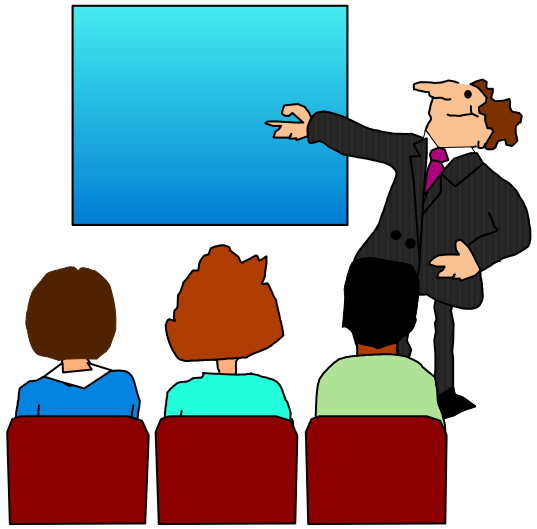
Assembler Language "Boot Camp" Part 3 - Assembly and Execution; Branching

SHARE in San Francisco

August 18 - 23, 2002

Session 8183



Introduction

- Who are we?
  - John Dravnieks, IBM Australia
  - John Ehrman, IBM Silicon Valley Lab
  - Michael Stack, Department of Computer Science, Northern Illinois University

Introduction

- Who are you?
  - An applications programmer who needs to write something in S/390 assembler?
  - An applications programmer who wants to understand S/390 architecture so as to better understand how HLL programs work?
  - A manager who needs to have a general understanding of assembler?

- Our goal is to provide for professionals an introduction to the S/390 assembly language

Introduction

- These sessions are based on notes from a course in assembler language at Northern Illinois University

- The notes are in turn based on the textbook, Assembler Language with ASSIST and ASSIST/I by Ross A Overbeek and W E Singletary, Fourth Edition, published by Macmillan

Introduction

- The original ASSIST (Assembler System for Student Instruction and Systems Teaching) was written by John Mashey at Penn State University

- ASSIST/I, the PC version of ASSIST, was written by Bob Baker, Terry Disz and John McCharen at Northern Illinois University

Introduction

- Both ASSIST and ASSIST/I are in the public domain, and are compatible with the System/370 architecture of about 1975 (fine for beginners)

- Both ASSIST and ASSIST/I are available at http://www.cs.niu.edu/~mstack/assist

Introduction

- Other materials described in these sessions can be found at the same site, at http://www.cs.niu.edu/~mstack/share

- Please keep in mind that ASSIST and ASSIST/I are not supported by Penn State, NIU, or any of us

Introduction

- Other references used in the course at NIU:
  - Principles of Operation
  - System/370 Reference Summary
  - High Level Assembler Language Reference
- Access to PoO and HLASM Ref is normally online at the IBM publications web site
- Students use the S/370 "green card" booklet all the time, including during examinations (SA22-7209)

Our Agenda for the Week

- Session 8181: Numbers and Basic Arithmetic
- Session 8182: Instructions and Addressing
- Session 8183: Assembly and Execution; Branching

Our Agenda for the Week

- Session 8184: Arithmetic; Program Structures
- Session 8185: Decimal and Logical Instructions
- Session 8186: Assembler Lab Using ASSIST/I

Today's Agenda

- Assembly of a Complete Program
- Execution of a Complete Program
- Implicit Addresses and USING
- The Condition Code and Branching
- X-Instructions and ASSIST

Assembly of a Complete Program

In Which We Take Baby Steps and are Amazed at How a Program Works!

A Complete Program

- Yesterday, we introduced a few instructions and used them to create a complete, if short, program
- Today, we will analyze the object code generated by the assembly of the program, then look at what happens when ASSIST/I executes the program
- "Object code - nothing else matters"

First Demo Program, Source List

```
* This program adds two numbers that are taken
* from the 5th and 6th words of the program.
* The sum is stored in the 7th word.
ADD2    CSECT
        L       1,16(,15)    Load 1st no. into R1
        L       2,20(,15)    Load 2nd no. into R2
        AR      1,2          Get sum in R1
        ST      1,24(,15)    Store sum
        BCR     B'1111',14   Return to caller
        DC      F'4'         Fullword initially 4
        DC      F'6'         Fullword initially 6
        DS      F            Rsrvd only, no init
        END     ADD2
```

First Demo Program, Assembled

```
  LOC   OBJECT CODE    SOURCE STATEMENT

000000                 ADD2     CSECT
000000 5810 F010                L       1,16(,15)
000004 5820 F014                L       2,20(,15)
000008 1A12                     AR      1,2
00000A 5010 F018                ST      1,24(,15)
00000E 07FE                     BCR     B'1111',14
000010 00000004                 DC      F'4'
000014 00000006                 DC      F'6'
000018                          DS      F
                                END     ADD2
```

