NEC 304

STLD

Lecture 4

Number Codes and Registers

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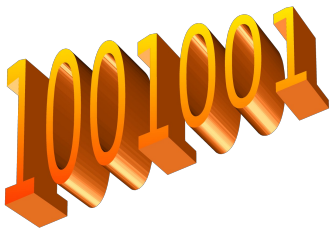
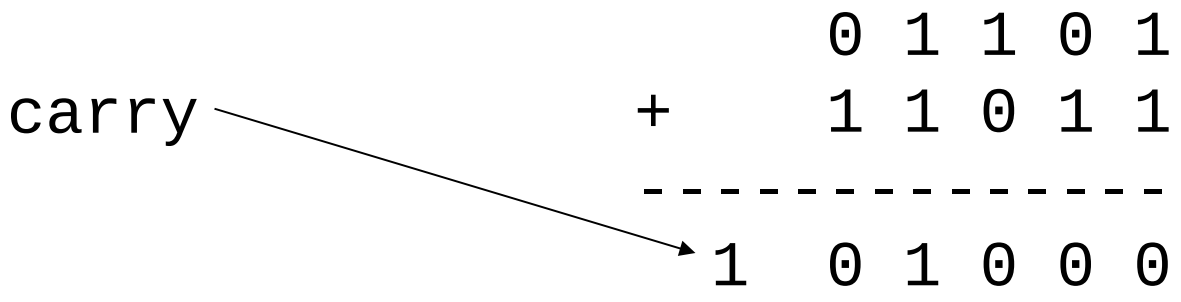
Overview

- 2’s complement numbers
  - Addition and subtraction
- Binary coded decimal
- Gray codes for binary numbers
- ASCII characters
- Moving towards hardware
  - Storing data
  - Processing data



2's Complement Subtraction

- **Let's compute $(13)_{10}$ - $(5)_{10}$.**
  - $(13)_{10}$ = $+(1101)_2$ = $(01101)_2$
  - $(-5)_{10}$ = $-(0101)_2$ = $(11011)_2$
- **Adding these two 5-bit codes…**



- **Discarding the carry bit, the sign bit is seen to be zero, indicating a correct result.**
- **Numbers in hexadecimal**

2's Complement Subtraction

- **Let's compute $(5)_{10} - (12)_{10}$.**
  - **$(-12)_{10} = -(1100)_2 = (10100)_2$**
  - **$(5)_{10} = +(0101)_2 = (00101)_2$**
- **Adding these two 5-bit codes…**

```
      0 0 1 0 1
+     1 0 1 0 0
---------------
      1 1 0 0 1
```

- **Here, there is no carry bit and the sign bit is 1. This indicates a negative result, which is what we expect. $(11001)_2 = -(7)_{10}$.**
- **Numbers in hexadecimal**

Binary Coded Decimal

Digit	BCD Code	Digit	BCD Code
0	**0000**	**5**	**0101**
1	**0001**	**6**	**0110**
2	**0010**	**7**	**0111**
3	**0011**	**8**	**1000**
4	**0100**	**9**	**1001**

- **Binary coded decimal (BCD) represents each decimal digit with four bits**
  - **Ex.** **0011 0010 1001 = 329_{10}**

    3 2 9

- **This is *NOT* the same as 001100101001_2**
- **Why do this? Because people think in decimal.**

Putting It All Together

Decimal	Binary	Octal	Hexadecimal	BCD
0	0	0	0	0000
1	1	1	1	0001
2	10	2	2	0010
3	11	3	3	0011
4	100	4	4	0100
5	101	5	5	0101
6	110	6	6	0110
7	111	7	7	0111
8	1000	10	8	1000
9	1001	11	9	1001
10	1010	12	A	0001 0000
11	1011	13	B	0001 0001
12	1100	14	C	0001 0010
13	1101	15	D	0001 0011
14	1110	16	E	0001 0100
15	1111	17	F	0001 0101

- **BCD not very efficient**
- **Used in early computers (40s, 50s)**
- **Used to encode numbers for seven-segment displays.**
- **Easier to read?**

