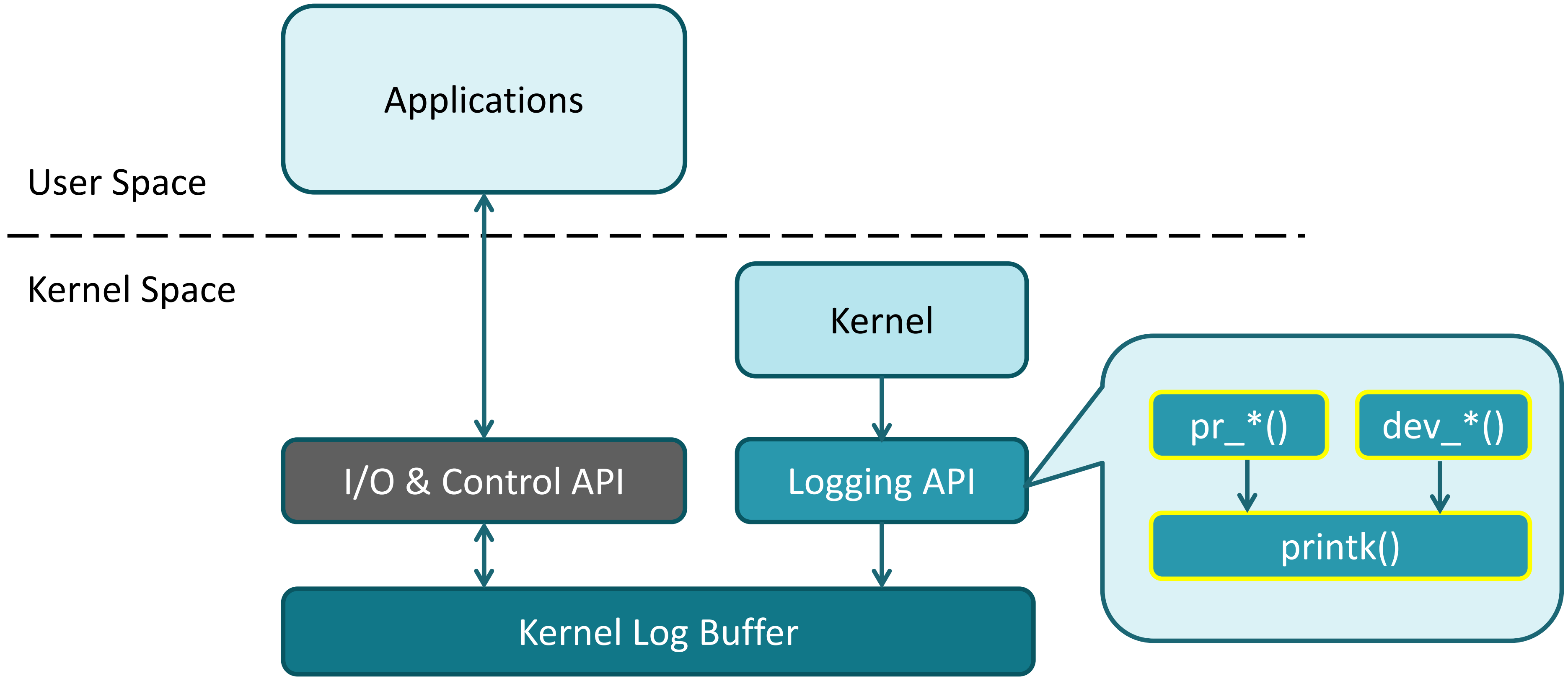
Debugging Embedded Linux Systems: printk and Variations

Debugging Embedded Linux Training Series [Part 3]

Texas Instruments

Debugging Embedded Linux Training Series

Kernel logging system architecture



Agenda

- printk()
- Kernel Log Message Levels
- pr_*(), dev_*()
- pr_debug(), dev_dbg()
- dev_vdbg()
- Enable Debug Log Messages
- Case Study

printk()

- Format and print data/message into kernel log buffer
- Foundation of Logging API
- Works in a similar way as `printf()` in user space
- Example:

```
printk(KERN_ALERT "DBG: passed %s %d\n", __FUNCTION__, __LINE__)
```