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000010 00000004                 DC       F'4'
000014 00000006                 DC       F'6'
000018                          DS       F
                                END      ADD2
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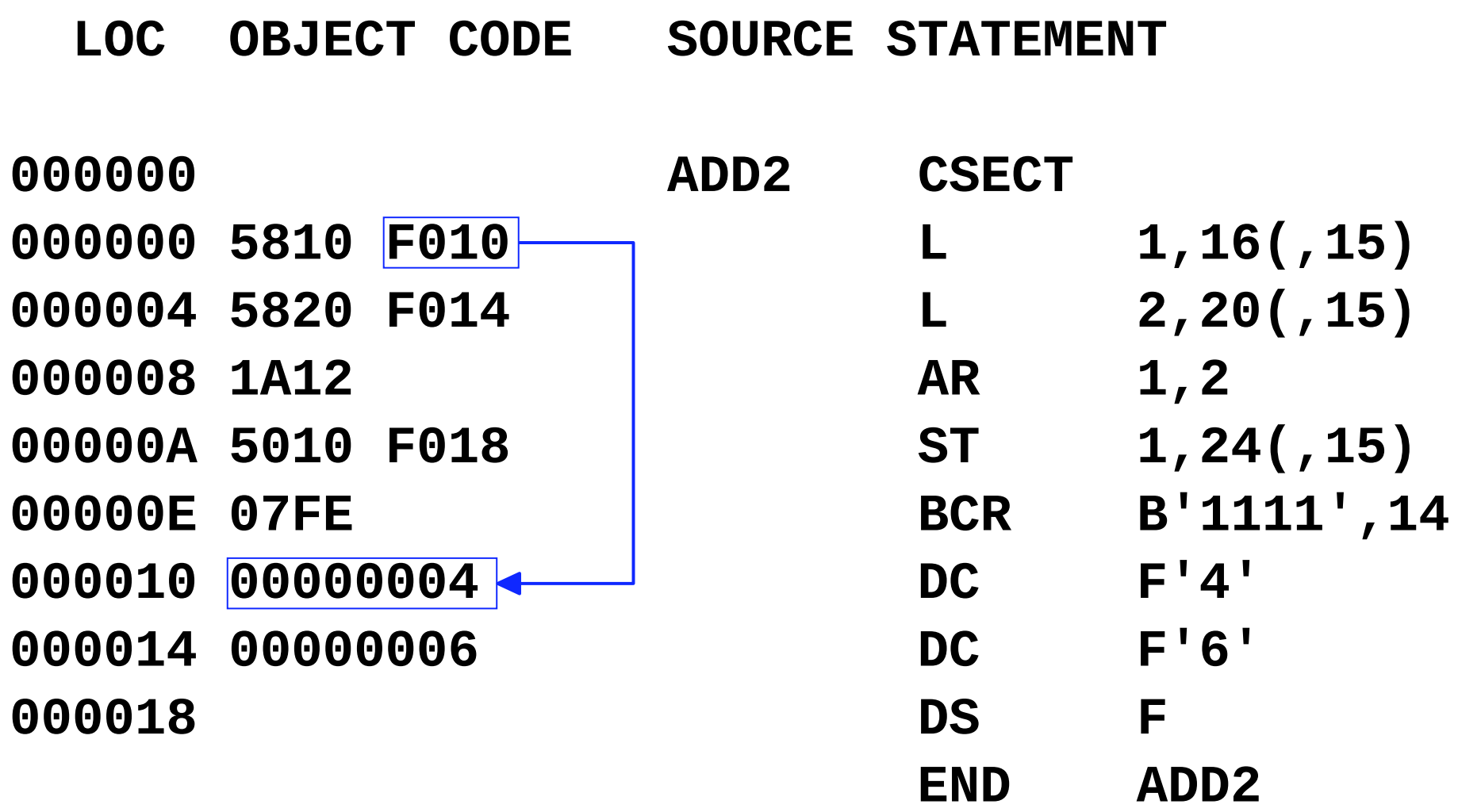
First Demo Program, Assembled



