

Assignment 1: Discovering VMX Features

- 1) For each member of your team, provide 1 paragraph detailing what parts of the lab that member implemented/researched. (You may skip this question if you are doing the lab by yourself).

- **Work done by Harsh Patel:**

- Downloaded and built the Linux Kernel code and installed the required libraries to create a local copy of the Linux Kernel.
- Modified half of the cmpe283assignment1vt.c code by adding custom logic to enable our system to read and give output for the capabilities of the various MSRs.
- Tested and verified the proper working of the functionality of code by comparing it with the sample output given to us.
- Wrote installation steps and troubleshooted various errors which were solved by installing a few libraries.

- **Work done by Piyush Mamidwar:**

- Created a VM Instance using Google Cloud Platform and configured it to enable nested virtualization.
- Modified the other half of the cmpe283assignment1vt.c code by adding custom logic to enable our system to read and give output for the capabilities of the various MSRs.
- Created makefile to compile kernel code which will create a .ko file which is our kernel module
- Wrote installation steps and troubleshooted errors.

- 2) Describe in detail the steps you used to complete the assignment. Consider your reader to be someone skilled in software development but otherwise unfamiliar with the assignment. Good answers to this question will be recipes that someone can follow to reproduce your development steps.

Steps (Steps for M1/M2 chip devices):

- Install gCloud CLI from the following link : <https://cloud.google.com/sdk/docs/install>
 - Extract the downloaded tar file from the above link and run the install.sh file using the following link:
`./google-cloud-sdk/install.sh`
 - To init gCloud CLI, run the following command: `./google-cloud-sdk/bin/gcloud init`
- Create a VM instance with Ubuntu OS using the following command with nested virtualization enabled:
`./gcloud compute instances create instance-1 --project=sodium-hangar-367902 --zone=us-west4-b --machine-type=e2-small --network-interface=network-tier=PREMIUM,subnet=default --maintenance-policy=MIGRATE --provisioning-model=STANDARD --service-account=410397892267-compute@developer.gserviceaccount.com --scopes=https://www.googleapis.com/auth/devstorage.read_only,https://www.googleapis.com/auth/logging.write,https://www.googleapis.com/auth/monitoring.write,https://www.googleapis.com/auth/servicecontrol,https://www.googleapis.com/auth/service.management.readonly,https://www.googleapis.com/auth/trace.append --create-disk=auto-delete=yes,boot=yes,device-name=instance-1,image=projects/ubuntu-os-cloud/global/images/ubuntu-2204-jammy-v20221101a,mode=rw,size=10,type=projects/sodium-hangar-367902/zones/us-west4-b/diskTypes/pd-ssd --no-shielded-secure-boot --shielded-vtpm --shielded-integrity-monitoring --reservation-affinity=any --enable-nested-virtualization`
- Once the Instance is created start the instance using the following command: `gcloud compute ssh VM_NAME`

- Install git and clone the Linux repo onto your VM. Link : <https://github.com/torvalds/linux.git>
- Write a .c (C language) file that will be used to discover the capabilities of the MSRs:
`vi cmpe283assignment1vt.c` (write code here)
- Install GCC and Make using the following command:
`apt install gcc make`
- Install header files for the Linux kernel using the command:
`sudo apt-get install linux-headers-$(uname -r)`
- Creating new kernel module for MSRs:
`Nano Makefile`
File content:

```
obj-m += cmpe283assignment1vt-1.o

all:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) modules

clean:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) clean
make all
```
- Now that we have our .ko file, we can insert this module into the kernel by using the insmod command as shown below:
`insmod ./cmpe283assignment1vt.ko`
- Using dmesg command, we can see the output from the sample Kernel module:
`Dmesg`

Appendix

1)Code:

```
/*
 * cmpe283-1.c - Kernel module for CMPE283 assignment 1
 */
#include <linux/module.h> /* Needed by all modules */
#include <linux/kernel.h> /* Needed for KERN_INFO */
#include <asm/msr.h>

#define MAX_MSG 80

/*
 * Model specific registers (MSRs) by the module.
 * See SDM volume 4, section 2.1
 */
#define IA32_VMX_PINBASED_CTL0 0x481
#define IA32_VMX_PROCBASED_CTL0 0x482
#define IA32_VMX_PROCBASED_CTL0S 0x48B
#define IA32_VMX_EXIT_CTL0 0x483
#define IA32_VMX_ENTRY_CTL0 0x484
#define IA32_VMX_PROCBASED_CTL0S3 0x492
```

```

/*
 * struct caapability_info
 *
 * Represents a single capability (bit number and description).
 * Used by report_capability to output VMX capabilities.
 */
struct capability_info {
    uint8_t bit;
    const char *name;
};

/*
 * Pinbased capabilities
 * See SDM volume 3, section 24.6.1
 */
struct capability_info pinbased[5] =
{
    { 0, "External Interrupt Exiting" },
    { 3, "NMI Exiting" },
    { 5, "Virtual NMIs" },
    { 6, "Activate VMX Preemption Timer" },
    { 7, "Process Posted Interrupts" }
};
struct capability_info primaryprocbased[22] =
{
    { 2, "Interrupt-window exiting" },
    { 3, "Use TSC offsetting" },
    { 7, "HLT exiting" },
    { 9, "INVLPG exiting" },
    { 10, "MWAIT exiting" },
    { 11, "RDPMC exiting" },
    { 12, "RDTSC exiting" },
    { 15, "CR3-load exiting" },
    { 16, "CR3-store exiting" },
    { 17, "Activate tertiary controls" },
    { 19, "CR8-load exiting" },
    { 20, "CR8-store exiting" },
    { 21, "Use TPR shadow" },
    { 22, "NMI-window exiting" },
    { 23, "MOV-DR exiting" },
    { 24, "Unconditional I/O exiting" },
    { 25, "Use I/O bitmaps" },
    { 27, "Monitor trap flag" },
    { 28, "Use MSR bitmaps" },
    { 29, "MONITOR exiting" },
    { 30, "PAUSE exiting" },
    { 31, "Activate secondary controls" }
}