Gray Code

Digit	Binary	Gray Code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

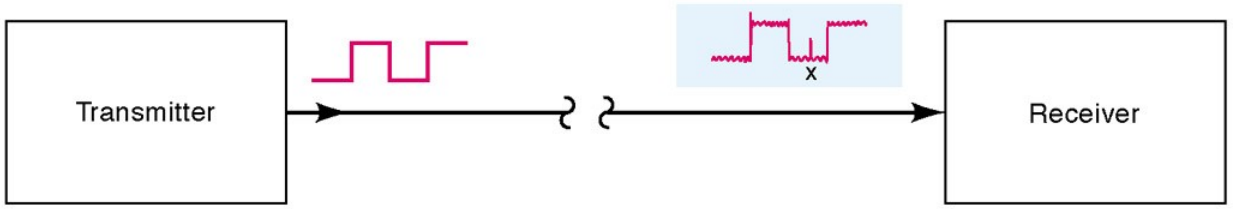
- **Gray code is not a number system.**
  - **It is an alternate way to represent four bit data**
- **Only one bit changes from one decimal digit to the next**
- **Useful for reducing errors in communication.**
- **Can be scaled to larger numbers.**

ASCII Code

- **American Standard Code for Information Interchange**
- **ASCII is a 7-bit code, frequently used with an 8th bit for error detection (more about that in a bit).**

Character	ASCII (bin)	ASCII (hex)	Decimal	Octal
A	1000001	41	65	101
B	1000010	42	66	102
C	1000011	43	67	103
…				
Z				
a				
…				
1				
‘				

ASCII Codes and Data Transmission



- **ASCII Codes**
  - **A – Z (26 codes), a – z (26 codes)**
  - **0-9 (10 codes), others (@#$%^&*….)**
  - **Complete listing in Mano text**
- **Transmission susceptible to noise**
- **Typical transmission rates (1500 Kbps, 56.6 Kbps)**
  - **How to keep data transmission accurate?**

Parity Codes

- **Parity codes are formed by concatenating a *parity bit, P* to each code word of C.**
- **In an *odd-parity code*, the parity bit is specified so that the total number of ones is odd.**
- **In an even-*parity code*, the parity bit is specified so that the total number of ones is even.**


```
1 1 0 0 0 0 1 1
↑
Added even parity bit
```

```
0 1 0 0 0 0 1 1
↑
Added odd parity bit
```

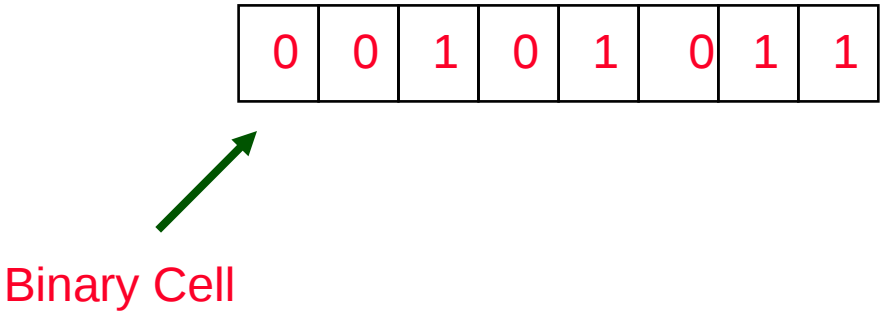
Parity Code Example

- **Concatenate a parity bit to the ASCII code for the characters 0, X, and = to produce both odd-parity and even-parity codes.**

Character	ASCII	Odd-Parity ASCII	Even-Parity ASCII
0	0110000	10110000	00110000
X	1011000	01011000	11011000
=	0111100	10111100	00111100