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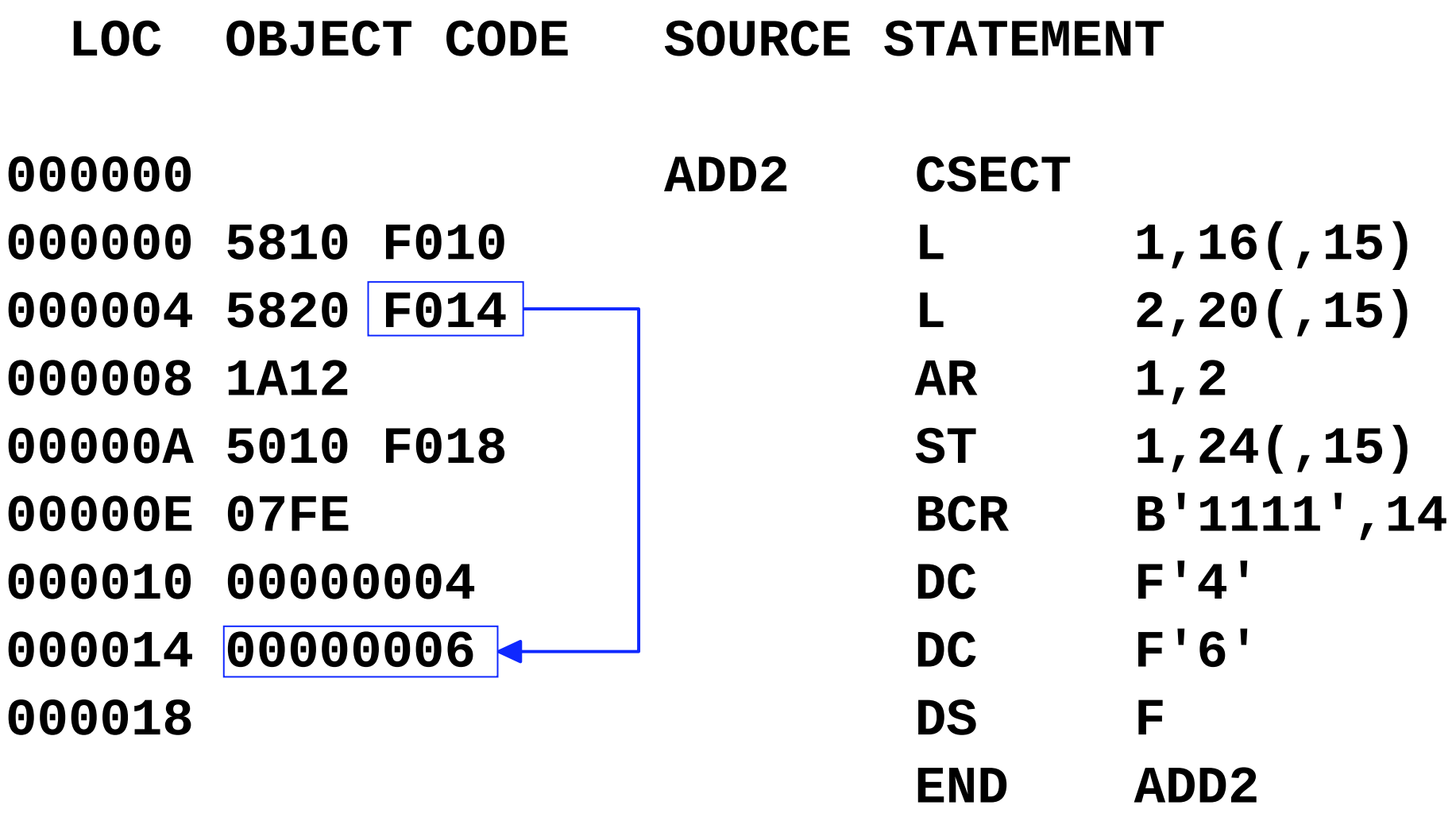
First Demo Program, Assembled



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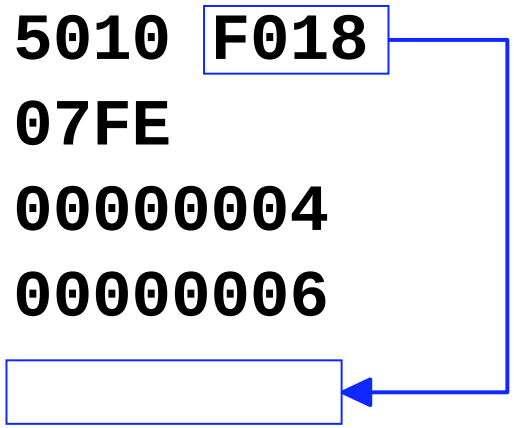
00000E 07FE                     BCR     B'1111',14
000010 00000004                 DC      F'4'
000014 00000006                 DC      F'6'
000018                          DS      F
                                END     ADD2
```



Execution of a Complete Program

In Which We See the World Go By in Single Steps

ADD2 Program Before Execution

```
PSW AT BREAK   FFC50000 0F000000

R0-7 :  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program Before Execution