```

```
};

struct capability_info secondaryprocbased[28] =
{
    { 0, "Virtualize APIC accesses" },
    { 1, "Enable EPT" },
    { 2, "Descriptor-table exiting" },
    { 3, "Enable RDTSCP" },
    { 4, "Virtualize x2APIC mode" },
    { 5, "Enable VPID" },
    { 6, "WBINVD exiting" },
    { 7, "Unrestricted guest" },
    { 8, "APIC-register virtualization" },
    { 9, "Virtual-interrupt delivery" },
    { 10, "PAUSE-loop exiting" },
    { 11, "RDRAND exiting" },
    { 12, "Enable INVPCID" },
    { 13, "Enable VM functions" },
    { 14, "VMCS shadowing" },
    { 15, "Enable ENCLS exiting" },
    { 16, "RDSEED exiting" },
    { 17, "Enable PML" },
    { 18, "EPT-violation #VE" },
    { 19, "Conceal VMX from PT" },
    { 20, "Enable XSAVES/XRSTORS" },
    { 22, "Mode-based execute control for EPT" },
    { 23, "Sub-page write permissions for EPT" },
    { 24, "Intel PT uses guest physical addresses" },
    { 25, "Use TSC scaling" },
    { 26, "Enable user wait and pause" },
    { 27, "Enable PCONFIG" },
    { 28, "Enable ENCLV exiting" }
};

struct capability_info exitctls[17] =
{
    { 2, "Save debug controls" },
    { 9, "Host address-space size" },
    { 12, "Load IA32_PERF_GLOBAL_CTRL" },
    { 15, "Acknowledge Interrupt on exit" },
    { 18, "Save IA32_PAT" },
    { 19, "Load IA32_PAT" },
    { 20, "Save IA32_EFER" },
    { 21, "Load IA32_EFER" },
    { 22, "Save VMX-preemption timer value" },
    { 23, "Clear IA32_BNDCFGS" },
    { 24, "Conceal VMX from PT" },
    { 25, "Clear IA32_RTIT_CTL" },
    { 26, "Clear IA32_LBR_CTL" },
    { 28, "Load CET state" },
}
```

```

    { 29, "Load PKRS" },
    { 30, "Save IA32_PERF_GLOBAL_CTL" },
    { 31, " Activate secondary controls" }
};

struct capability_info entry[13] =
{
    { 2, "Load debug controls" },
    { 9, "IA-32e mode guest" },
    { 10, "Entry to SMM" },
    { 11, "Deactivate dual-monitor treatment" },
    { 13, "load IA32_PERF_GLOBAL_CTRL" },
    { 14, "Load IA32_PAT" },
    { 15, "Load IA32_EFER" },
    { 16, "Load IA32_BNDCFGS" },
    { 17, "Conceal VMX from PT" },
    { 18, "Load IA32_RTIT_CTL" },
    { 20, "Load CET state" },
    { 21, "Load guest IA32_LBR_CTL" },
    { 22, "Load PKRS" }
};

struct capability_info tertiaryprocbased[4] =
{
    { 0, "LOADIWKEY exiting" },
    { 1, "Enable HLAT" },
    { 2, "EPT paging-write control" },
    { 3, "Guest-paging verification" }
};

/*
 * report_capability
 *
 * Reports capabilities present in 'cap' using the corresponding MSR values
 * provided in 'lo' and 'hi'.
 *
 * Parameters:
 *   cap: capability_info structure for this feature
 *   len: number of entries in 'cap'
 *   lo: low 32 bits of capability MSR value describing this feature
 *   hi: high 32 bits of capability MSR value describing this feature
 */
void
report_capability(struct capability_info *cap, uint8_t len, uint32_t lo,
                  uint32_t hi)
{
    uint8_t i;
    struct capability_info *c;
    char msg[MAX_MSG];

    memset(msg, 0, sizeof(msg));

```

```

        for (i = 0; i < len; i++) {
            c = &cap[i];
            snprintf(msg, 79, " %s: Can set=%s, Can clear=%s\n",
                      c->name,
                      (hi & (1 << c->bit)) ? "Yes" : "No",
                      !(lo & (1 << c->bit)) ? "Yes" : "No");
            printk(msg);
        }
    }

/*
 * detect_vmx_features
 *
 * Detects and prints VMX capabilities of this host's CPU.
 */
void
detect_vmx_features(void)
{
    uint32_t lo, hi;

    /* Pinbased controls */
    rdmsr(IA32_VMX_PINBASED_CTLs, lo, hi);
    pr_info("Pinbased Controls MSR: 0x%llx\n",
            (uint64_t)(lo | (uint64_t)hi << 32));
    report_capability(pinbased, 5, lo, hi);

    /* Primary Processor-Based VM-Execution Controls */
    rdmsr(IA32_VMX_PROCBASED_CTLs, lo, hi);
    pr_info("Primary Processor-Based VM-Execution Controls MSR: 0x%llx\n",
            (uint64_t)(lo | (uint64_t)hi << 32));
    report_capability(primaryprocbased, 22, lo, hi);

    /* Secondary Processor-Based VM-Execution Controls */
    rdmsr(IA32_VMX_PROCBASED_CTLs2, lo, hi);
    pr_info("Secondary Processor-Based VM-Execution Controls MSR: 0x%llx\n",
            (uint64_t)(lo | (uint64_t)hi << 32));
    report_capability(secondaryprocbased, 28, lo, hi);

    /* Primary VM-Exit Controls */
    rdmsr(IA32_VMX_EXIT_CTLs, lo, hi);
    pr_info("Primary VM-Exit Controls MSR: 0x%llx\n",
            (uint64_t)(lo | (uint64_t)hi << 32));
    report_capability(exitctlts, 17, lo, hi);

    /* VM-Entry Controls */
    rdmsr(IA32_VMX_ENTRY_CTLs, lo, hi);
    pr_info("VM-Entry Controls MSR: 0x%llx\n",
            (uint64_t)(lo | (uint64_t)hi << 32));
}

```

```

        report_capability(entry, 13, lo, hi);

        /* Tertiary Processor-Based VM-Execution Controls */
        rdmsr(IA32_VMX_PROCBASED_CTL3, lo, hi);
        pr_info("Tertiary Processor-Based VM-Execution Controls MSR: 0x%llx\n",
                (uint64_t)(lo | (uint64_t)hi << 32));
        report_capability(tertiaryprocbased, 4, lo, hi);
    }

/*
 * init_module
 *
 * Module entry point
 *
 * Return Values:
 * Always 0
 */
int
init_module(void)
{
    printk(KERN_INFO "CMPE 283 Assignment 1 Module Start\n");

    detect_vmx_features();

    /*
     * A non 0 return means init_module failed; module can't be loaded.
     */
    return 0;
}

/*
 * cleanup_module
 *
 * Function called on module unload
 */
void
cleanup_module(void)
{
    printk(KERN_INFO "CMPE 283 Assignment 1 Module Exits\n");
}

MODULE_LICENSE("GPL");

