Math Co-Processor 8087

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Compatible Processor and Coprocessor Processors

1. 8086 & 8088
2. 80286
3. 80386DX
4. 80386SX
5. 80486DX
6. 80486SX

Coprocessors

1. 8087
2. 80287,80287XL
3. 80287,80387DX
4. 80387SX
5. It is Inbuilt
6. 80487SX

Introduction

- 8087 was the first math coprocessor for 16-bit processors designed by Intel.
- It was built to pair with 8086 and 8088.
- The purpose of 8087 was to speed up the computations involving floating point calculations.
- Addition, subtraction, multiplication and division of simple numbers is not the coprocessor’s job.
- It does all the calculations involving floating point numbers like scientific calculations and algebraic functions.

Introduction

- By having a coprocessor, which performs all the calculations, it can free up a lot of CPU's time.
- This would allow the CPU to focus all of its resources on the other functions it has to perform.
- This increases the overall speed and performance of the entire system.
- This coprocessor introduced about 60 new instructions available to the programmer.
- All the mnemonics begin with "F" to differentiate them from the standard 8086 instructions.
- For e.g.: in contrast to ADD/MUL, 8087 provide FADD/FMUL.

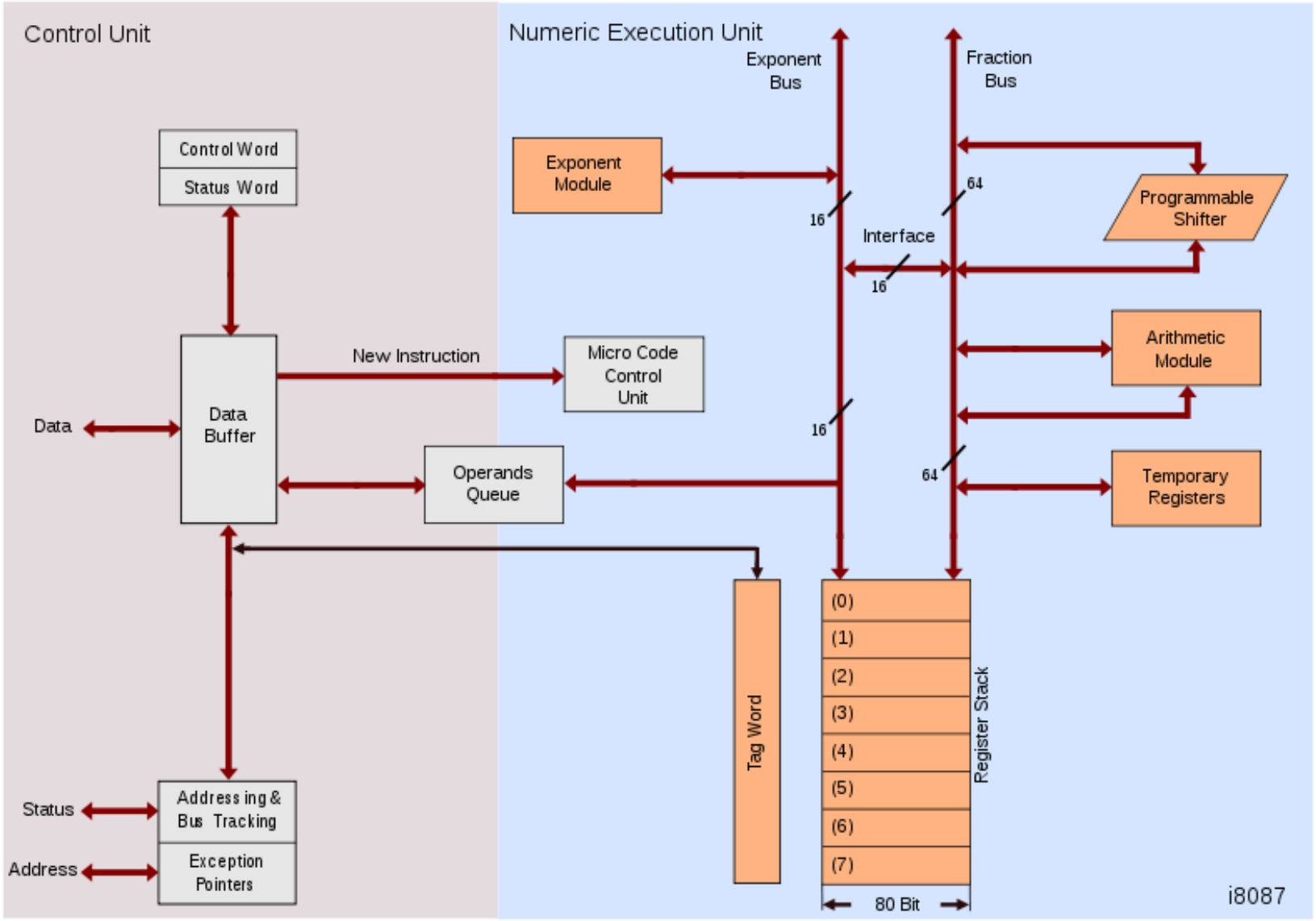
Introduction

- Math coprocessor is also called as:
  - Numeric Processor Extension (NPX)
  - Numeric Data Processor (NDP)
  - Floating Point Unit (FPU)

Architecture of 8087

- 8087 coprocessor is designed to operate with 8086 microprocessor.
- The microprocessor and coprocessor can execute their respective instructions simultaneously.
- Microprocessor interprets and executes the normal instruction set and the coprocessor interprets and executes only the coprocessor instructions.
- All the coprocessor instructions are ESC instructions, i.e. they start with “F”.

ARCHITECTURE OF 8087



Architecture of 8087

- The internal structure of 8087 coprocessor is divided into two major sections:
  - Control Unit (CU)
  - Numerical Execution Unit (NEU)

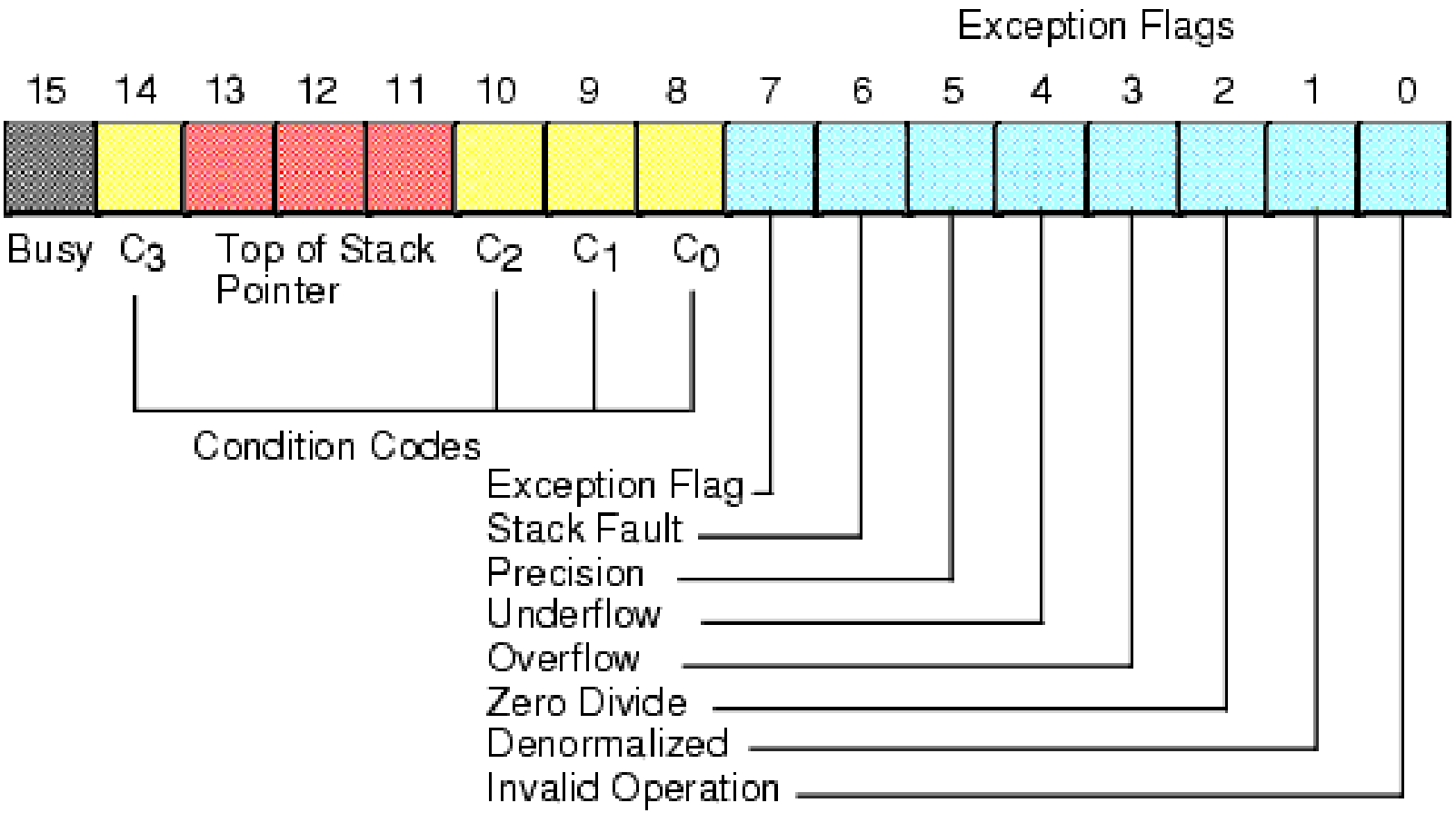
Control Unit (CU)