- Kernel-specific conversion specifiers:

  Ex.: “%pS” - print symbol name with offset: `versatile_init+0x0/0x110`

Log message level

```
printk(KERN_ALERT "DBG: passed %s %d\n", __FUNCTION__, __LINE__)
```

Log message levels

Macro*	Level
KERN_EMERG	“<0>”
KERN_ALERT	“<1>”
KERN_CRIT	“<2>”
KERN_ERR	“<3>”
KERN_WARNING	“<4>”
KERN_NOTICE	“<5>”
KERN_INFO	“<6>”
KERN_DEBUG	“<7>”

*Defined in `include/linux/kern_levels.h`

Used by the kernel to determine the importance of a message

```
printk(KERN_ALERT "DBG: passed %s %d\n",
          __FUNCTION__, __LINE__);
```

```
<1>DBG: passed ……
```

Filtering log messages

- Userspace tool can filter messages based on the message level.
- Examples:

```
dmesg -n 5
```

Set console logging filter to KERN_WARNING or more severe.

```
dmesg -l warn
```

Only print the logs of KERN_WARNING in the kernel ring buffer.

pr_*(), dev_*()

- `pr_emerg, pr_alert, pr_crit, pr_err, pr_warning, pr_notice, pr_info pr_debug`
  - Macro definitions for the printk calls with respective message level
  - Should be used in **kernel (not device drivers)** instead of calling `printk()` directly

- `dev_emerg, dev_alert, dev_crit, dev_err, dev_warn, dev_notice, dev_info dev_dbg`
  - Macro definitions for the printk calls with respective message level
  - Should be used in **device drivers** instead of calling `printk()` directly

Logging API

Level	Base	For Kernel	For Drivers
0	printk(KERN_EMERG…)	pr_emerg()	dev_emerg()
1	printk(KERN_ALERT…)	pr_alert()	dev_alert()
2	printk(KERN_CRIT…)	pr_crit()	dev_crit()
3	printk(KERN_ERR…)	pr_err()	dev_err()
4	printk(KERN_WARNING…)	pr_warning()	dev_warn()
5	printk(KERN_NOTICE…)	pr_notice()	dev_notice()
6	printk(KERN_INFO…)	pr_info()	dev_info()
7	printk(KERN_DEBUG…)	pr_debug()	dev_dbg(),dev_vdbg()

pr_debug(), dev_dbg()

- Macros defined with the lowest message level 7 - *KERN_DEBUG*
- Used for printing *debug* messages in kernel or device drivers, respectively.
- Only enabled when DEBUG compiler macro is defined.
- Kernel production build would have DEBUG macro undefined.

```
#ifdef DEBUG
    #define pr_debug(...)          printk(KERN_DEBUG ...)
    #define dev_dbg(...)           dev_printk(KERN_DEBUG ...)
#else
    #define pr_debug(...)          ({})
    #define dev_dbg(...)           ({})
#endif
```

dev_vdbg()

- Print verbose debug messages
- Macro definition for dev_dbg( )
- Controlled by VERBOSE_DEBUG compiler macro

```
#ifdef VERBOSE_DEBUG
    #define dev_vdbg  dev_dbg
#else
    #define dev_vdbg  ({})
#endif
```

Enable DEBUG/VERBOSE_DEBUG macro

- Three options to enable DEBUG macro:
  1. Kernel config option
  2. Add -DDBUG in Makefile ccflags
  3. Add "#define DEBUG" in *.c
     Above **any** #include <...> lines
- Three options to enable VERBOSE_DEBUG macro:
  1. Kernel config option
  2. Add -DVERBOSE_DBUG in Makefile ccflags
  3. Add "#define VERBOSE_DEBUG" in *.c
     Above **any** #include <...> lines

Case study: Locate Kconfig option for debug/vdebug

- Procedure:
  1. Find the kernel config option referred for DDBUG/DVERBOSE_DEBUG in the Makefile.
  2. (Optional) Find the corresponding config option in Kconfig.
  3. Use the search function to locate the config option in kernel menuconfig.

- Example: Enable DDBUG in GPIO drivers.