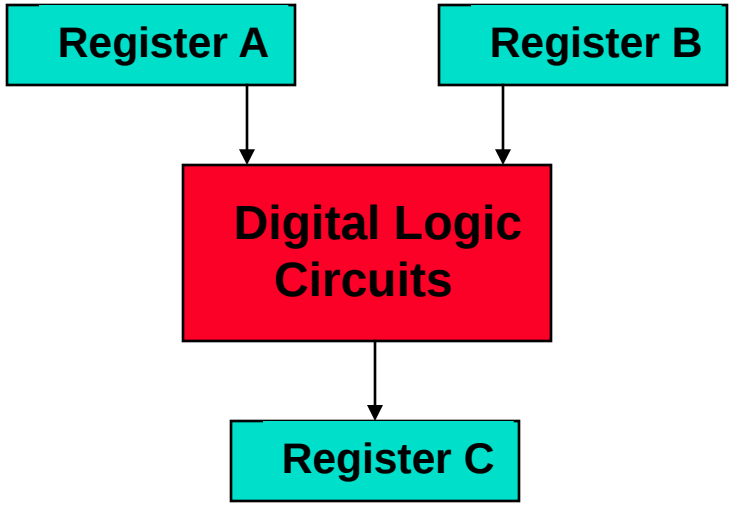
Binary Data Storage

- **Binary cells store individual bits of data**
- **Multiple cells form a register.**
- **Data in registers can indicate different values**
  - **Hex (decimal)**
  - **BCD**
  - **ASCII**



Register Transfer

- Data can move from register to register.
- Digital logic used to process data
- We will learn to design this logic