```

OUTPUT:

```

b 0d 77 8b 0d 00 f7 d8 64 89 01 48
1509.099897] RSP: 002b:00007ffcab7c9e78 EFLAGS: 00000246 ORIG_RAX: 000000000000000139
1509.107917] RAX: ffffffff0fffffda RBX: 000055a29081c7b0 RCX: 00007f3d021f92e9
1509.116691] RDX: 0000000000000000 RSI: 000055a28f39f260 RDI: 0000000000000003
1509.124051] RBP: 0000000000000000 R08: 0000000000000000 R09: 00007f3d022d5960
1509.131321] R10: 0000000000000003 R11: 00000000000000246 R12: 000055a28f39f260
1509.139957] R13: 0000000000000000 R14: 000055a29081c760 R15: 0000000000000000
1509.147226] Pinbased Controls MSR: 0x0
1509.152468] External Interrupt Exiting: Can set=No, Can clear=Yes
1509.158854] NMI Exiting: Can set=No, Can clear=Yes
1509.163966] Virtual NMIs: Can set=No, Can clear=Yes
1509.169235] Activate VMX Preemption Timer: Can set=No, Can clear=Yes
1509.177300] Process Posted Interrupts: Can set=No, Can clear=Yes
1509.183685] Primary Processor-Based VM-Execution Controls MSR: 0x0
1509.191318] Interrupt-Window exiting: Can set=No, Can clear=Yes
1509.197639] Use TSC offsetting: Can set=No, Can clear=Yes
1509.203330] HLT exiting: Can set=No, Can clear=Yes
1509.208496] INVLPG exiting: Can set=No, Can clear=Yes
1509.215247] MWAIT exiting: Can set=No, Can clear=Yes
1509.220754] RDPMC exiting: Can set=No, Can clear=Yes
1509.226030] RDTS C exiting: Can set=No, Can clear=Yes
1509.232791] CR3-load exiting: Can set=No, Can clear=Yes
1509.238420] CR3-store exiting: Can set=No, Can clear=Yes
1509.245410] Activate tertiary controls: Can set=No, Can clear=Yes
1509.251842] CR8-load exiting: Can set=No, Can clear=Yes
1509.258740] CR8-store exiting: Can set=No, Can clear=Yes
1509.264351] Use TPR shadow: Can set=No, Can clear=Yes
1509.271335] NMI-window exiting: Can set=No, Can clear=Yes
1509.277030] MOV-DR exiting: Can set=No, Can clear=Yes
1509.282452] Unconditional I/O exiting: Can set=No, Can clear=Yes
1509.288799] Use I/O bitmaps: Can set=No, Can clear=Yes
1509.294243] Monitor trap flag: Can set=No, Can clear=Yes
1509.301361] Use MSR bitmaps: Can set=No, Can clear=Yes
1509.306828] MONITOR exiting: Can set=No, Can clear=Yes
1509.312402] PAUSE exiting: Can set=No, Can clear=Yes
1509.317689] Activate secondary controls: Can set=No, Can clear=Yes
1509.325657] Secondary Processor-Based VM-Execution Controls MSR: 0x0
1509.333685] Virtualize APIC accesses: Can set=No, Can clear=Yes
1509.341528] Enable EPT: Can set=No, Can clear=Yes
1509.346561] Descriptor-table exiting: Can set=No, Can clear=Yes
1509.352906] Enable RDTSCP: Can set=No, Can clear=Yes
1509.359824] Virtualize x2APIC mode: Can set=No, Can clear=Yes
1509.365871] Enable VPID: Can set=No, Can clear=Yes
1509.372370] WBINVD exiting: Can set=No, Can clear=Yes
1509.377863] Unrestricted guest: Can set=No, Can clear=Yes
1509.383588] APIC-register virtualization: Can set=No, Can clear=Yes
1509.391788] Virtual-interrupt delivery: Can set=No, Can clear=Yes
1509.398197] PAUSE-loop exiting: Can set=No, Can clear=Yes
1509.403897] RDAND exiting: Can set=No, Can clear=Yes
1509.40734] Enable INVPCID: Can set=No, Can clear=Yes
1509.416191] Enable VM functions: Can set=No, Can clear=Yes
1509.423532] VMCS shadowing: Can set=No, Can clear=Yes
1509.428887] Enable ENCLS exiting: Can set=No, Can clear=Yes
1509.436138] RDSEED exiting: Can set=No, Can clear=Yes
1509.441480] Enable PML: Can set=No, Can clear=Yes
1509.447856] EPT-violation #VE: Can set=No, Can clear=Yes
1509.453650] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.459439] Enable XSAVES/XRSTORS: Can set=No, Can clear=Yes
1509.465399] Mode-based execute control for EPT: Can set=No, Can clear=Yes
1509.473961] Sub-page write permissions for EPT: Can set=No, Can clear=Yes
1509.481219] Intel PT uses guest physical addresses: Can set=No, Can clear=Yes
1509.488656] Use TSC scaling: Can set=No, Can clear=Yes
1509.494139] Enable user wait and pause: Can set=No, Can clear=Yes
1509.500525] Enable PCONFIG: Can set=No, Can clear=Yes
1509.505892] Enable ENCLV exiting: Can set=No, Can clear=Yes
1509.511819] Primary VM-Exit Controls MSR: 0x0
1509.517628] Save debug controls: Can set=No, Can clear=Yes
1509.523599] Host address-space size: Can set=No, Can clear=Yes
1509.529905] Load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.537684] Acknowledge interrupt on exit: Can set=No, Can clear=Yes
1509.544537] Save IA32_PAT: Can set=No, Can clear=Yes
1509.549801] Load IA32_PAT: Can set=No, Can clear=Yes
1509.556549] Save IA32_EFER: Can set=No, Can clear=Yes
1509.561913] Load IA32_EFER: Can set=No, Can clear=Yes
1509.567520] Save VMX-preemption timer value: Can set=No, Can clear=Yes
1509.575818] Clear IA32_BNDCFGS: Can set=No, Can clear=Yes
1509.581708] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.587753] Clear IA32_RTIT_CTRL: Can set=No, Can clear=Yes
1509.593583] Clear IA32_LBR_CTRL: Can set=No, Can clear=Yes
1509.600760] Load CET state: Can set=No, Can clear=Yes
1509.606120] Load PKRS: Can set=No, Can clear=Yes
1509.611152] Save IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.618841] Activate secondary controls: Can set=No, Can clear=Yes
1509.625551] VM-Entry Controls MSR: 0x0
1509.631221] Load debug controls: Can set=No, Can clear=Yes
1509.637202] IA-32e mode guest: Can set=No, Can clear=Yes
1509.644191] Entry to SMM: Can set=No, Can clear=Yes
1509.649374] Deactivate dual-monitor treatment: Can set=No, Can clear=Yes
1509.656394] load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes

```

```

1509.341528] Enable EPT: Can set=No, Can clear=Yes
1509.346561] Descriptor-table exiting: Can set=No, Can clear=Yes
1509.352906] Enable RDTSCP: Can set=No, Can clear=Yes
1509.359824] Virtualize x2APIC mode: Can set=No, Can clear=Yes
1509.365871] Enable VPID: Can set=No, Can clear=Yes
1509.372370] WBINVD exiting: Can set=No, Can clear=Yes
1509.377863] Unrestricted guest: Can set=No, Can clear=Yes
1509.383588] APIC-register virtualization: Can set=No, Can clear=Yes
1509.391788] Virtual-interrupt delivery: Can set=No, Can clear=Yes
1509.398197] PAUSE-loop exiting: Can set=No, Can clear=Yes
1509.403897] RDAND exiting: Can set=No, Can clear=Yes
1509.40734] Enable INVPCID: Can set=No, Can clear=Yes
1509.416191] Enable VM functions: Can set=No, Can clear=Yes
1509.423532] VMCS shadowing: Can set=No, Can clear=Yes
1509.428887] Enable ENCLS exiting: Can set=No, Can clear=Yes
1509.436138] RDSEED exiting: Can set=No, Can clear=Yes
1509.441480] Enable PML: Can set=No, Can clear=Yes
1509.447856] EPT-violation #VE: Can set=No, Can clear=Yes
1509.453650] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.459439] Enable XSAVES/XRSTORS: Can set=No, Can clear=Yes
1509.465399] Mode-based execute control for EPT: Can set=No, Can clear=Yes
1509.473961] Sub-page write permissions for EPT: Can set=No, Can clear=Yes
1509.481219] Intel PT uses guest physical addresses: Can set=No, Can clear=Yes
1509.488656] Use TSC scaling: Can set=No, Can clear=Yes
1509.494139] Enable user wait and pause: Can set=No, Can clear=Yes
1509.500525] Enable PCONFIG: Can set=No, Can clear=Yes
1509.505892] Enable ENCLV exiting: Can set=No, Can clear=Yes
1509.511819] Primary VM-Exit Controls MSR: 0x0
1509.517628] Save debug controls: Can set=No, Can clear=Yes
1509.523599] Host address-space size: Can set=No, Can clear=Yes
1509.529905] Load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.537684] Acknowledge interrupt on exit: Can set=No, Can clear=Yes
1509.544537] Save IA32_PAT: Can set=No, Can clear=Yes
1509.549801] Load IA32_PAT: Can set=No, Can clear=Yes
1509.556549] Save IA32_EFER: Can set=No, Can clear=Yes
1509.561913] Load IA32_EFER: Can set=No, Can clear=Yes
1509.567520] Save VMX-preemption timer value: Can set=No, Can clear=Yes
1509.575818] Clear IA32_BNDCFGS: Can set=No, Can clear=Yes
1509.581708] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.587753] Clear IA32_RTIT_CTRL: Can set=No, Can clear=Yes
1509.593583] Clear IA32_LBR_CTRL: Can set=No, Can clear=Yes
1509.600760] Load CET state: Can set=No, Can clear=Yes
1509.606120] Load PKRS: Can set=No, Can clear=Yes
1509.611152] Save IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.618841] Activate secondary controls: Can set=No, Can clear=Yes
1509.625551] VM-Entry Controls MSR: 0x0
1509.631221] Load debug controls: Can set=No, Can clear=Yes
1509.637202] IA-32e mode guest: Can set=No, Can clear=Yes
1509.644191] Entry to SMM: Can set=No, Can clear=Yes
1509.649374] Deactivate dual-monitor treatment: Can set=No, Can clear=Yes
1509.656394] load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes

```