Case study: Locate debug Kconfig option in GPIO drivers (1)

./drivers/gpio/Makefile

```
#generic gpio support: platform drivers, dedicated expander chips, etc

ccflags-$(CONFIG_DEBUG_GPIO)     += -DDEBUG
obj-$(CONFIG_GPIO_DEVRES)        += devres.o
obj-$(CONFIG_GPIOLIB)            += gpiolib.o
obj-$(CONFIG_GPIOLIB)            += gpiolib-legacy.o
obj-$(CONFIG_OF_GPIO)            += gpiolib-of.o
obj-$(CONFIG_GPIO_SYSFS)         += gpiolib-sysfs.o
obj-$(CONFIG_GPIO_ACPI)          += gpiolib-acpi.o
```

Case study: Locate debug Kconfig option in GPIO drivers (2)

```
$ find . -name Kconfig -exec grep -Hn '\<config DEBUG_GPIO\>' {} \;
```

Case study: Locate debug Kconfig option in GPIO drivers (2)

```
$ find . -name Kconfig -exec grep -Hn '\<config DEBUG_GPIO\>' {} \;
./drivers/gpio/Kconfig:63:config DEBUG_GPIO
```

Case study: Locate debug Kconfig option in GPIO drivers (2)

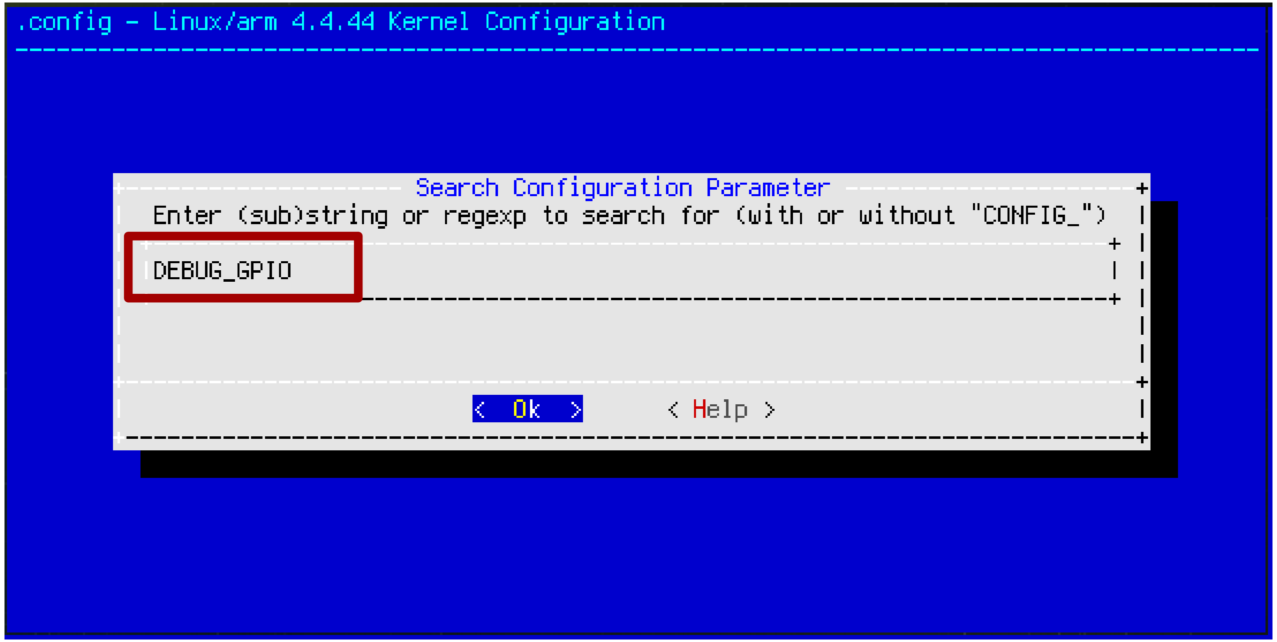
```
$ find . -name Kconfig -exec grep -Hn '\<config DEBUG_GPIO\>' {} \;
./drivers/gpio/Kconfig:63:config DEBUG_GPIO
```

```
59 config GPIOLIB_IRQCHIP
60         select IRQ_DOMAIN
61         bool
62
63 config DEBUG_GPIO
64         bool "Debug GPIO calls"
65         depends on DEBUG_KERNEL
66         help
67           Say Y here to add some extra checks and diagnostics to GPIO calls.
```

