Quadrature Signal Interface to a COP400 Microcontroller

National Semiconductor
Application Note 749
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INTRODUCTION

Switches have always been a popular way of getting information into a microcontroller. Two-bit quadrature output devices, also known as two-bit gray code output, use two switches that are mechanically coupled together thru a shaft so that as the shaft is rotated the switches generate two square waves that are 90 degrees out of phase with each other. This is also known as being in quadrature, see *Figure 1*. The reason for doing this is that within the two signals there is the information to detect the direction of rotation, i.e., clockwise (CW) or counterclockwise (CCW). This type of device allows an input variable to be increased or decreased by CW or CCW rotation of the shaft. Additionally, these devices allow continuous rotation in either direction, which lets the span and resolution of the input variable to be a function of the software.

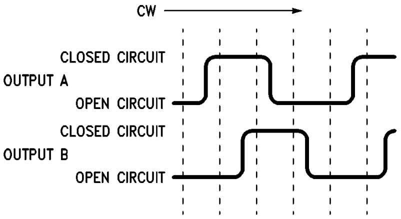

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FIGURE 1

OPERATION

Figure 2 shows a hardware connection of a quadrature output device to the COP400 microcontroller. Although in this example the G0 and G1 I/O pins are used, any pin that can be used as an input could be used with the appropriate changes in the software.

In this example the output of device QD1 is processed to detect a state change in the quadrature signal and which direction the change was in. A 3-digit BCD variable, which is stored in RAM, is then incremented or decremented. The variable is defined to have a range of 200 to 350 units. The routine allows the variable to saturate at it's upper and lower limits when reached.

Figure 3 displays the two waveforms that are generated by QD1 as it's shaft is rotated from an arbitrary starting position. Each edge represents a change of state. By keeping track of the state that was moved from and the state that currently exists, it can be determined which direction the rotation was in.

Referring to *Figure 3*, there are 4 possible states for a starting position, (00, 01, 11, 10), and they will be referred to as the previous state. There are also 4 possible states to move to, (00, 01, 11, 10), and they will be referred to as the current state. *Figure 4* lists the 8 possible combinations of bits that can be formed by starting from each previous state and rotating CW or CCW to the current state. If the two bits of the previous state and current state are concatenated into one 4-bit value, each value will be unique. The routine

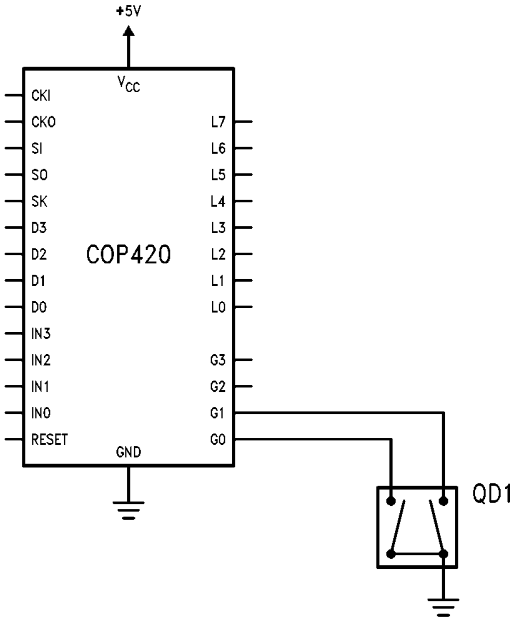

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FIGURE 2

RRD-B30M75/Printed in U. S. A.

POSITION	OUTPUT STATE A	OUTPUT STATE B
−5	0	1
−4	0	0
−3	1	0
−2	1	1
−1	0	1
0	0	0
1	1	0
2	1	1
3	0	1
4	0	0
5	1	0

CCW ↑ CW ↓

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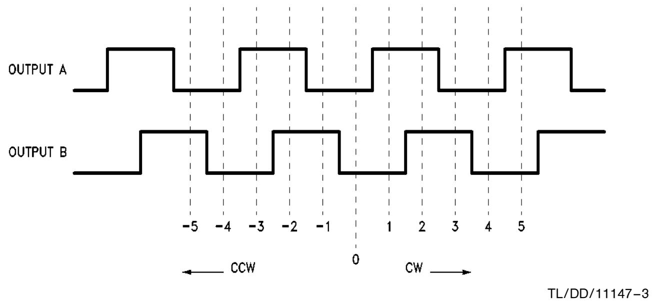

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FIGURE 3. Quadrature Signal Output (Gray Code)

used in this example assigns the two bits of the current state to the low 2 bits of a 4-bit value, and the 2 bits of the previous state to the high 2 bits of a 4-bit value. This 4-bit value (see the column under the PS/CS heading in *Figure 4*) is then used as a pointer into a jump table which branches to the add or subtract part of the routine. This method takes advantage of the "jump indirect" instruction which implements a multiway branch based on the value of a pointer.