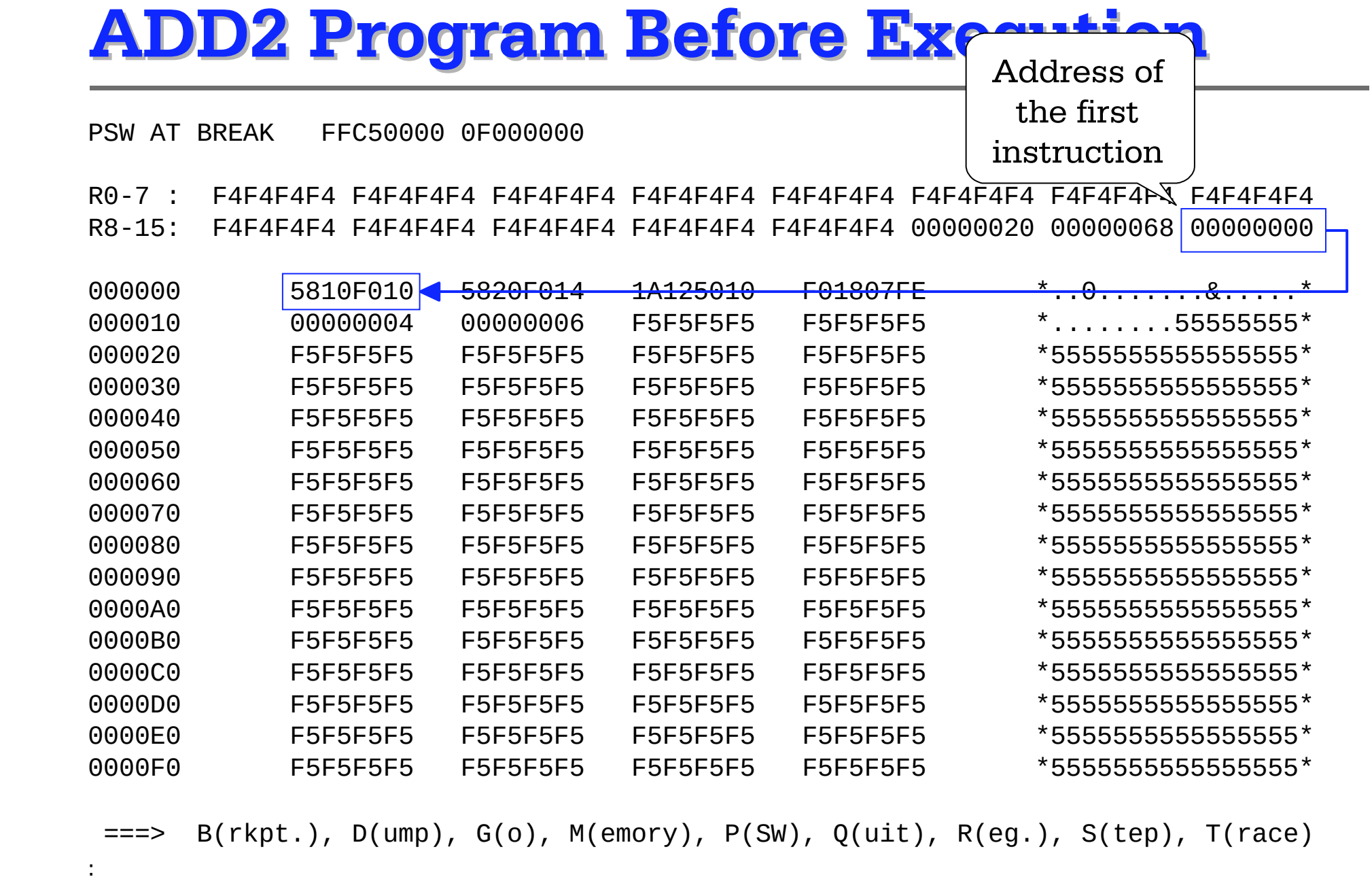

```
                FFC50000 0F000000

F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

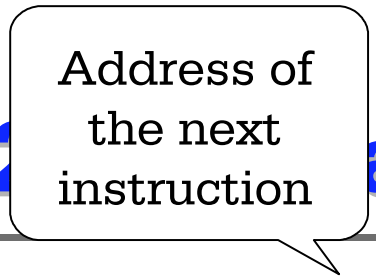
000000      5810F010   5820F014   1A125010   F01807FE      *..0.......&.....*
000010      00000004   00000006   F5F5F5F5   F5F5F5F5      *........55555555*
000020      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000030      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000040      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000050      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000060      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000070      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000080      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
000090      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000A0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000B0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000C0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000D0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000E0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*
0000F0      F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5      *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program Before Execution



ADD2 ...am Before Execution




```
PSW AT BREAK    FFC50000 0F000000

R0-7 :  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000        5810F010   5820F014   1A125010   F01807FE        *..0.......&.....*
000010        00000004   00000006   F5F5F5F5   F5F5F5F5        *........55555555*
000020        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000030        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000040        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000050        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000060        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000070        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000080        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000090        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000A0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000B0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000C0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000D0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000E0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000F0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program After 1st Instruction

```
PSW AT BREAK   FFC50000 8F000004

R0-7 :  F4F4F4F4 00000004 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

Contents of word 5 LOADed to R1

rogram After 1st Instruction

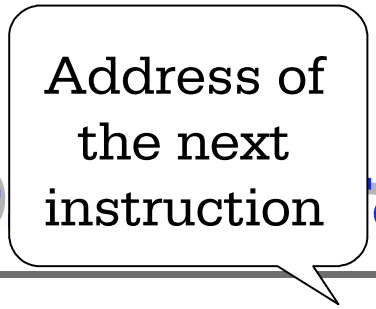
```
                  C50000 8F000004

R0-7 :  F4F4F4F4 00000004 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD ram After 1st Instruction




```
PSW AT BREAK    FFC50000 8F000004

R0-7 :  F4F4F4F4 00000004 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000        5810F010   5820F014   1A125010   F01807FE        *..0.......&.....*
000010        00000004   00000006   F5F5F5F5   F5F5F5F5        *........55555555*
000020        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000030        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000040        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000050        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000060        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000070        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000080        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000090        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000A0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000B0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000C0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000D0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000E0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000F0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program After 2nd Instruction

```
PSW AT BREAK   FFC50000 8F000008

R0-7 :  F4F4F4F4 00000004 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADI ...am After 2nd Instruction

Contents of word 6 LOADed to R2

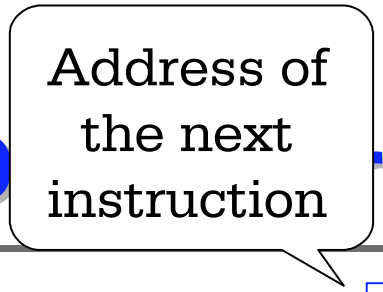
```
PSW AT BR...                    ...000008

R0-7 :  F4F4F4F4 00000004 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD ram After 2nd Instruction