- It interfaces coprocessor to the microprocessor system bus.
- It also synchronize the operation of the coprocessor and the microprocessor.
- This unit has a Control Word, Status Word and Data Buffer.
- If an instruction is ESC instruction, then coprocessor executes it.
- If not, then microprocessor executes.

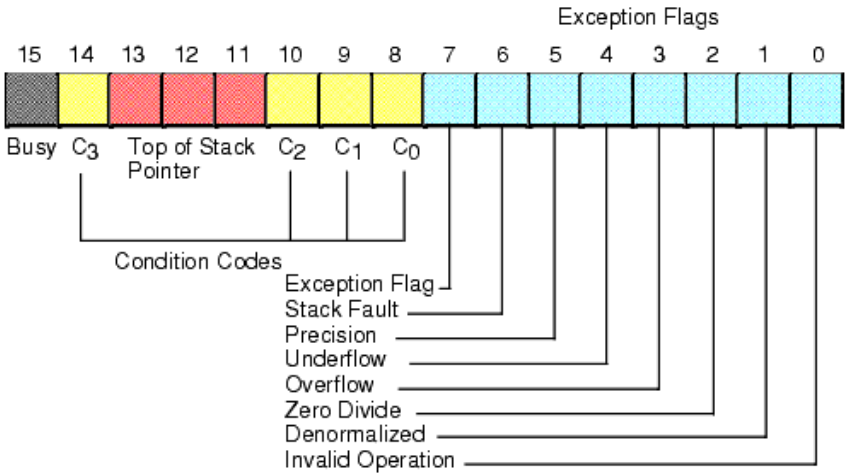
Numeric Execution Unit (NEU)

- This unit is responsible for executing all coprocessor instructions.
- It has an 8 register stack that holds the operands for instructions and result of instructions.
- The stack contains 8 registers that are 80-bits wide.
- Numeric data is transferred inside the coprocessor in two parts:
  - 64-bit mantissa bus
  - 16-bit exponent bus