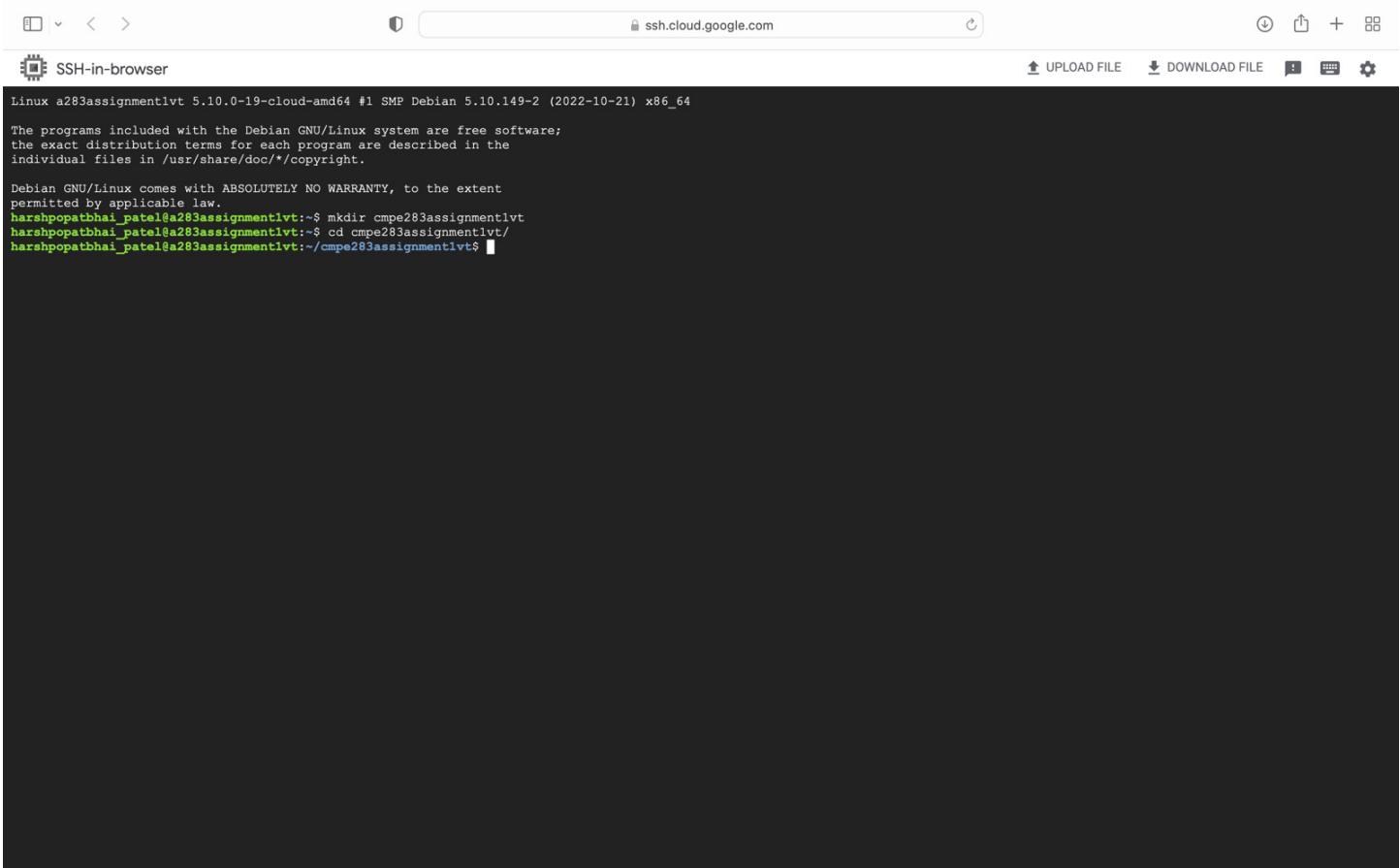
```

1509.428887] Enable ENCLS exiting: Can set=No, Can clear=Yes
1509.436138] RDSEED exiting: Can set=No, Can clear=Yes
1509.441480] Enable PMI: Can set=No, Can clear=Yes
1509.447856] EPT-violation #VE: Can set=No, Can clear=Yes
1509.453650] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.459439] Enable XSAVES/XRSTORS: Can set=No, Can clear=Yes
1509.465399] Mode-based execute control for EPT: Can set=No, Can clear=Yes
1509.473961] Sub-page write permissions for EPT: Can set=No, Can clear=Yes
1509.481219] Intel PT uses guest physical addresses: Can set=No, Can clear=Yes
1509.488656] Use TSC scaling: Can set=No, Can clear=Yes
1509.494139] Enable user wait and pause: Can set=No, Can clear=Yes
1509.500525] Enable PCONFIG: Can set=No, Can clear=Yes
1509.505892] Enable ENCLV exiting: Can set=No, Can clear=Yes
1509.511815] Primary VM-Exit Controls MSR: 0x0
1509.517628] Save debug controls: Can set=No, Can clear=Yes
1509.523599] Host address-space size: Can set=No, Can clear=Yes
1509.529905] Load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.537684] Acknowledge Interrupt on exit: Can set=No, Can clear=Yes
1509.544537] Save IA32_PAT: Can set=No, Can clear=Yes
1509.549801] Load IA32_PAT: Can set=No, Can clear=Yes
1509.556549] Load IA32_EFER: Can set=No, Can clear=Yes
1509.561913] Load IA32_EFER: Can set=No, Can clear=Yes
1509.567520] Save VMX-preemption timer value: Can set=No, Can clear=Yes
1509.575818] Clear IA32_BNDCFGS: Can set=No, Can clear=Yes
1509.581708] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.587753] Clear IA32_RTIT_CTL: Can set=No, Can clear=Yes
1509.593583] Clear IA32_LBR_CTL: Can set=No, Can clear=Yes
1509.600760] Load CET state: Can set=No, Can clear=Yes
1509.606120] Load PKRS: Can set=No, Can clear=Yes
1509.611152] Save IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.618841] Activate secondary controls: Can set=No, Can clear=Yes
1509.625551] VM-Entry Controls MSR: 0x0
1509.631221] Load debug controls: Can set=No, Can clear=Yes
1509.637202] IA-32e mode guest: Can set=No, Can clear=Yes
1509.644191] Entry to SMB: Can set=No, Can clear=Yes
1509.649374] Deactivate dual-monitor treatment: Can set=No, Can clear=Yes
1509.656394] Load IA32_PERF_GLOBAL_CTRL: Can set=No, Can clear=Yes
1509.662888] Load IA32_PAT: Can set=No, Can clear=Yes
1509.668172] Load IA32_EFER: Can set=No, Can clear=Yes
1509.673541] Load IA32_BNDCFGS: Can set=No, Can clear=Yes
1509.679163] Conceal VMX from PT: Can set=No, Can clear=Yes
1509.685037] Load IA32_RTIT_CTL: Can set=No, Can clear=Yes
1509.692219] Load CET state: Can set=No, Can clear=Yes
1509.697655] Load guest IA32_LBR_CTL: Can set=No, Can clear=Yes
1509.705279] Load PKRS: Can set=No, Can clear=Yes
1509.710335] Tertiary Processor-Based VM-Execution Controls MSR: 0x0
1509.718406] LOADIKEY exiting: Can set=No, Can clear=Yes
1509.724050] Enable HLT: Can set=No, Can clear=Yes
1509.729314] EPT paging-write control: Can set=No, Can clear=Yes
1509.737061] Guest-paging verification: Can set=No, Can clear=Yes
harshpopathai_patel@a283assignment1vt:~/cmpe283assignment1vt$ 