```
PSW AT BREAK    FFC50000 8F000008

R0-7 :  F4F4F4F4 00000004 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000        5810F010   5820F014   1A125810   F01807FE        *..0.......&.....*
000010        00000004   00000006   F5F5F5F5   F5F5F5F5        *........55555555*
000020        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000030        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000040        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000050        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000060        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000070        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000080        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000090        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000A0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000B0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000C0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000D0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000E0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000F0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program After 3rd Instruction

```
PSW AT BREAK   FFC50000 8F00000A

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

Contents of R2 added to contents of R1

rogram After 3rd Instruction

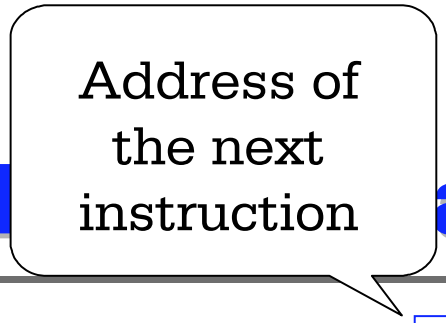
```
                50000 8F00000A

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   F5F5F5F5   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADI ...am After 3rd Instruction




```
PSW AT BREAK    FFC50000 8F00000A

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000        5810F010   5820F014   1A125010   F0180FFE        *..0.......&.....*
000010        00000004   00000006   F5F5F5F5   F5F5F5F5        *........55555555*
000020        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000030        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000040        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000050        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000060        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000070        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000080        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
000090        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000A0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000B0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000C0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000D0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000E0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*
0000F0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5        *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

ADD2 Program After 4th Instruction

```
PSW AT BREAK   FFC50000 8F00000E

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   0000000A   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

rogram After 4th Instruction

Contents of R1 STOREd to word 7

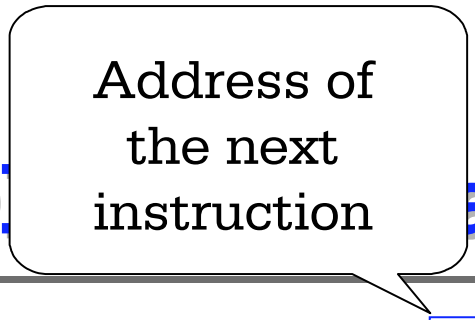
```
                C50000 8F00000E

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000       5810F010   5820F014   1A125010   F01807FE       *..0.......&.....*
000010       00000004   00000006   0000000A   F5F5F5F5       *........55555555*
000020       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000030       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000040       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000050       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000060       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000070       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000080       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
000090       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000A0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000B0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000C0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000D0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000E0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*
0000F0       F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5       *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

AD… am After 4th Instruction




```
PSW AT BREAK    FFC50000 8F00000E

R0-7 :  F4F4F4F4 0000000A 00000006 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4
R8-15:  F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 F4F4F4F4 00000020 00000068 00000000

000000        5810F010   5820F014   1A125010   F01807FE   *..0.......&.....*
000010        00000004   00000006   0000000A   F5F5F5F5   *........55555555*
000020        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000030        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000040        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000050        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000060        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000070        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000080        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
000090        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000A0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000B0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000C0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000D0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000E0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*
0000F0        F5F5F5F5   F5F5F5F5   F5F5F5F5   F5F5F5F5   *5555555555555555*

 ===>  B(rkpt.), D(ump), G(o), M(emory), P(SW), Q(uit), R(eg.), S(tep), T(race)
:
```

Implicit Addresses and USING

In Which We Make Assembler Programming "Easy"

A Slight Change

- What if we want to make a change to our original program? Maybe use register 12 as the base instead of R15
- That's no problem - just insert one LR instruction in front of the first LOAD, copying R15 to R12
- Then change all instructions which use R15 as the base register!

A Slight Change

- But that moves everything down and our data areas are no longer where they were, and that means we have to re-calculate the displacements

Updated ADD2 Demo Program

```
* This program adds two numbers that are taken
* from the 6th and 7th words of the program.
* The sum is stored in the 8th word.
ADD2    CSECT
        LR      12,15           Copy addr of 1st inst
        L       1,??(,12)       Load 1st no. into R1
        L       2,??(,12)       Load 2nd no. into R2
        AR      1,2             Get sum in R1
        ST      1,??(,12)       Store sum
        BCR     B'1111',14      Return to caller
        DC      F'4'            Fullword initially 4
        DC      F'6'            Fullword initially 6
        DS      F               Rsrvd only, no init
        END     ADD2
```

Updated ADD2 Demo Program

```
* This program adds two numbers that are taken
* from the 6th and 7th words of the program.
* The sum is stored in the 8th word.
ADD2    CSECT
        LR      12,15           Copy addr of 1st inst
        L       1,20(,12)       Load 1st no. into R1
        L       2,24(,12)       Load 2nd no. into R2
        AR      1,2             Get sum in R1
        ST      1,28(,12)       Store sum
        BCR     B'1111',14      Return to caller
        DC      F'4'            Fullword initially 4
        DC      F'6'            Fullword initially 6
        DS      F               Rsrvd only, no init
        END     ADD2
```

Updated ADD2 Demo Program

- As you are looking at this altered program, you should ask yourself why the locations of the three data areas increased by four bytes, when we added only a two-byte instruction at the beginning of the program

- Specifically, look at the first DC, just after the BCR instruction, and notice that BCR occupies only two bytes of storage

Updated ADD2 Demo Program Assembled