Status Register

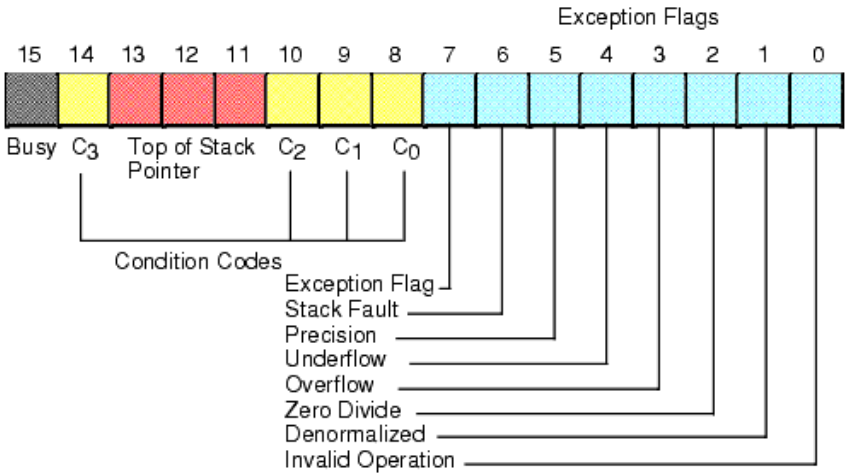


STATUS REGISTER



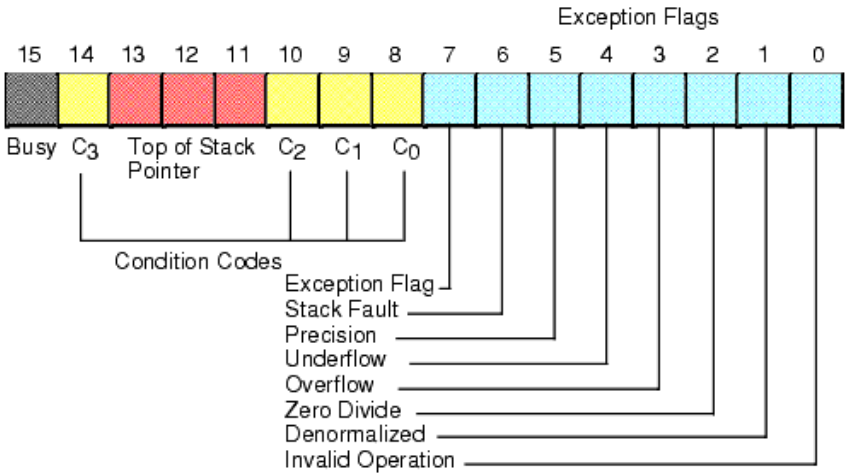
- Status Register tells the overall status of 8087 coprocessor.
- It is a 16-bit register.
- It is accessed by executing the FSTSW instruction.
- This instruction stores the contents of status register into memory.
- Once the status is stored in memory, the bit positions of the status register can be examined.

Status Register



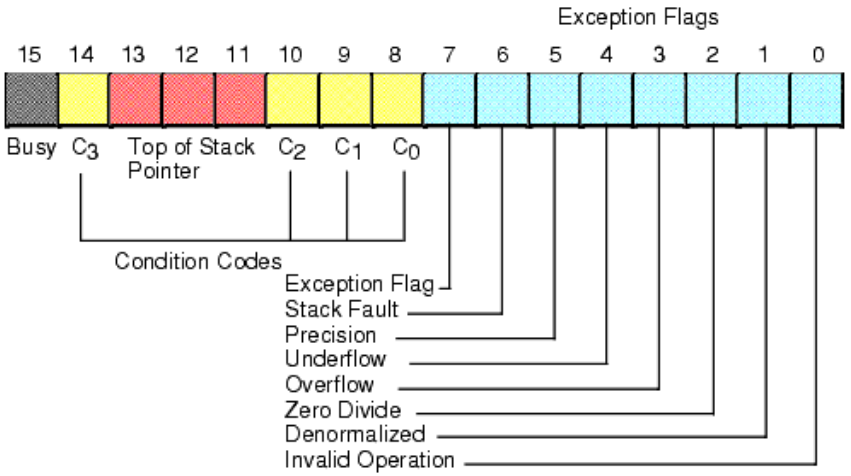
- **Busy:** It indicates that the coprocessor is busy executing the task.
- **Condition Codes (C_0-C_3):** They indicate various conditions about the coprocessor.
- **Top of Stack:** It indicates a register as top of stack register, out of the eight stack registers.
- **Exception Flag:** It is set if any of the exception flag bits (SF, PR, UF, OF, ZD, DN, IO) are set.

