

## OS Services are Implemented as Subroutines

How does the OS provide services for user (unprivileged) programs?

Using subroutines! (Also known as traps or system calls.)

Remember TRAP? RTL for TRAP is...

```
R7 ← PC, PC ← M[ZEXT16(vec8)]
```

The first part is the same as JSR, and LC-3 traps end with RET (JMP R7).

## Trap Vector Table Contains Starting Addresses of Traps

In the LC-3,

- Memory locations **x0000-x00FF** are called the **trap vector table**.
- (Vector is another word for pointer, or memory address.)
- Each entry** in the table **contains** the **starting address for one system call**.
- Each system call ends with **RET**.

Note: You can look at the code for the LC-3 system calls in **lc3sim**.

## Code for the OUT Trap

For example, OUT is TRAP x21.

In M[x0021], we find x0450.

Listing x0450 gives the following...

```
TRAP_OUT      ST R1,TOUT_R1
TRAP_OUT_WAIT LDI R1,OS_DSR
              BRzp TRAP_OUT_WAIT
              STI R0,OS_DDR
              LD R1,TOUT_R1
              RET
              JMP R7
```

R1 saved to prevent changes

wait for display

write DDR

restore R1

## How Fast are Humans?

Let's change the topic.

**How many cycles pass between keystrokes when a human types?**

Let's say a good typist.

Answer:\*

- 100 milliseconds, so
- probably **10s of millions of cycles**.

\* "Good" means 100 words per minute, or 10 characters per second.