Case study: Locate debug Kconfig option in GPIO drivers (3)

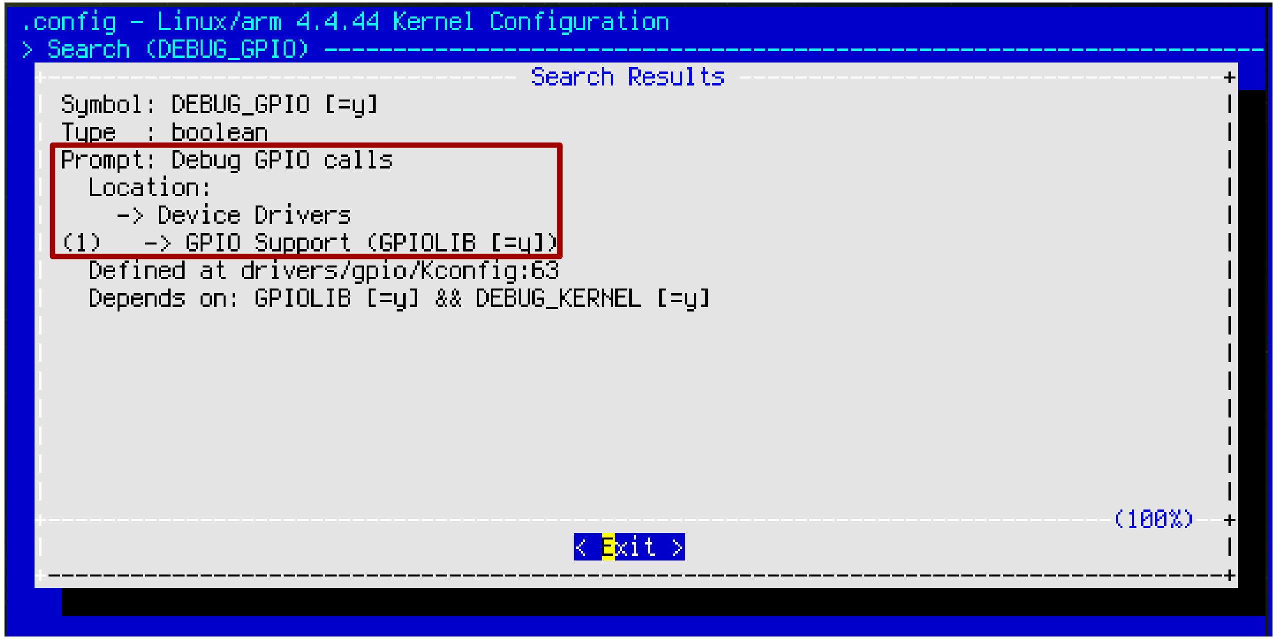
$ make menuconfig

/DEBUG_GPIO



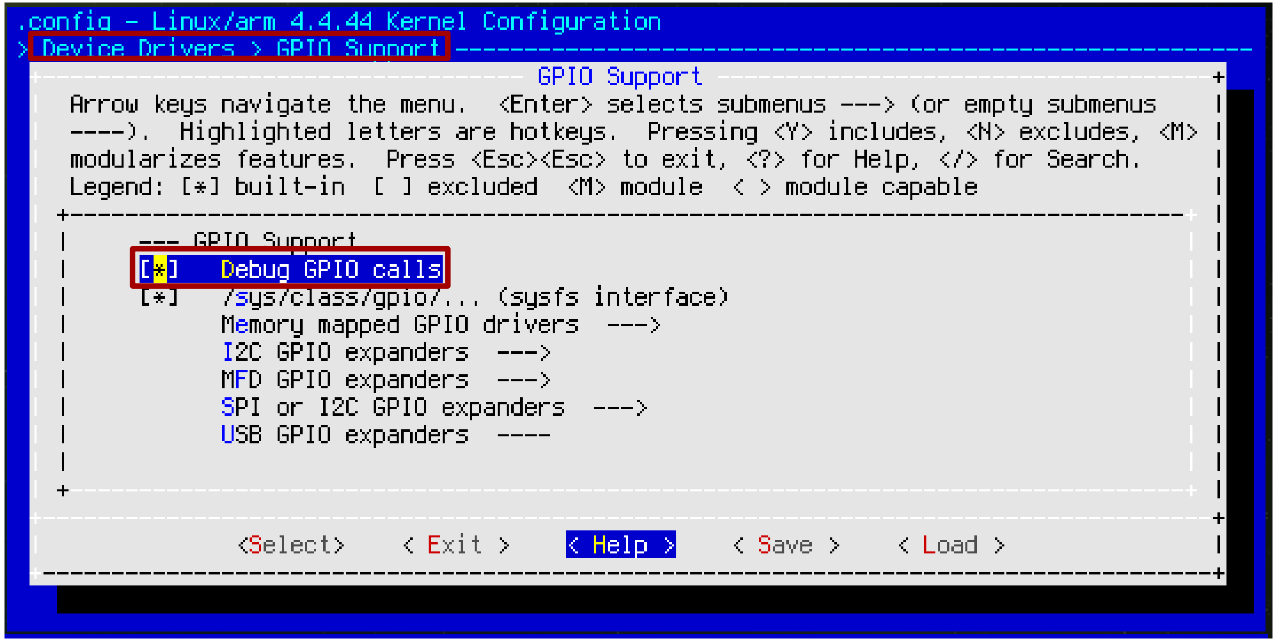
```
.config - Linux/arm 4.4.44 Kernel Configuration
-----------------------------------------------------------------------------------
                     Search Configuration Parameter
   Enter (sub)string or regexp to search for (with or without "CONFIG_")

   DEBUG_GPIO

                          < Ok >         < Help >
```

Case study: Locate debug Kconfig option in GPIO drivers (3)