The routine to input data from the quadrature device reads the value of G0 and G1 and compares it to the value stored from the previous read operation. If the two values are equal there is no input to process. If the two values are not equal there is an input and the data is processed to determine if one is to be added to or subtracted from the variable.

The flow chart details the operation of the subroutine "QUAD".

In *Figure 4*, only 8 of the possible 16 combinations are used. To account for potential spurious operation if one of the 8 undefined combinations occur, they are ignored by this routine by branching to a return instruction which bypasses any additional processing.

The source listing for this example subroutine, which is named "QUAD", is provided. An initialization routine that is required to set up the starting parameters is also included.

CONCLUSION

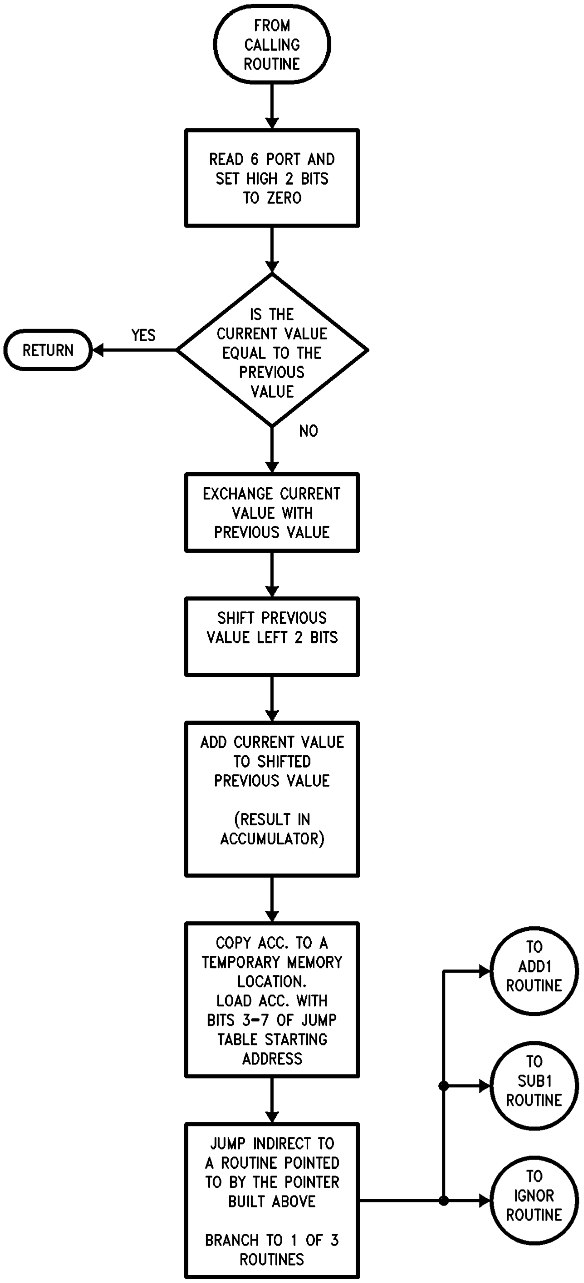
This application note demonstrates the relative ease of interfacing a quadrature device to a COP400 microcontroller. The combination of a low cost microcontroller and input device can provide the basis for a cost effective instrument or appliance design.