```
  LOC   OBJECT CODE    SOURCE STATEMENT

000000                 ADD2     CSECT
000000 18CF                     LR      12,15
000002 5810 C014                L       1,20(,12)
000006 5820 C018                L       2,24(,12)
00000A 1A12                     AR      1,2
00000C 5010 C01C                ST      1,28(,12)
000010 07FE                     BCR     B'1111',14
000014 00000004                 DC      F'4'
000018 00000006                 DC      F'6'
00001C                          DS      F
                                END     ADD2
```

Updated ADD2 Demo Program Assembled

```
   LOC   OBJECT CODE    SOURCE STATEMENT

                         ADD2     CSECT
                                  LR      12,15
000008 58F0 C014                  L       1,20(,12)
00000C 58F0 C018                  L       2,24(,12)
000010 07FE                       AR      1,2
000012 50F0 C01C                  ST      1,28(,12)
000016 07FE                       BCR     B'1111',14
000018 00000004                   DC      F'4'
00001C 00000006                   DC      F'6'
                                  DS      F
                                  END     ADD2
```

The next field is fullword aligned, even though this instruction ends two bytes "early"

There Must Be an Easier Way!

- What if our program has hundreds or thousands of instructions? Do we have to calculate displacements for every data area?
- Or, what if we change something? Do we have to re-calculate all displacements?
- Fortunately, no (or no one would ever use the assembler)

Use Labels!

- Remember: "Object Code - Nothing Else Matters"
- So, as long as the assembler generates the correct object code, we can do "anything we want" by way of writing source instructions

Use Labels!

- We want to use labels - implicit addresses - instead of explicit base and displacement, and let the assembler do the calculations

- We can do this as long as we tell the assembler what base register and base address to use

The USING Instruction

- So, instead of writing a base and displacement form of address, we will simply place a label on the storage area definition, then write that label in any instruction operand which references that data

- The assembler must convert the implicit reference to a valid base and displacement

The USING Instruction

- We tell the assembler which base register it can use and what base address the register has via the USING assembler instruction (or directive)

- The USING instruction is not executable, and has the following format:
  - **`USING baseaddress,baseregister`**

The USING Instruction

- This tells the assembler how to choose the correct base register and how to assign displacements

- USING is your "promise" that at execution time the base register will contain the memory address at which the base address has been loaded

The USING Instruction

- Be sure to compare the object code generated by the next version of the program, with the object code generated by the version without USING and labels
- The object code is exactly the same, so the program will execute in exactly the same way
- "Object code - nothing else matters"

Demo Program with Labels

```
* This program adds two numbers that are taken
* from WORD1 and WORD2 in the program.
* The sum is stored in WORD3.
ADD2    CSECT
        LR      12,15          Copy addr of 1st inst
        USING   ADD2,12        Tell assembler
        L       1,WORD1        Load 1st no. into R1
        L       2,WORD2        Load 2nd no. into R2
        AR      1,2            Get sum in R1
        ST      1,WORD3        Store sum
        BCR     B'1111',14     Return to caller
WORD1   DC      F'4'           Fullword initially 4
WORD2   DC      F'6'           Fullword initially 6
WORD3   DS      F              Rsrvd only, no init
        END     ADD2
```

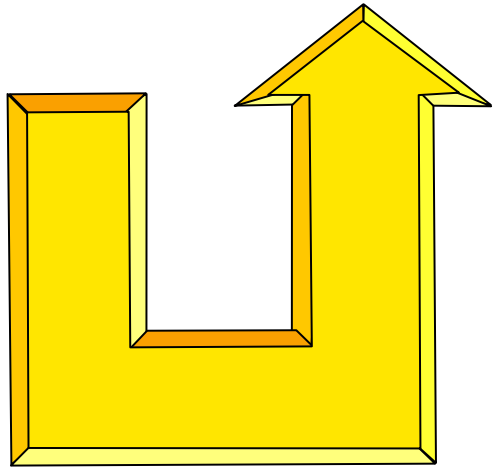
Demo Program with Labels