STATUS REGISTER



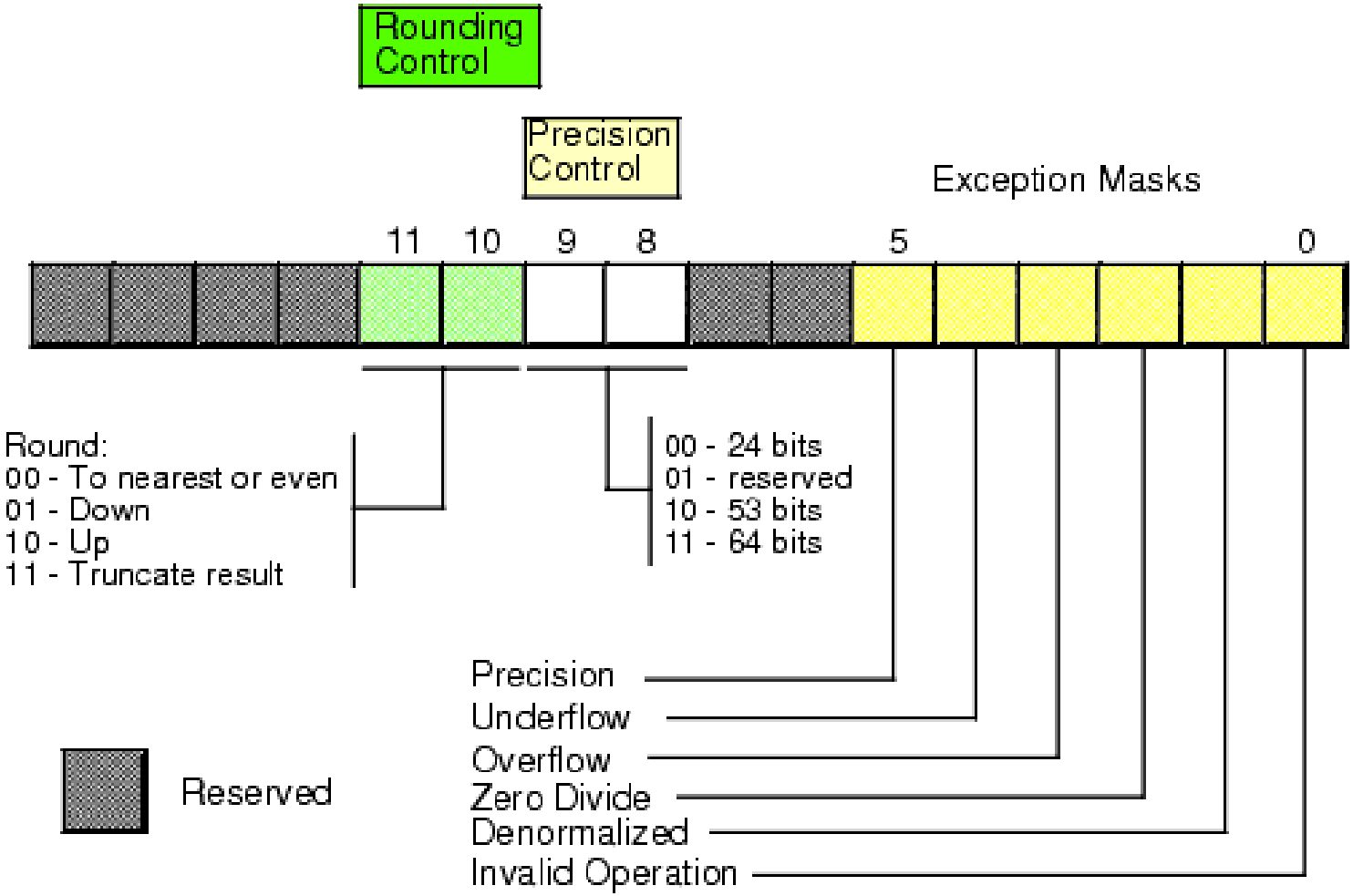
- **Stack Fault:** It is not available in 8087. It is active only in 80387 and above.
- **Precision:** It indicates that the result has exceeded the selected precision.
- **Underflow:** It tells if the result is too small to fit in a register.
- **Overflow:** It tells if the result is too large to fit in a register.

STATUS REGISTER

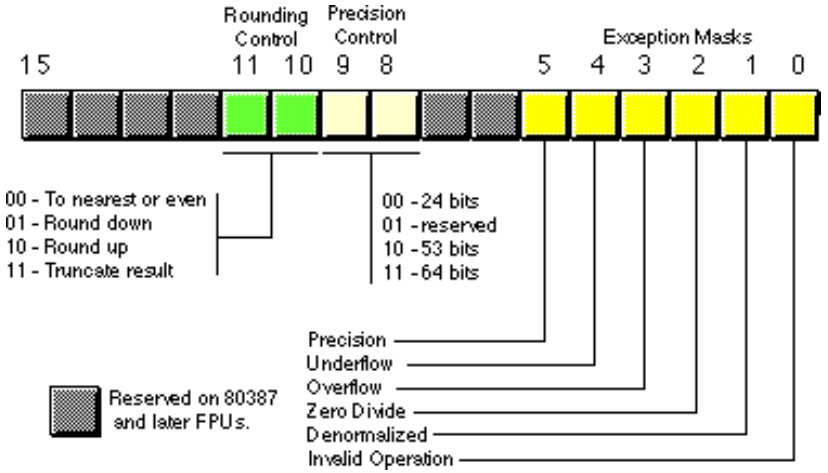


- **Zero Divide:** It indicates that you try to divide a non-zero value by zero.
- **Denormalized:** It indicates that at least one of the operand is de-normalized.
- **Invalid Operation:** It indicates an invalid operation. For e.g.: pushing more than eight items onto the stack, attempting to pop an item off an empty stack or taking the square root of a negative number.