Direction	PS/CS	Hex Value	Operation
CW CCW	00 10 00 01	2 1	Add 1 Subtract 1
CW CCW	01 00 01 11	4 7	Add 1 Subtract 1
CW CCW	11 01 11 10	D E	Add 1 Subtract 1
CW CCW	10 11 10 00	B 8	Add 1 Subtract 1

PS = Previous State
CS = Current State

FIGURE 4

QUAD


FROM CALLING ROUTINE
READ 6 PORT AND SET HIGH 2 BITS TO ZERO
IS THE CURRENT VALUE EQUAL TO THE PREVIOUS VALUE
YES
RETURN
NO
EXCHANGE CURRENT VALUE WITH PREVIOUS VALUE
SHIFT PREVIOUS VALUE LEFT 2 BITS
ADD CURRENT VALUE TO SHIFTED PREVIOUS VALUE
(RESULT IN ACCUMULATOR)
COPY ACC. TO A TEMPORARY MEMORY LOCATION.
LOAD ACC. WITH BITS 3–7 OF JUMP TABLE STARTING ADDRESS
JUMP INDIRECT TO A ROUTINE POINTED TO BY THE POINTER BUILT ABOVE
BRANCH TO 1 OF 3 ROUTINES
TO ADD1 ROUTINE
TO SUB1 ROUTINE
TO IGNOR ROUTINE

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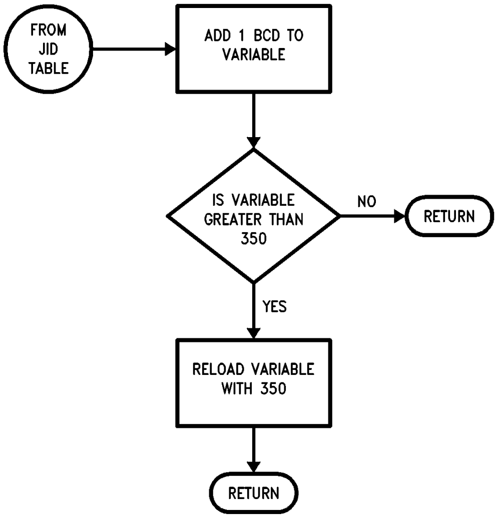
ADD1



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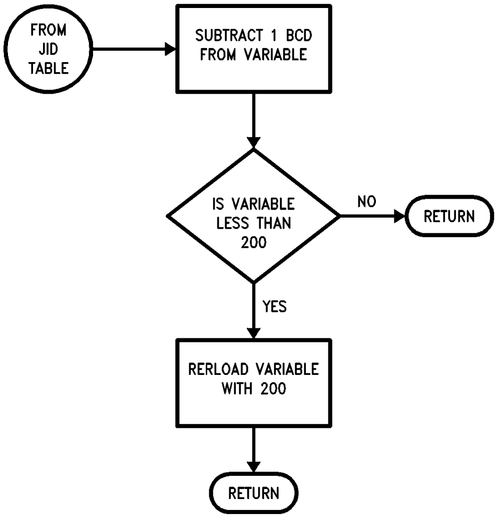
SUB1


FROM JID TABLE
SUBTRACT 1 BCD FROM VARIABLE
IS VARIABLE LESS THAN 200
NO
RETURN
YES
RERLOAD VARIABLE WITH 200
RETURN

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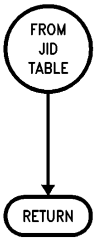
IGNOR



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```
NATIONAL SEMICONDUCTOR CORPORATION
COP400 CROSS ASSEMBLER,REV:D,8 MAY 85
QUAD