```
   LOC   OBJECT CODE    SOURCE STATEMENT

000000                  ADD2     CSECT
000000 18CF                      LR       12,15
000000                           USING    ADD2,12
000002 5810 C014                 L        1,WORD1
000006 5820 C018                 L        2,WORD2
00000A 1A12                      AR       1,2
00000C 5010 C01C                 ST       1,WORD3
000010 07FE                      BCR      B'1111',14
000014 00000004         WORD1    DC       F'4'
000018 00000006         WORD2    DC       F'6'
00001C                  WORD3    DS       F
                                 END      ADD2
```

The Condition Code and Branching

In Which We Learn How to Go Back Where We Came From, or Maybe Go Somewhere Else



The Condition Code

- The ADD (A, AR) and SUBTRACT (S, SR) instructions have an additional characteristic not yet mentioned - they set the condition code in the following way

CC	Meaning
0	Result is 0
1	Result is < 0
2	Result is > 0
3	Overflow occurred

The Condition Code

- Another pair of instructions, COMPARE (C, CR) also set the condition code, but its values are interpreted in a slightly different way

CC	Meaning
0	Contents equal
1	1st operand val < 2nd operand val
2	1st operand val > 2nd operand val
3	---- (not set)

The Condition Code

- The condition code is actually two bits of the PSW (bits 34 & 35 in ASSIST/I, bits 18 & 19 in S/390)

- In order to test for all possible combinations of the four CC values, we can use a four-bit mask
  - Mask `B'x x x x'` (B means binary)
  - CC `0 1 2 3` (CC value tested)

BRANCH ON CONDITION

- Then a bit mask of **B'1010'** will test for condition codes 0 and 2

- The condition code can be tested in only one way - by using the BRANCH ON CONDITION instruction (BC, BCR)

BRANCH ON CONDITION

- The two forms of BRANCH ON CONDITION are
  - [RX] **label BC B'mask',$D_2(X_2,B_2)$**
  - [RR] **label BCR B'mask',R_2**

- The encoded form of each instruction is
  - [RX] $h_{OP}h_{OP}h_{M1}h_{X2}\ h_{B2}h_{D2}h_{D2}h_{D2}$
  - [RR] $h_{OP}h_{OP}h_{M1}h_{R2}$

BRANCH ON CONDITION

- If the mask part of the BC or BCR has a 1 in a position corresponding to the current setting of the CC, the next instruction to be executed will be the one whose address is given by the second operand

- Otherwise, the next instruction will be the one whose address is already in the PSW, the one in memory immediately after the branch instruction

BRANCH ON CONDITION

- Notice that **`BCR B'1111',R14`** is an unconditional branch to the address in R14 and is the instruction used to end execution of a program

- The mask **`B'1111'`** matches all possible CC values

A Program Which Tests the Condition Code by Branching

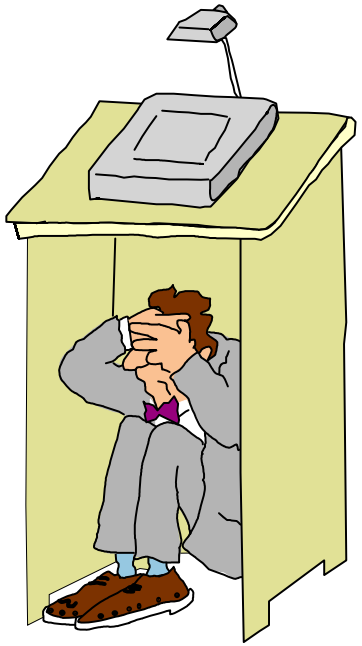
```
MAX      CSECT
         USING MAX,15
         L     1,W1     Get First number
         L     2,W2     Get second number
         CR    1,2      Compare
         BC    B'0010',ONEHIGH Branch if W1 high
         ST    2,W3     Else store second number
         BCR   B'1111',14 Return to caller
ONEHIGH  ST    1,W3     Store first number
         BCR   B'1111',14 Return to caller
W1       DC    F'321'   First number
W2       DC    F'123'   Second number
W3       DS    F        Max of first and second
         END   MAX
```

A Program Which Tests the Condition Code by Branching