Control Register

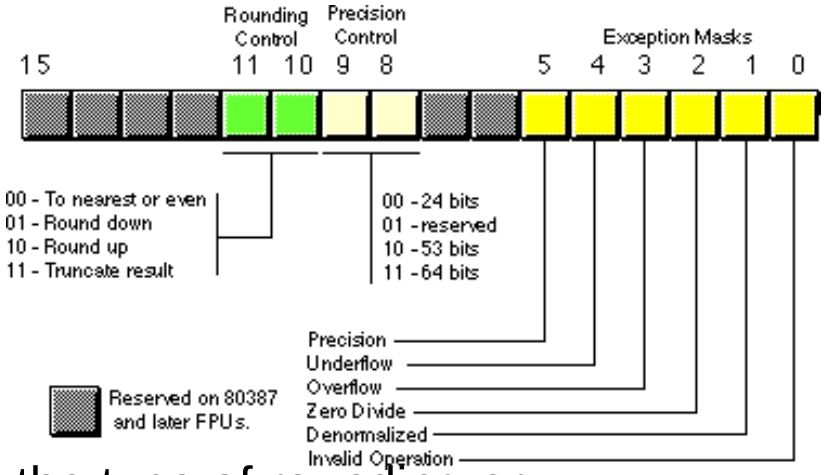


CONTROL REGISTER



- Control Register controls the operating modes of 8087.
- It is also a 16-bit register.
- It performs rounding control and precision control.
- It is also used to do masking and unmasking of the exception bits that correspond to the rightmost six bits of the status register.
- FLDCW instruction is used to load the value into control register.

CONTROL REGISTER



- **Rounding Control:** It determines the type of rounding or truncating to be done.

  00=Round to nearest or even
  01=Round down towards minus infinity
  10=Round up towards plus infinity
  11=Chop or truncate towards zero
- **Precision Control:** It sets the precision of the result.

  00=Single precision (short)
  01=Reserved
  10=Double precision (long)
  11=Extended precision (temporary)
- **Exception Masks:** It determines that whether an error effects the exception bits in the status register.
  - If it is one, then the corresponding error is ignored.
  - If it is zero and the corresponding error occurs, then it generates an interrupt, and the corresponding bit in status register is set.

Tag Register

TAG 7	TAG 6	TAG 5	TAG 4	TAG 3	TAG 2	TAG 1	TAG 0

Tag Values:
00 = Valid
01 = Zero
10 = Invalid
11 = Empty

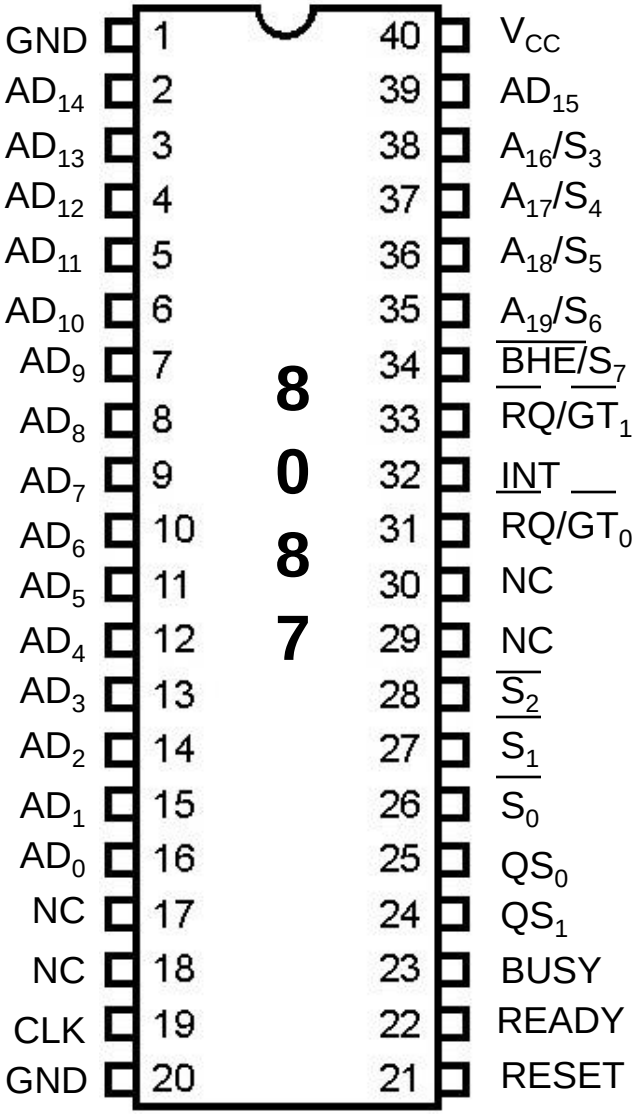
TAG 7	TAG 6	TAG 5	TAG 4	TAG 3	TAG 2	TAG 1	TAG 0

TAG REGISTER

Tag Values:
00 = Valid
01 = Zero
10 = Invalid
11 = Empty

- Tag Register is used to indicate the contents of each register in the stack.
- There are total 8 tags (Tag 0 to Tag 7) in this register and each tag uses 2 bits to represent a value.
- Therefore, it is a 16-bit register.