```

SCREENSHOTS

Status	Name	Zone	Recommendations	In use	Connect
●	a283assignment1vt	us-west4-b		SSH	⋮



SSH-in-browser

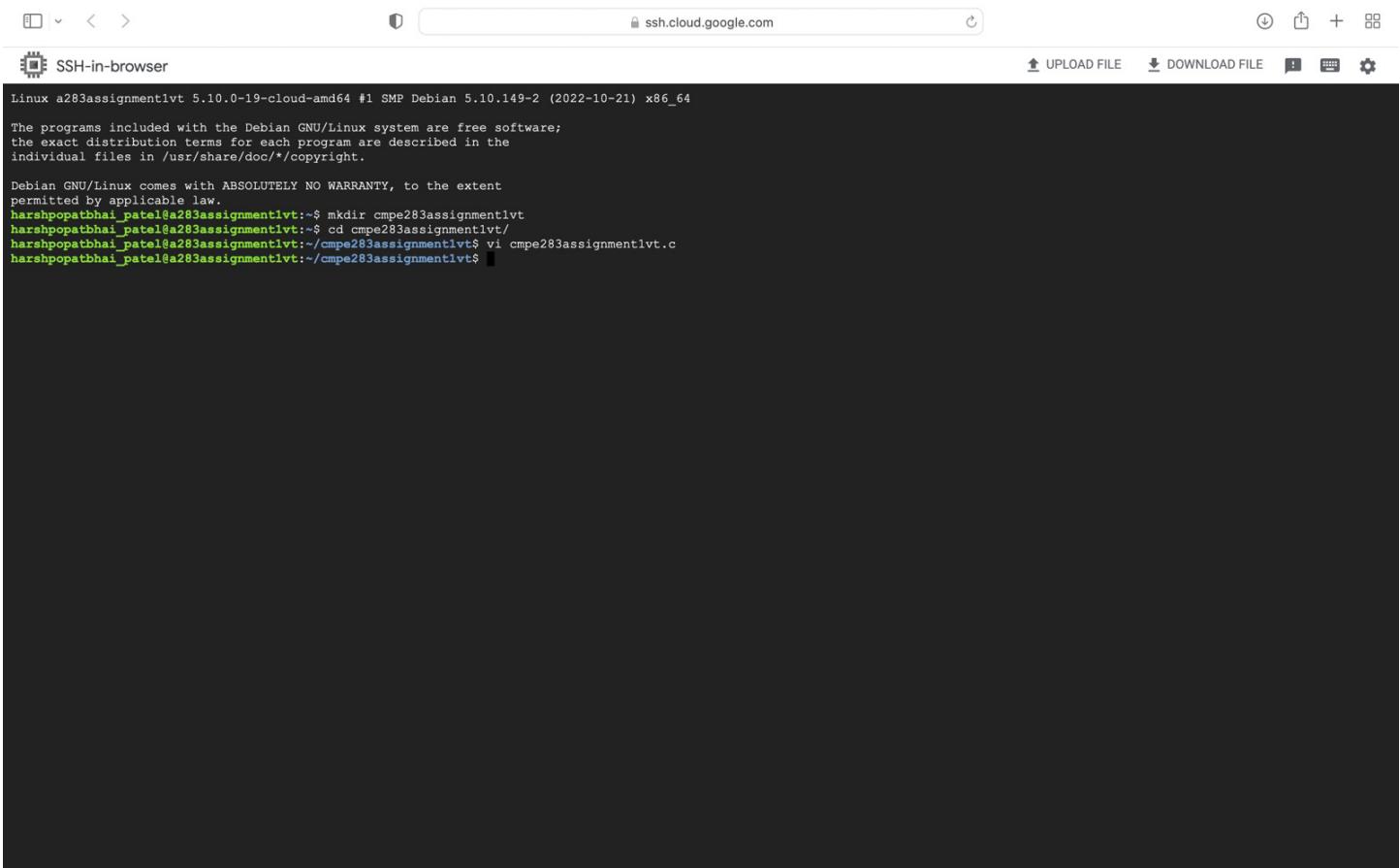
ssh.cloud.google.com

Linux a283assignment1vt 5.10.0-19-cloud-amd64 #1 SMP Debian 5.10.149-2 (2022-10-21) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.

```
harshpopatbhai_patel@a283assignment1vt:~$ mkdir cmpe283assignment1vt
harshpopatbhai_patel@a283assignment1vt:~$ cd cmpe283assignment1vt/
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ 
```