```
  LOC   OBJECT CODE   SOURCE STATEMENT
000000                MAX      CSECT
000000                         USING MAX,15
000000 5810 F01C               L     1,W1
000004 5820 F020               L     2,W2
000008 1912                    CR    1,2
00000A 4720 F014               BC    B'0010',ONEHIGH
00000E 5020 F024               ST    2,W3
000012 07FE                    BCR   B'1111',14
000014 5010 F024     ONEHIGH   ST    1,W3
000018 07FE                    BCR   B'1111',14
00001C 00000141      W1        DC    F'321'
000020 0000007B      W2        DC    F'123'
000024               W3        DS    F
                               END   MAX
```

X-Instructions and ASSIST/I

In Which We Get Data Into and Out of an Assembler Program



Character Data

- At this point, we've seen only numeric data, represented as binary fullwords, and created in assemblies as data type F
- But binary data is much too difficult to type, so a different, external, format is used
- In order to work with external data, we will have to know how to represent characters

Character Data

- There are two standards in current use for representating character data: EBCDIC & ASCII

- We will stick to the EBCDIC representation in these sessions, since
  - It's the only representation known to ASSIST/I
  - It's the representation most common in OS/390

Some EBCDIC Representations

A	C1
B	C2
C	C3
D	C4
E	C5
F	C6
G	C7
H	C8
I	C9
J	D1
K	D2
L	D3
M	D4

N	D5
O	D6
P	D7
Q	D8
R	D9
S	E2
T	E3
U	E4
V	E5
W	E6
X	E7
Y	E8
Z	E9

0	F0
1	F1
2	F2
3	F3
4	F4
5	F5
6	F6
7	F7
8	F8
9	F9

blank	40

.	4B
<	4C
(	4D
+	4E
&	50
!	5A
$	5B
*	5C
)	5D
-	60
>	6E
@	7C
'	7D

Character Data

- We can create character data in our programs by using data type C in a DC instruction

- **`MESSAGE  DC  C'1HELLO WORLD!'`**

- The object code generated by this DC is
  - **`F1C8C5D3D3D640E6D6D9D3C45A`**

Character Data

- The 1 in front of the message is a "carriage control" character which will cause the message to be printed at the top of a new page

- Other carriage control characters are
  - `' '` (blank) - Single space
  - `'0'` - Double space
  - `'-'` - Triple space

The X-Instructions of ASSIST/I

- For assembler programmers, moving data into and out of a program is a very complex affair, involving numerous operating system I/O "macros"

- For users of ASSIST and ASSIST/I, however, the process is extremely simple and requires only the use of a few non-standard instructions

The X-Instructions of ASSIST/I

- In ASSIST and ASSIST/I, these instructions assemble just like "real" instructions, but they are not part of the standard (or any other) instruction set

- The first is XREAD, which reads a record from the input file and places as many bytes as requested (up to 80) starting at the memory address provided

The XREAD Instruction

- **label XREAD $D_1(X_1,B_1),L_2$**
  - **$D_1(X_1,B_1)$** is the address of the first byte of the input buffer
  - **L_2** is the number of characters (1 to 80) to be transferred from the input record

- The input record contains character data

The XREAD Instruction

- The XREAD instruction sets the condition code
  - 0 - Read was successful, data placed in memory
  - 1 - end-of-file encountered, no data transferred
  - 2 - not set
  - 3 - not set

The XDECI Instruction

- Numbers are input as characters in the EBCDIC representation and must be converted to binary before we can manipulate them (e.g., ADD or SUBTRACT)

- Input conversion is performed by XDECI

The XDECI Instruction

- The XDECI instruction converts an EBCDIC numeric value in memory to a binary numeric value and places it in a register

- **label XDECI R_1,D_2(X_2,B_2)**

  - **R_1** is the register to hold the result

  - **D_2(X_2,B_2)** is the memory location at which the search for numeric characters begins

The XDECI Instruction Logic

1. Start at $D_2(X_2,B_2)$, scan for the first non-blank

2. If the first non-blank is anything but **+** or **-** or a decimal digit, set the condition code to 3 and quit

3. Otherwise, 1 to 9 digits are scanned and the resulting number is converted to binary and placed in register R_1

The XDECI Instruction Logic

4. Register 1 is set to the address of the first non-digit (so register operand R_1 should not be 1!)

5. If ten or more digits are found, register 1 is set to the address of the first non-digit, the condition code is set to 3, and register R_1 is unchanged

The XDECI Instruction Logic

- XDECI sets the condition code
  - 0 - The number converted was 0
  - 1 - The number converted was < 0
  - 2 - The number converted was > 0
  - 3 - Non-numeric scanned, or too many digits

- To avoid scanning past the end of the buffer:
  - **`INPUT  DS  CL80`** Input Buffer
  - **`       DC  C'*'`** Non-digit stopper

The XDECO Instruction

- The XDECO instruction converts a binary numeric value in a register to an EBCDIC numeric value in memory (action opposite that of XDECI)

The XDECO Instruction

- **label XDECO R_1,D_2(X_2,B_2)**
  - **R_1** is the register containing the binary number to convert
  - **D_2(X_2,B_2)** is the beginning memory location, usually within a print buffer, to store the EBCDIC number, right-justified, occupying 12 bytes

The XPRNT Instruction

- The XPRNT instruction will print one line of output of maximum length 133 characters (including the carriage control)

- **label XPRNT $D_1(X_1,B_1),L_2$**
  - **$D_1(X_1,B_1)$** is the address of the first byte of the output buffer (the CC character)
  - **L_2** is the number of characters (including carriage control) to be transferred from memory to the print line

Example With X-Instructions (1 of 2)

```
* THIS PROGRAM READS DATA CARDS EACH HAVING TWO
*  NUMBERS.  THE SUM OF THE NUMBERS IS PRINTED.
*
SUMUP    CSECT
         USING SUMUP,15
*
         XPRNT HEADING,28      PRINT PAGE HDR
         XREAD CARD,80         READ 1ST CARD
*
CHECKEOF BC    B'0100',EXIT    BR ON EOF
*
         XDECI 2,CARD          ASSUME BOTH NUMS
         XDECI 3,0(,1)          ARE VALID
*
         AR    2,3             CALCULATE THE SUM
```

Example With X-Instructions (2 of 2)

```
         XDECO 2,OUTPUT          PRINTABLE FORM
*                                 INTO PRINT LINE
         XPRNT CRG,13            PRINT THE SUM
*                                AFTER SINGLE SPACE
         XREAD CARD,80           TRY ANOTHER READ
         BC    B'1111',CHECKEOF GO CHECK FOR EOF
*
EXIT     BCR   B'1111',14        TERMINATE PROGRAM
*
CARD     DS    CL80              INPUT BUFFER
*
CRG      DC    C' '              SINGLE SPACE CC
OUTPUT   DS    CL12              SUM GOES HERE
HEADING  DC    C'1THIS IS THE OUTPUT OF SUMUP'
         END   SUMUP
```

What's Next?

- Tomorrow, we will do more arithmetic (multiplication and division), and we will construct program loops

- We will also see one of the simplest and most challenging machine instructions, the LOAD ADDRESS instruction (when you are comfortable with addresses, you will have a good understanding of assembler)