PIN DIAGRAM OF 8087



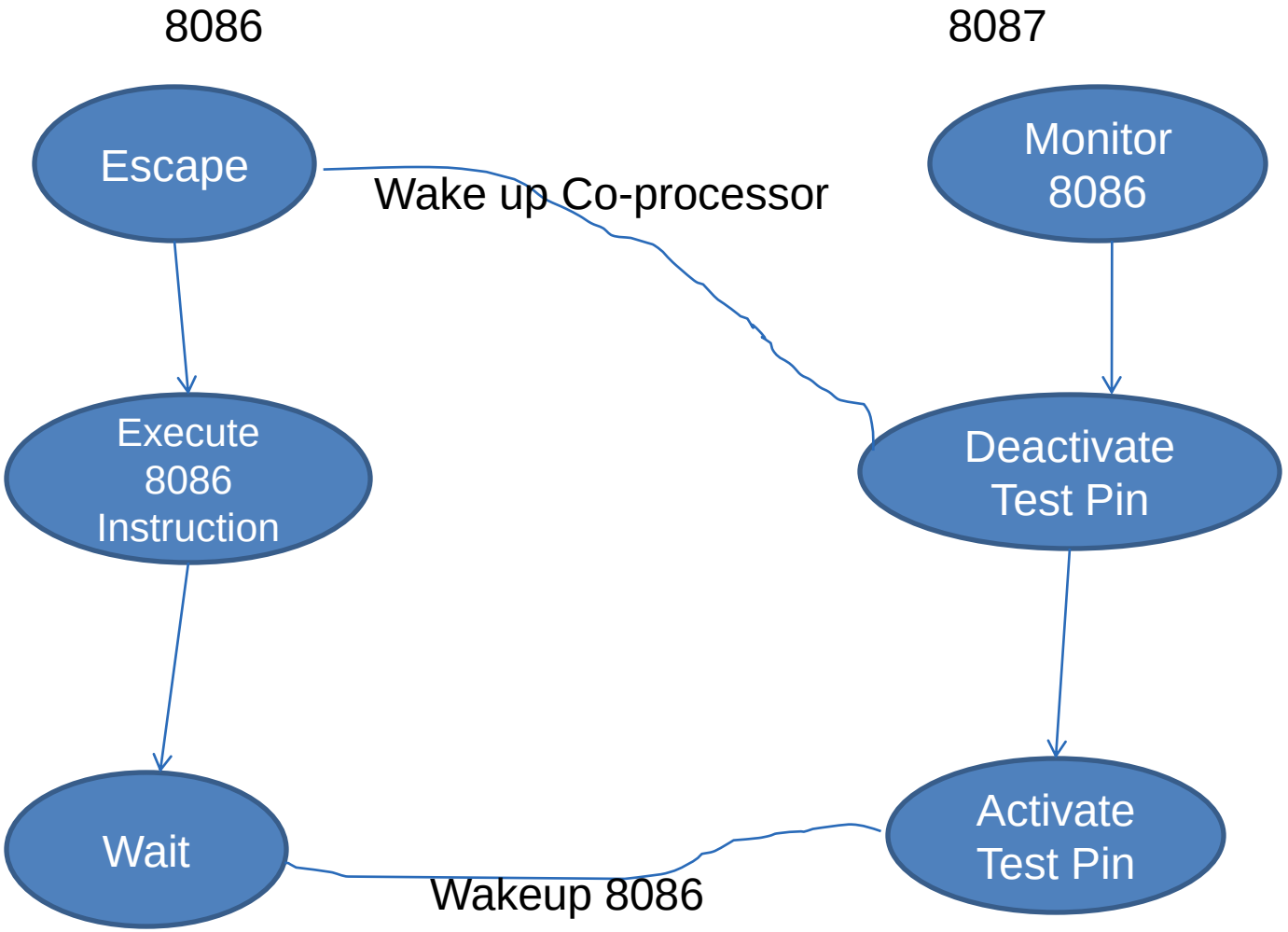
Interfacing of 8086 and 8087

- Multiplexed address-data bus lines are connected directly from 8086 to 8087.
- The status lines and the queue status lines are connected directly from 8086 to 8087.
- The Request/Grant (RQ/GT_0 and RQ/GT_1) signals of 8087 are connected to RQ/GT_0 and RQ/GT_1 of 8086.
- BUSY signal of 8087 is connected to TEST pin of 8086.

