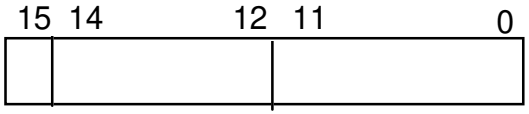
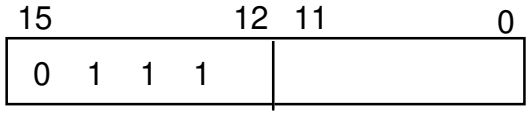
- Homework #5 was collected
- Reminder: midterm #2 is November 9
- Last day to request re-grading on midterm #1 is Tuesday 10/31.
- Reading for Thursday 5-4 to 5-6

Instructions

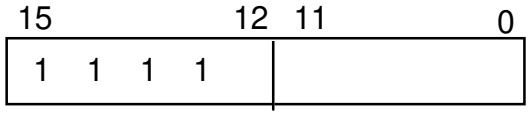
- Three forms of instructions:
  - memory reference



  - register reference



  - I/O



The Memory Instructions

Symbol	I=0	I=1	Description
AND	0xxx	8xxx	And memory word to AC
ADD	1xxx	9xxx	Add memory word to AC
LDA	2xxx	Axxx	Load memory word to AC\
STA	3xxx	Bxxx	Store content of AC to memory
BUN	4xxx	Cxxx	Branch unconditionally
BSA	5xxx	Dxxx	Branch and save return address
ISZ	6xxx	Exxx	Increment and skip if zero

The Register Instructions

Symbol	Code	Description
CLA	7800	Clear AC
CLE	7400	Clear E
CMA	7200	Complement AC
CME	7300	Complement E
CIR	7080	Circulate right AC and E
CIL	7040	Circulate left AC and E
INC	7020	Increment AC
SPA	7010	Skip next insn if AC positive
SNA	7008	Skip next insn if AC negative
SZA	7004	Skip next insn if AC zero
SZE	7002	Skip next insn if E =0
HALT	7001	Halt

Input/Output Instructions

Symbol	Code	Description
INP	F800	Input character to AC
OUT	F400	Output Character from AC
SKI	F200	Skip on input flag
SKO	F100	Skip on output flag
ION	F080	Interrupt on
IOF	F040	Interrupt off

Rules for executing instructions

- List of instructions is called a program
  - instructions are stored in memory
- Computer executes next instruction in the program
  - branch instruction changes the next instruction to execute.
  - programs start execution at memory location 0.
  - one instruction at a time is executed.
- State
  - memory and registers are assumed to start empty (all 0's)
  - after executing an instruction any change to memory or registers remains.

Simple Program

- subtract two numbers
  - idea is to use two's complement to create subtract
  - first operand is in memory location 6
  - second operand is in memory location 7
  - results of subtraction goes into memory location 8
- Program:

LAD 007	2007	00
CMA	7200	01
INC	7020	02
ADD 006	1006	03
STA 008	3008	04
HLT	7001	05
	0010	06
	000A	07
	0000	08

(Slightly) More Complex Program

- Add 100 numbers stored in memory (starting at 08)
- Program:

ADD	8 I	9008	00	
ISZ	8	6008	01	
ISZ	7	6007	02	
BUN	0	4000	03	
STA	6	3006	04	
HLT		7001	05	
		0000	06	# total
		FF9C	07	# count
		0009	08	# address
		….		

Completeness of Instructions

- Need to ensure that the computer can execute any computable function.
  - equivalent to a turning machine
  - more instructions make the machine faster, but not more powerful
- Arithmetic
  - add, complement, increment
  - AND and NOT (provides NAND which is enough)
- Data movement instructions
  - LAD, STA
- Control instructions
  - check status of words/AC
  - provide a way to change the next instruction to execute
- Input/Output Instructions