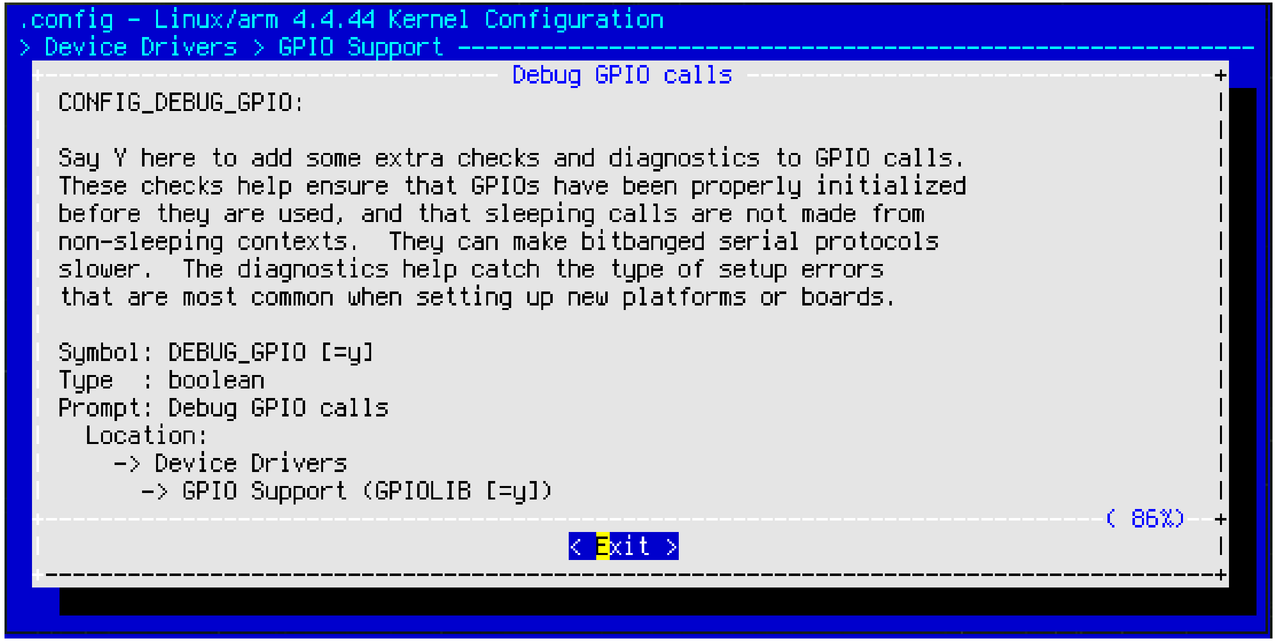
```
.config - Linux/arm 4.4.44 Kernel Configuration
> Search (DEBUG_GPIO) ---------------------------------------------------------------
                                 Search Results
 Symbol: DEBUG_GPIO [=y]
 Type  : boolean
 Prompt: Debug GPIO calls
   Location:
     -> Device Drivers
 (1)   -> GPIO Support (GPIOLIB [=y])
   Defined at drivers/gpio/Kconfig:63
   Depends on: GPIOLIB [=y] && DEBUG_KERNEL [=y]
                                                                          (100%)
                                   < Exit >
```