Exception Handling

- The 8087 detects six different types of exception conditions that occur during instruction execution. These will cause an interrupt if unmasked and interrupts are enabled.
- 1) INVALID OPERATION
- 2) OVERFLOW
- 3) ZERO DIVISOR
- 4) UNDERFLOW
- 5) DENORMALIZED OPERAND
- 6) INEXACT RESULT

Synchronization Between 8086 and 8087



Data Types

- Internally, all data operands are converted to the 80-bit temporary real format.
- We have 3 types.
- •Integer data type
- •Packed BCD data type
- •Real data type

INSTRUCTION SET

- The 8087 instruction mnemonics begins with the letter F which stands for Floating
- point and distinguishes from 8086.
- The 8087 detects an error condition usually called an exception when it executing an
- instruction it will set the bit in its Status register.
- **Types**
- I. DATA TRANSFER INSTRUCTIONS.
- II. ARITHMETIC INSTRUCTIONS.
- III. COMPARE INSTRUCTIONS.

Data Transfers Instructions

- **REAL TRANSFER**
- FLD Load real
- FST Store real
- FSTP Store real and pop
- FXCH Exchange registers

- **INTEGER TRANSFER**
- FILD Load integer
- FIST Store integer
- FISTP Store integer and pop

- **FLD Source- Decrements the stack pointer by one and copies a real number from a**
- stack element or memory location to the new ST.
- •FLD ST(3) ;Copies ST(3) to ST.
- •FLD LONG_REAL[BX] ;Number from memory copied to ST.
- **FLD Destination- Copies ST to a specified stack position or to a specified memory** location .
- •FST ST(2) ;Copies ST to ST(2),and increment stack pointer.
- •FST SHORT_REAL[BX] ;Copy ST to a memory at a SHORT_REAL[BX]

- **FXCH Destination – Exchange the contents of ST with the contents of a specified**
- stack element.
- •FXCH ST(5) ;Swap ST and ST(5)

- **FILD Source – Integer load. Convert integer number from memory to temporary-real**

  sformat and push on 8087 stack.
- •FILD DWORD PTR[BX] ;Short integer from memory at [BX].
- **FIST Destination- Integer store. Convert number from ST to integer and copy to** memory.
- •FIST LONG_INT ;ST to memory locations named LONG_INT.

Arithmetic Instructions.

Four basic arithmetic functions: Addition, Subtraction, Multiplication, and Division

- **Addition**
- FADD Add real
- FADDP Add real and pop
- FIADD Add integer

- **Subtraction**
- FSUB Subtract real
- FSUBP Subtract real and pop
- FISUB Subtract integer

- **Multiplication**
- FMUL Multiply real
- FMULP Multiply real and pop
- FIMUL Multiply integer
- **Advanced**
- FABS Absolute value
- FCHS Change sign
- FPREM Partial remainder
- FPRNDINT Round to integer
- FSCALE Scale
- FSQRT Square root
- FXTRACT Extract exponent and mantissa.

- FADD ST(3), ST ;Add ST to ST(3), result in ST(3)
- •FADD ST,ST(4) ;Add ST(4) to ST, result in ST.
- •FADD ;ST + ST(1), pop stack result at ST
- •FADDP ST(1) ;Add ST(1) to ST. Increment stack pointer so ST(1) become ST.

- •FSUB ST(2), ST ;ST(2)=ST(2) – ST.
- •FSUB Rate ;ST=ST – real no from memory.
- •FSUB ;ST=(ST(1) – ST)
- **FSUBP - Subtract ST from specified stack element and put result in specified stack**
- element .Then increment the pointer by one.
- •FSUBP ST(1) ;ST(1)-ST. ST(1) becomes new ST

Compare Instructions.

- FCOM Compare real
- FCOMP Compare real and pop
- FCOMPP Compare real and pop twice
- FICOM Compare integer
- FICOMP Compare integer and pop
- FTST Test ST against +0.0
- FXAM Examine ST
- Transcendental Instruction.

Thank You

Have a Nice Day