                ;
                ;                       QUAD.MAC
                ;                       QUADRATURE SIGNAL INTERFACE TO THE COP420
                ;                       AUGUST 1, 1990
                ;                       WALTER BACHAROWSKI
                ;
                                .TITLE QUAD
                                .CHIP 420
                        ;
                        ;********
                        ;
                        ;ASSIGNMENTS
                        ;
                        ;********
                        ;
     000F               PV      =       0,15    ;PREVIOUS VALUE REGISTER
     003D               SCR0    =       3,13    ;SCRATCH PAD LOCATION
     003E               SCR1    =       3,14    ;SCRATCH PAD LOCATION
     003F               SCR2    =       3,15    ;SCRATCH PAD LOCATION
     001D               VLD     =       1,13    ;VARIABLE VALUE, LOW DIGIT
     001E               VMD     =       1,14    ;VARIABLE VALUE, MIDDLE DIGIT
     001F               VHD     =       1,15    ;VARIABLE VALUE, HIGH DIGIT
                        ;
                        ;***********
                        ;
                        ;PROGRAM START
                        ;
                        ;***********
                        ;
                POR:
0000 00                 CLRA
0001 335F               OGI     15      ;SET G PORT TO 1's SO THEY CAN BE USED AS INPUTS.
0003 0E                 LBI     PV      ;GET INITIAL SETTING OF QUADRATURE DEVICE
0004 332A               ING             ;AND STORE IN PREVIOUS VALUE REGISTER
0006 06                 X
0007 42                 RMB     2       ;MASK HIGH 2 BITS
0008 43                 RMB     3
                        ;
0009 1C                 LBI     VLD     ;LOAD MINIMIUM VALUE FOR THE VARIABLE
000A 70                 STII    0
000B 70                 STII    0
000C 72                 STII    2
                        ;
                IDLE:
000D 6A11               JSR     QUAD    ;CONTINUOUS LOOP TO CHECK THE INPUT
000F CD                 JP      IDLE
                        ;
                        ;
     0200               . =     X'200   ;FORCE THE QUAD ROUTINE TO START AT HEX 200
                        ;
                        ;
```

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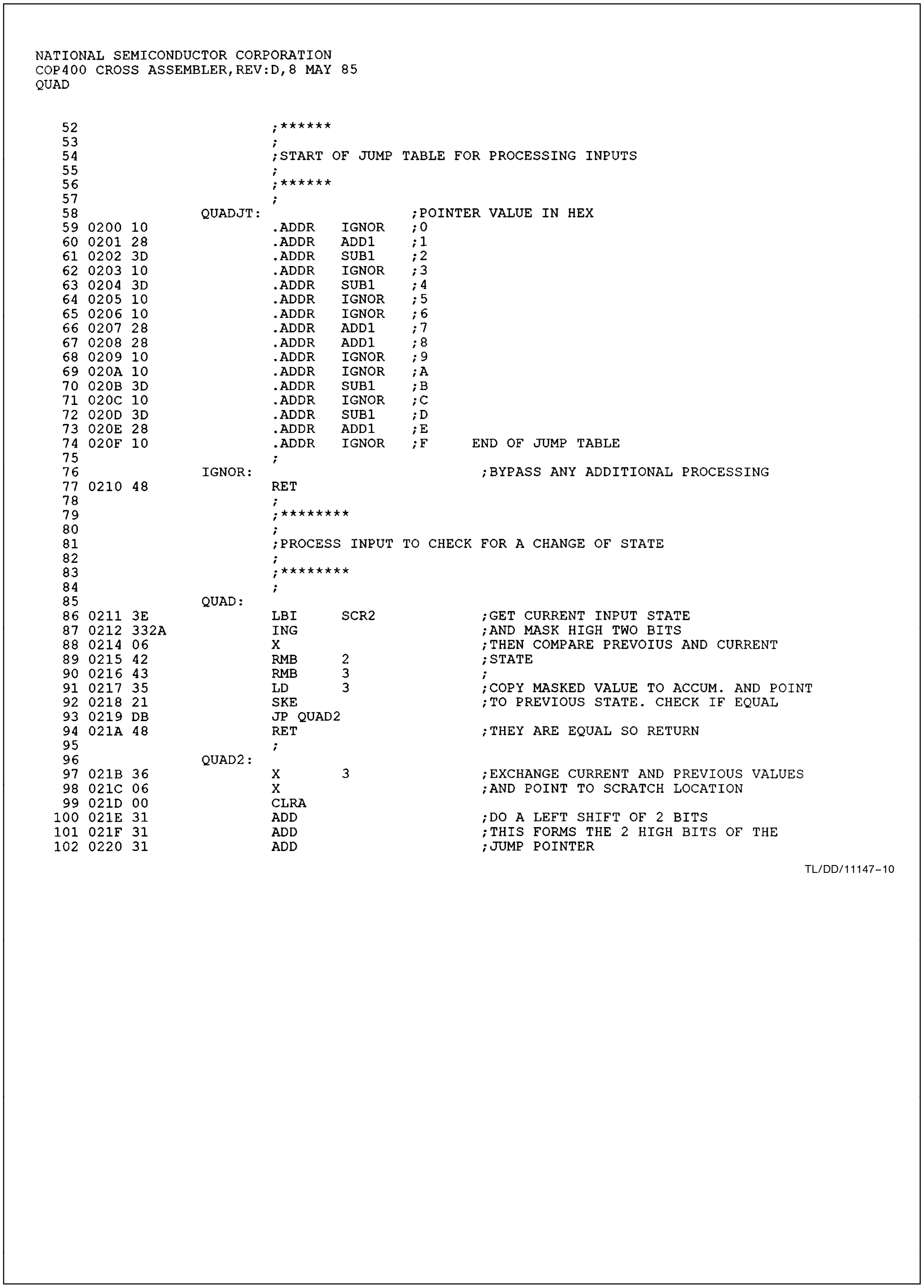