SSH-in-browser

ssh.cloud.google.com

Linux a283assignment1vt 5.10.0-19-cloud-amd64 #1 SMP Debian 5.10.149-2 (2022-10-21) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.

```
harshpopatbhai_patel@a283assignment1vt:~$ mkdir cmpe283assignment1vt
harshpopatbhai_patel@a283assignment1vt:~$ cd cmpe283assignment1vt/
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ vi cmpe283assignment1vt.c
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ 
```

The screenshot shows a terminal window titled "SSH-in-browser" connected to "ssh.cloud.google.com". The terminal displays the content of the file "cmpe283-1.c". The code is a kernel module for CMPE283 assignment 1, defining various constants and structures related to VMX capabilities.

```
/*
 * cmpe283-1.c - Kernel module for CMPE283 assignment 1
 */
#define include <linux/module.h>      /* Needed by all modules */
#define include <linux/kernel.h>      /* Needed for KERN_INFO */
#define include <asm/msr.h>

#define MAX_MSG 80

/*
 * Model specific registers (MSRs) by the module.
 * See SDM volume 4, section 2.1
 */
#define IA32_VMX_PINBASED_CTL0 0x481
#define IA32_VMX_PROCBASED_CTL0 0x482
#define IA32_VMX_PROCBASED_CTL2 0x48B
#define IA32_VMX_EXIT_CTL0 0x483
#define IA32_VMX_ENTRY_CTL0 0x484
#define IA32_VMX_PROCBASED_CTL3 0x492

/*
 * struct capability_info
 *
 * Represents a single capability (bit number and description).
 * Used by report_capability to output VMX capabilities.
 */
struct capability_info {
    uint8_t bit;
    const char *name;
};

/*
 * Pinbased capabilities
 * See SDM volume 3, section 24.6.1
 */
struct capability_info pinbased[5] =
{
    { 0, "External Interrupt Exiting" },
    { 3, "NNMI Exiting" },
    { 5, "Virtual NMIs" },
    { 6, "Activate VMX Preemption Timer" },
    { 7, "Process Posted Interrupts" }
};
struct capability_info primaryprocbased[22] =
{
    { 2, "Interrupt-window exiting" },
    { 3, "Use TSC offsetting" },
    { 7, "HLT exiting" },
    { 9, "INVLPG exiting" },
    { 10, "MWAIT exiting" },
    { 11, "INVLPG exiting" },
    { 12, "MWAIT exiting" },
    { 13, "INVLPG exiting" },
    { 14, "MWAIT exiting" },
    { 15, "INVLPG exiting" },
    { 16, "MWAIT exiting" },
    { 17, "INVLPG exiting" },
    { 18, "MWAIT exiting" },
    { 19, "INVLPG exiting" },
    { 20, "MWAIT exiting" },
    { 21, "INVLPG exiting" },
    { 22, "MWAIT exiting" }
};
```

The screenshot shows a terminal window titled "SSH-in-browser" connected to "ssh.cloud.google.com". The terminal displays a Linux shell session on an "a283assignment1vt" cloud instance. The session starts with the standard Debian 5.10.0-19-cloud-amd64 welcome message, followed by a root prompt and a series of commands related to the "cmpe283assignment1vt" directory.

```
Linux a283assignment1vt 5.10.0-19-cloud-amd64 #1 SMP Debian 5.10.149-2 (2022-10-21) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
harshpopatbhai_patel@a283assignment1vt:~$ mkdir cmpe283assignment1vt
harshpopatbhai_patel@a283assignment1vt:~$ cd cmpe283assignment1vt/
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ vi cmpe283assignment1vt.c
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ vi cmpe283assignment1vt.c
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ sudo bash
root@a283assignment1vt:/home/harshpopatbhai_patel/cmpe283assignment1vt#
```

```
Linux a283assignment1vt 5.10.0-19-cloud-amd64 #1 SMP Debian 5.10.149-2 (2022-10-21) x86_64
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.

harshpopatbhai_patel@a283assignment1vt:~$ mkdir cmpe283assignment1vt
harshpopatbhai_patel@a283assignment1vt:~$ cd cmpe283assignment1vt/
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ vi cmpe283assignment1vt.c
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ vi cmpe283assignment1vt.c
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ sudo bash
root@a283assignment1vt:/home/harshpopatbhai_patel/cmpe283assignment1vt# apt install gcc make
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
binutils binutils-common binutils-x86_64-linux-gnu cpp cpp-10
fontconfig-config fonts-dejavu-core gcc-10 libasan6 libatomic1 libbinutils
libc-dev-bin libc-devtools libc6-dev libccl1-0 libcrypt-dev libctf-nobfd0
libctf libdeflate0 libfontconfig libgcc-10-dev libgd3 libgomp1 libis123
libl1m1 liblbig1 libjpeg62-turbo liblsan0 libmpc3 libmpfr6 libns1-dev
libquadmath0 libtiff5 libtirpc-dev libtsan0 libubsan1 libwebp6 libx11-6
libx11-data libxau6 libxcb1 libxdmp6 libxml4 linux-libc-dev manpages
manpages-dev
Suggested packages:
binutils-doc cpp-doc gcc-10-locales gcc-multilib autoconf automake libtool
flex bison gdb gcc-doc gcc-10-multilib gcc-10-doc glibc-doc libgd-tools
make-doc
The following NEW packages will be installed:
binutils binutils-common binutils-x86_64-linux-gnu cpp cpp-10
fontconfig-config fonts-dejavu-core gcc gcc-10 libasan6 libatomic1
libbinutils libc-dev-bin libc-devtools libc6-dev libccl1-0 libcrypt-dev
libctf-nobfd0 libctf0 libdeflate0 libfontconfig libgcc-10-dev libgd3
libgomp1 libis123 libl1m1 liblbig0 libjpeg62-turbo liblsan0 libmpc3 libmpfr6
libns1-dev libquadmath0 libtiff5 libtirpc-dev libtsan0 libubsan1 libwebp6
libx11-6 libx11-data libxau6 libxcb1 libxdmp6 libxml4 linux-libc-dev make
manpages manpages-dev
0 upgraded, 48 newly installed, 0 to remove and 0 not upgraded.
Need to get 54.3 MB of archives.
After this operation, 192 MB of additional disk space will be used.
Do you want to continue? [Y/n] ■
```

```
Setting up libx11-data (2:1.7.2-1) ...
Setting up make (4.3-4.1) ...
Setting up libmpfr6:amd64 (4.1.0-3) ...
Setting up libquadmath0:amd64 (10.2.1-6) ...
Setting up libmpc3:amd64 (1.2.0-1) ...
Setting up libatomic1:amd64 (10.2.1-6) ...
Setting up libwebp6:amd64 (0.6.1-2.1) ...
Setting up fonts-dejavu-core (2.37-2) ...
Setting up libubsan1:amd64 (10.2.1-6) ...
Setting up libn11-dev:amd64 (1.3.0-2)
Setting up libcrypt-dev:amd64 (1:4.4.18-4) ...
Setting up libx11-6:amd64 (2:1.7.2-1) ...
Setting up libtiff5:amd64 (4.2.0-1+deb11u1) ...
Setting up libbinutils:amd64 (2.35.2-2) ...
Setting up libis123:amd64 (0.23-1) ...
Setting up libc-dev-bin (2.31-13+deb11u5) ...
Setting up libcc1-0:amd64 (10.2.1-6) ...
Setting up liblsan0:amd64 (10.2.1-6) ...
Setting up cpp (10.2.1-6) ...
Setting up libitm1:amd64 (10.2.1-6) ...
Setting up libtsan0:amd64 (10.2.1-6) ...
Setting up libctf0:amd64 (2.35.2-2) ...
Setting up manpages-dev (5.10-1) ...
Setting up libxml4:amd64 (1:3.5.12-1) ...
Setting up fontconfig-config (2.13.1-4.2) ...
Setting up libgcc-10-dev:amd64 (10.2.1-6) ...
Setting up cpp (4:10.2.1-1) ...
Setting up lib6c-dev:amd64 (2.31-13+deb11u5) ...
Setting up libfontconfig:amd64 (2.13.1-4.2) ...
Setting up binutils-x86-64-linux-gnu (2.35.2-2) ...
Setting up binutils (2.35.2-2) ...
Setting up libgd3:amd64 (2.3.0-2) ...
Setting up gcc-10 (10.2.1-6) ...
Setting up libc-devtools (2.31-13+deb11u5) ...
Setting up gcc (4:10.2.1-1) ...
Processing triggers for man-db (2.9.4-2) ...
Processing triggers for libc-bin (2.31-13+deb11u5) ...
root@a283assignment1vt:/home/harshpopatbhai_patel/cmpe283assignment1vt# exit
exit
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ sudo apt install linux-headers-$(uname -r)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-common linux-kbuild-5.10
The following NEW packages will be installed:
linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-cloud-amd64
linux-headers-5.10.0-19-common linux-kbuild-5.10
0 upgraded, 4 newly installed, 0 to remove and 0 not upgraded.
Need to get 11.1 MB of archives.
After this operation, 58.7 MB of additional disk space will be used.
Do you want to continue? [Y/n] ■
```