Transfer of Information

- Data input at keyboard
- Shifted into place
- Stored in memory

NOTE: Data input in ASCII

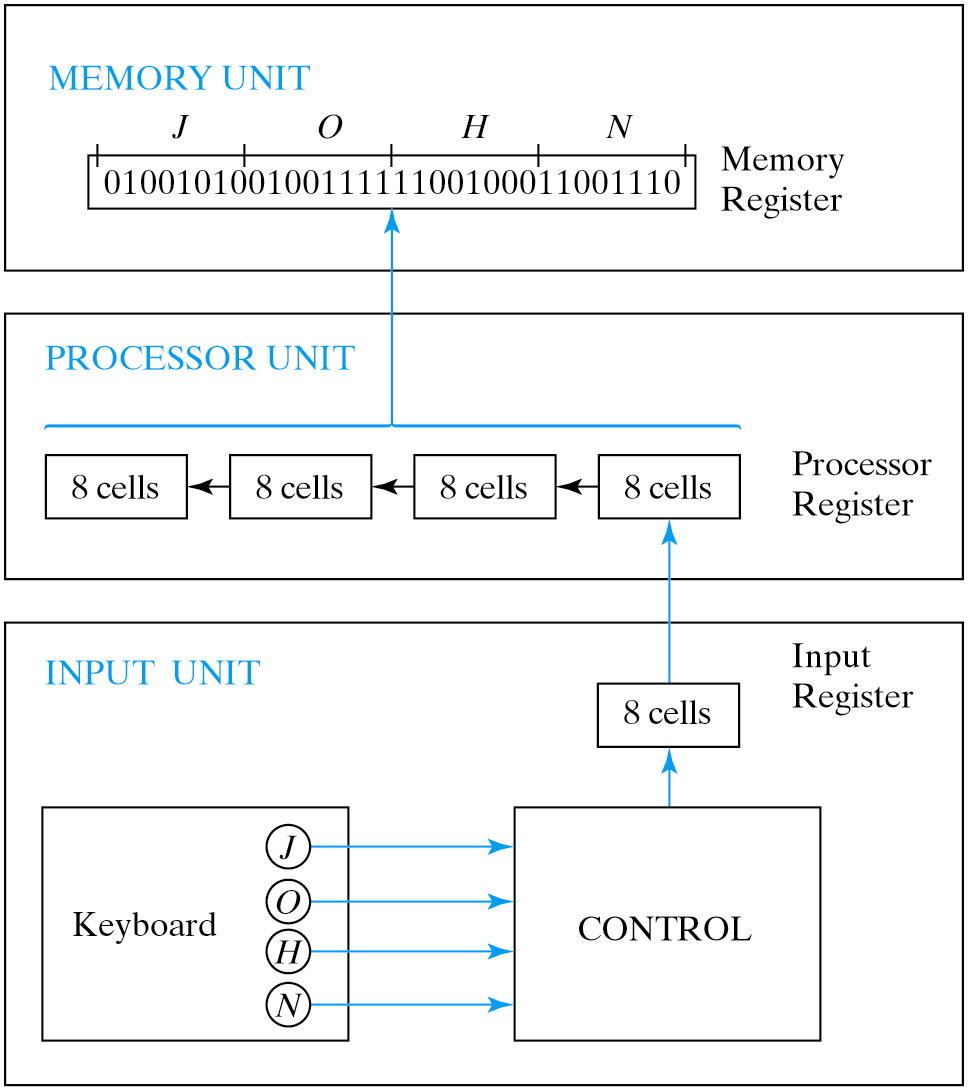


Fig. 1-1 Transfer of information with registers

Building a Computer

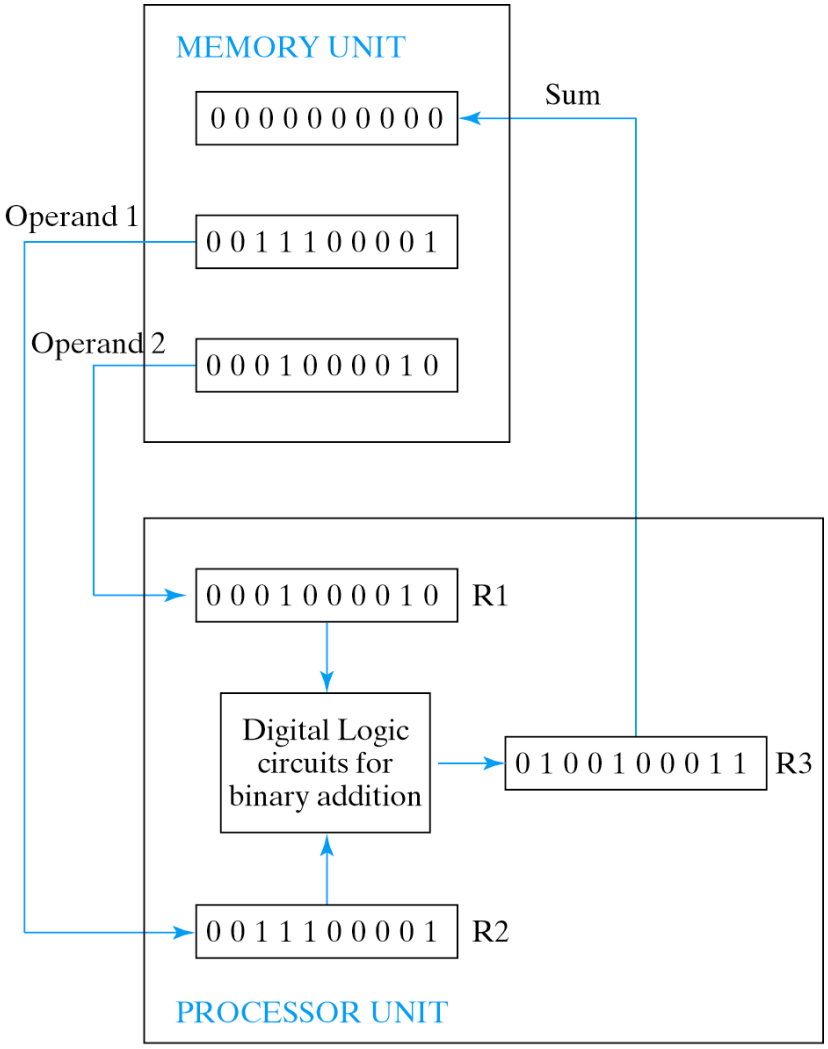


Fig. 1-2 Example of binary information processing

- We need processing
- We need storage
- We need communication

- **You will learn to use and design these components.**

Summary

- Although 2's complement most important, other number codes exist
- ASCII code used to represent characters (including those on the keyboard)
- Registers store binary data
- Next time: Building logic circuits!