```
NATIONAL SEMICONDUCTOR CORPORATION
COP400 CROSS ASSEMBLER,REV:D,8 MAY 85
QUAD

                           ;******
                           ;
                           ;START OF JUMP TABLE FOR PROCESSING INPUTS
                           ;
                           ;******
                           ;
                   QUADJT:                 ;POINTER VALUE IN HEX
      0200 10              .ADDR   IGNOR   ;0
      0201 28              .ADDR   ADD1    ;1
      0202 3D              .ADDR   SUB1    ;2
      0203 10              .ADDR   IGNOR   ;3
      0204 3D              .ADDR   SUB1    ;4
      0205 10              .ADDR   IGNOR   ;5
      0206 10              .ADDR   IGNOR   ;6
      0207 28              .ADDR   ADD1    ;7
      0208 28              .ADDR   ADD1    ;8
      0209 10              .ADDR   IGNOR   ;9
      020A 10              .ADDR   IGNOR   ;A
      020B 3D              .ADDR   SUB1    ;B
      020C 10              .ADDR   IGNOR   ;C
      020D 3D              .ADDR   SUB1    ;D
      020E 28              .ADDR   ADD1    ;E
      020F 10              .ADDR   IGNOR   ;F     END OF JUMP TABLE
                           ;
                   IGNOR:                          ;BYPASS ANY ADDITIONAL PROCESSING
      0210 48              RET
                           ;
                           ;********
                           ;
                           ;PROCESS INPUT TO CHECK FOR A CHANGE OF STATE
                           ;
                           ;********
                           ;
                   QUAD:
      0211 3E              LBI     SCR2            ;GET CURRENT INPUT STATE
      0212 332A            ING                     ;AND MASK HIGH TWO BITS
      0214 06              X                       ;THEN COMPARE PREVOIUS AND CURRENT
      0215 42              RMB     2               ;STATE
      0216 43              RMB     3               ;
      0217 35              LD      3               ;COPY MASKED VALUE TO ACCUM. AND POINT
      0218 21              SKE                     ;TO PREVIOUS STATE. CHECK IF EQUAL