SSH-in-browser

```
GNU nano 5.4                                         Makefile *
obj-m := cmpe283assignment1vt.o

all:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) modules

clean:
    make -C /lib/modules/$(shell uname -r)/build M=$(PWD) clean

Save modified buffer?
Y Yes
N No      ^C Cancel
```

SSH-in-browser

```
Processing triggers for libc-bin (2.31-13+deb11u5) ...
root@a283assignment1vt:/home/harshpopatbhai_patel/cmpe283assignment1vt# exit
exit
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ sudo apt install linux-headers-$(uname -r)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-common linux-kbuild-5.10
The following NEW packages will be installed:
  linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-cloud-amd64
  linux-headers-5.10.0-19-common linux-kbuild-5.10
0 upgraded, 4 newly installed, 0 to remove and 0 not upgraded.
Need to get 11.1 MB of archives.
After this operation, 58.7 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://security.debian.org/debian-security bullseye-security/main amd64 linux-compiler-gcc-10-x86 amd64 5.10.149-2 [519 kB]
Get:2 http://security.debian.org/debian-security bullseye-security/main amd64 linux-headers-5.10.0-19-common all 5.10.149-2 [9033 kB]
Get:3 http://security.debian.org/debian-security bullseye-security/main amd64 linux-kbuild-5.10 amd64 5.10.149-2 [765 kB]
Get:4 http://security.debian.org/debian-security bullseye-security/main amd64 linux-headers-5.10.0-19-cloud-amd64 amd64 5.10.149-2 [790 kB]
Fetched 11.1 MB in 0s (27.1 MB/s)
Selecting previously unselected package linux-compiler-gcc-10-x86.
(Reading database ... 59544 files and directories currently installed.)
Preparing to unpack .../linux-compiler-gcc-10-x86_5.10.149-2_amd64.deb ...
Unpacking linux-compiler-gcc-10-x86 (5.10.149-2) ...
Selecting previously unselected package linux-headers-5.10.0-19-common.
Preparing to unpack .../linux-headers-5.10.0-19-common_5.10.149-2_all.deb ...
Unpacking linux-headers-5.10.0-19-common (5.10.149-2) ...
Selecting previously unselected package linux-kbuild-5.10.
Preparing to unpack .../linux-kbuild-5.10_5.10.149-2_amd64.deb ...
Unpacking linux-kbuild-5.10 (5.10.149-2) ...
Selecting previously unselected package linux-headers-5.10.0-19-cloud-amd64.
Preparing to unpack .../linux-headers-5.10.0-19-cloud-amd64_5.10.149-2_amd64.deb ...
Unpacking linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
Setting up linux-compiler-gcc-10-x86 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-common (5.10.149-2) ...
Setting up linux-kheaders-5.10.0-19-common (5.10.149-2) ...
Setting up linux-kbuild-5.10 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ nano Makefile
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ make
make -C /lib/modules/5.10.0-19-cloud-amd64/build M=/home/harshpopatbhai_patel/cmpe283assignment1vt modules
make[1]: Entering directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
  CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.o
  MODPOST /home/harshpopatbhai_patel/cmpe283assignment1vt/Module.symvers
  CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.mod.o
  LD [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$ ls
Makefile          cmpe283assignment1vt.ko      cmpe283assignment1vt.mod.o
Module.symvers    cmpe283assignment1vt.mod    cmpe283assignment1vt.o
cmpe283assignment1vt.c  cmpe283assignment1vt.mod.c  modules.order
harshpopatbhai_patel@a283assignment1vt:~/cmpe283assignment1vt$
```

```
SSH-in-browser
root@a283assignment1vt:/home/harshpopatbhai_patel/cmpe283assignment1vt# exit
exit
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ sudo apt install linux-headers-$(uname -r)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-common linux-kbuild-5.10
The following NEW packages will be installed:
linux-compiler-gcc-10-x86 linux-headers-5.10.0-19-cloud-amd64
linux-headers-5.10.0-19-common linux-kbuild-5.10
0 upgraded, 4 newly installed, 0 to remove and 0 not upgraded.
Need to get 11.1 MB of archives.
After this operation, 58.7 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://security.debian.org/debian-security/bullseye-security/main amd64 linux-compiler-gcc-10-x86 amd64 5.10.149-2 [519 kB]
Get:2 http://security.debian.org/debian-security/bullseye-security/main amd64 linux-headers-5.10.0-19-common all 5.10.149-2 [9033 kB]
Get:3 http://security.debian.org/debian-security/bullseye-security/main amd64 linux-kbuild-5.10 amd64 5.10.149-2 [765 kB]
Get:4 http://security.debian.org/debian-security/bullseye-security/main amd64 linux-headers-5.10.0-19-cloud-amd64 amd64 5.10.149-2 [790 kB]
Fetched 11.1 MB in 0s (27.1 MB/s)
Selecting previously unselected package linux-compiler-gcc-10-x86.
(Reading database ... 59544 files and directories currently installed.)
Preparing to unpack .../linux-compiler-gcc-10-x86_5.10.149-2_amd64.deb ...
Unpacking linux-compiler-gcc-10-x86 (5.10.149-2) ...
Selecting previously unselected package linux-headers-5.10.0-19-common.
Preparing to unpack .../linux-headers-5.10.0-19-common_5.10.149-2_all.deb ...
Unpacking linux-headers-5.10.0-19-common (5.10.149-2) ...
Selecting previously unselected package linux-kbuild-5.10.
Preparing to unpack .../linux-kbuild-5.10_5.10.149-2_amd64.deb ...
Unpacking linux-kbuild-5.10 (5.10.149-2) ...
Selecting previously unselected package linux-headers-5.10.0-19-cloud-amd64.
Preparing to unpack .../linux-headers-5.10.0-19-cloud-amd64_5.10.149-2_amd64.deb ...
Unpacking linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
Setting up linux-compiler-gcc-10-x86 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-common (5.10.149-2) ...
Setting up linux-kbuild-5.10 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ nano Makefile
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ make
make -C /lib/modules/5.10.0-19-cloud-amd64/build M=/home/harshpopatbhai_patel/cmpe283assignment1vt modules
make[1]: Entering directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.o
MODPOST /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt/Module.symvers
CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.mod.o
LD [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ ls
Makefile cmpe283assignment1vt.ko cmpe283assignment1vt.mod.o
Module.symvers cmpe283assignment1vt.mod cmpe283assignment1vt.o
cmpe283assignment1vt.c cmpe283assignment1vt.mod.c modules.order
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ sudo insmod cmpe283assignment1vt.ko
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$
```

```
SSH-in-browser
Preparing to unpack .../linux-headers-5.10.0-19-cloud-amd64_5.10.149-2_amd64.deb ...
Unpacking linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
Setting up linux-compiler-gcc-10-x86 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-common (5.10.149-2) ...
Setting up linux-kbuild-5.10 (5.10.149-2) ...
Setting up linux-headers-5.10.0-19-cloud-amd64 (5.10.149-2) ...
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ nano Makefile
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ make
make -C /lib/modules/5.10.0-19-cloud-amd64/build M=/home/harshpopatbhai_patel/cmpe283assignment1vt modules
make[1]: Entering directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.o
MODPOST /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt/Module.symvers
CC [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt/cmpe283assignment1vt.mod.o
LD [M] /home/harshpopatbhai_patel/cmpe283assignment1vt/cmpe283assignment1vt.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.10.0-19-cloud-amd64'
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ ls
Makefile cmpe283assignment1vt.ko cmpe283assignment1vt.mod.o
Module.symvers cmpe283assignment1vt.mod cmpe283assignment1vt.o
cmpe283assignment1vt.c cmpe283assignment1vt.mod.c modules.order
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ sudo insmod cmpe283assignment1vt.ko
harshpopatbhai_patel@a283assignment1vt:~/:cmpe283assignment1vt$ sudo dmesg
[ 0.000000] Linux version 5.10.0-19-cloud-amd64 (debian-kernel@lists.debian.org) (gcc-10 (Debian 10.2.1-6) 10.2.1 20210110, GNU ld (GNU Binutils for Debian) 2.35.2) #1 SMP Debian 5.10.149-2 (2022-10-21)
[ 0.000000] Command line: BOOT_IMAGE=/boot/vmlinuz-5.10.0-19-cloud-amd64 root=UUID=92ecc6c8-3db2-4c78-81db-94a92e02e405 ro console=tty0 console=ttyS0,115200 earlyprintk=ttyS0,115200 consoleblank=0
[ 0.000000] BIOS-e820: [mem 0x0000000000000000-0x00000000000fff] reserved
[ 0.000000] BIOS-e820: [mem 0x00000000001000-0x00000000005fff] usable
[ 0.000000] BIOS-e820: [mem 0x00000000005500-0x00000000005ffff] reserved
[ 0.000000] BIOS-e820: [mem 0x00000000006000-0x000000000097fff] usable
[ 0.000000] BIOS-e820: [mem 0x00000000009800-0x00000000009ffff] reserved
[ 0.000000] BIOS-e820: [mem 0x00000000010000-0x000000000fbffff] usable
[ 0.000000] BIOS-e820: [mem 0x000000000fb8ef000-0x000000000fbfeffff] reserved
[ 0.000000] BIOS-e820: [mem 0x000000000fb9ef000-0x000000000fbfaeffff] type 20
[ 0.000000] BIOS-e820: [mem 0x000000000fbafef000-0x000000000fbh6efff] reserved
[ 0.000000] BIOS-e820: [mem 0x000000000fb5f6000-0x000000000fb7efff] ACPI data
[ 0.000000] BIOS-e820: [mem 0x000000000fb7f000-0x000000000fbffefff] ACPI NVS
[ 0.000000] BIOS-e820: [mem 0x000000000fbff000-0x000000000bfffffff] usable
[ 0.000000] BIOS-e820: [mem 0x000000000bfbe0000-0x000000000bfffffff] reserved
[ 0.000000] BIOS-e820: [mem 0x0000000001000000-0x000000013fffffff] usable
[ 0.000000] printk: bootconsole [earlyser0] enabled
[ 0.000000] NX (Execute Disable) protection: active
[ 0.000000] efi: EFI v2.70 by EDK II
[ 0.000000] efi: TPMFinalLog=0xbfbf7000 ACPI=0xbfb7e000 ACPI 2.0=0xbfb7e014 SMBIOS=0xbfb9cc000 MEMATTR=0xbe940018
[ 0.000000] secureboot: Secure boot disabled
[ 0.000000] SMBIOS 2.4 present.
[ 0.000000] DMI: Google Google Compute Engine/Google Compute Engine, BIOS Google 10/11/2022
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