Case study: Locate debug Kconfig option in GPIO drivers (3)



```
.config - Linux/arm 4.4.44 Kernel Configuration
> Device Drivers > GPIO Support ----------------------------------------------
                          GPIO Support
  Arrow keys navigate the menu.  <Enter> selects submenus ---> (or empty submenus
  ----).  Highlighted letters are hotkeys.  Pressing <Y> includes, <N> excludes, <M>
  modularizes features.  Press <Esc><Esc> to exit, <?> for Help, </> for Search.
  Legend: [*] built-in  [ ] excluded  <M> module  < > module capable

        --- GPIO Support
        [*]   Debug GPIO calls
        [*]   /sys/class/gpio/... (sysfs interface)
              Memory mapped GPIO drivers  --->
              I2C GPIO expanders  --->
              MFD GPIO expanders  --->
              SPI or I2C GPIO expanders  --->
              USB GPIO expanders  ----

          <Select>    < Exit >    < Help >    < Save >    < Load >
```

Case study: Locate debug Kconfig option in GPIO drivers (3)



```
.config - Linux/arm 4.4.44 Kernel Configuration
> Device Drivers > GPIO Support ----------------------------------------
+------------------------- Debug GPIO calls --------------------------+
| CONFIG_DEBUG_GPIO:                                                   |
|                                                                      |
| Say Y here to add some extra checks and diagnostics to GPIO calls.   |
| These checks help ensure that GPIOs have been properly initialized   |
| before they are used, and that sleeping calls are not made from      |
| non-sleeping contexts.  They can make bitbanged serial protocols     |
| slower.  The diagnostics help catch the type of setup errors         |
| that are most common when setting up new platforms or boards.        |
|                                                                      |
| Symbol: DEBUG_GPIO [=y]                                              |
| Type  : boolean                                                      |
| Prompt: Debug GPIO calls                                             |
|   Location:                                                          |
|     -> Device Drivers                                                |
|       -> GPIO Support (GPIOLIB [=y])                                 |
+---------------------------------------------------------( 86%)-----+
|                            < Exit >                                  |
+----------------------------------------------------------------------+
```

Summary

- printk() is the foundation of the kernel logging API. But it should not be used directly in kernel modules or device drivers.
- pr_*() are macros wrapping printk() for kernel module logging.
- dev_*() are macros wrapping printk() for device driver logging.
- pr_debug(), dev_dbg()/dev_vdbg() are for logging debug messages.
  - Disabled in production build
  - Controlled by DEBUG or VERBOSE DEBUG compiler macro

For more information

- Processor SDK Training Series: http://training.ti.com/processor-sdk-training-series
- Debugging Embedded Linux Training Series: http://training.ti.com/debug-embedded-linux-training-series
- Processor SDK Linux Getting Started Guide: http://processors.wiki.ti.com/index.php/Processor_SDK_Linux_Getting_Started_Guide
- Download Processor SDK Linux for Embedded Processors: http://www.ti.com/processorsdk
- For questions about this training, refer to the E2E Embedded Linux Community Forum: http://e2e.ti.com/support/embedded/linux/f/354

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