      0219 DB              JP QUAD2
      021A 48              RET                     ;THEY ARE EQUAL SO RETURN
                           ;
                   QUAD2:
      021B 36              X       3               ;EXCHANGE CURRENT AND PREVIOUS VALUES
      021C 06              X                       ;AND POINT TO SCRATCH LOCATION
      021D 00              CLRA
      021E 31              ADD                     ;DO A LEFT SHIFT OF 2 BITS
      021F 31              ADD                     ;THIS FORMS THE 2 HIGH BITS OF THE
      0220 31              ADD                     ;JUMP POINTER
```

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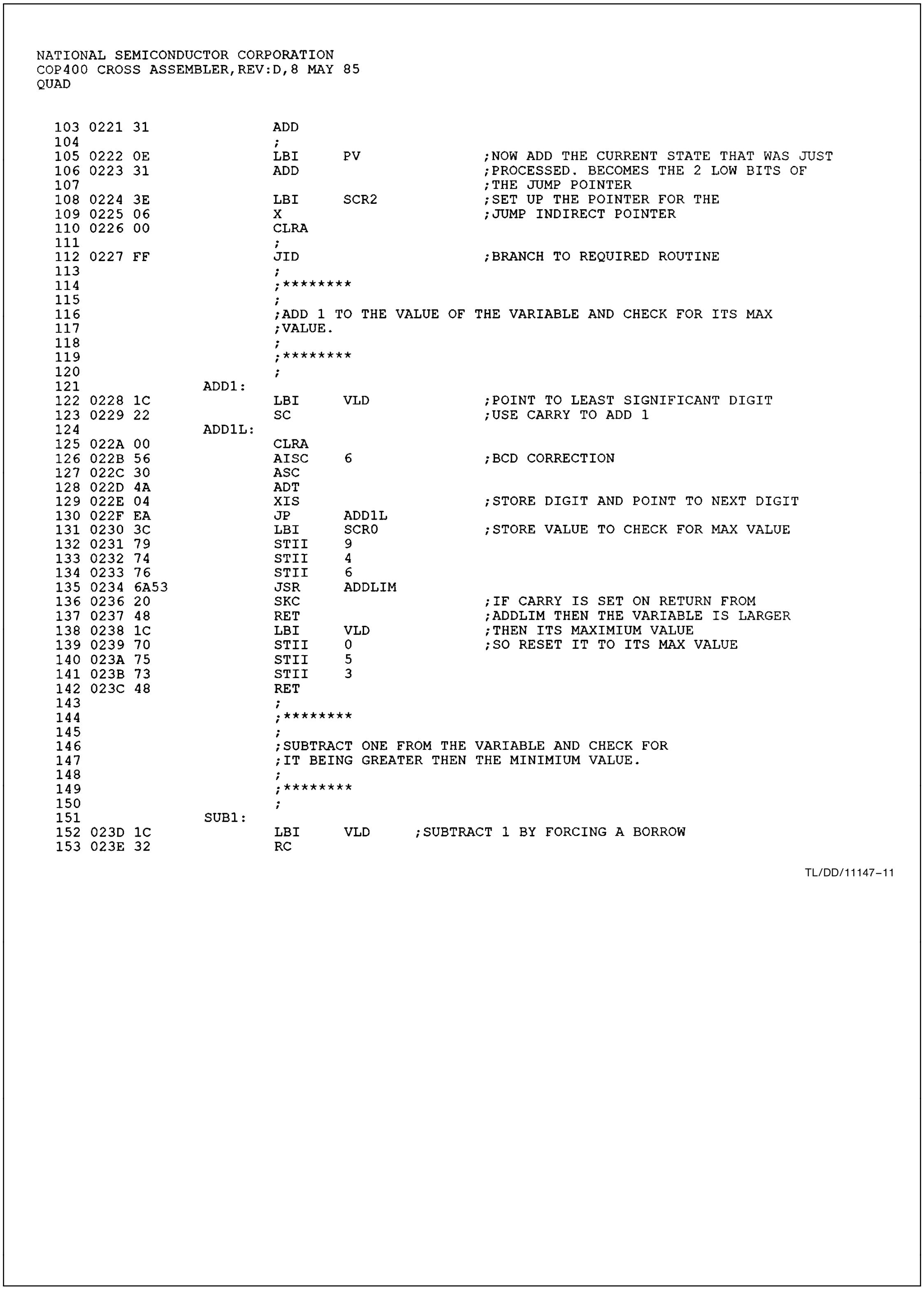

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COP400 CROSS ASSEMBLER,REV:D,8 MAY 85
QUAD

  103 0221 31              ADD
  104                      ;
  105 0222 0E              LBI     PV              ;NOW ADD THE CURRENT STATE THAT WAS JUST
  106 0223 31              ADD                     ;PROCESSED. BECOMES THE 2 LOW BITS OF
  107                                              ;THE JUMP POINTER
  108 0224 3E              LBI     SCR2            ;SET UP THE POINTER FOR THE
  109 0225 06              X                       ;JUMP INDIRECT POINTER
  110 0226 00              CLRA
  111                      ;
  112 0227 FF              JID                     ;BRANCH TO REQUIRED ROUTINE
  113                      ;
  114                      ;********
  115                      ;
  116                      ;ADD 1 TO THE VALUE OF THE VARIABLE AND CHECK FOR ITS MAX
  117                      ;VALUE.
  118                      ;
  119                      ;********
  120                      ;
  121              ADD1:
  122 0228 1C              LBI     VLD             ;POINT TO LEAST SIGNIFICANT DIGIT
  123 0229 22              SC                      ;USE CARRY TO ADD 1
  124              ADD1L:
  125 022A 00              CLRA
  126 022B 56              AISC    6               ;BCD CORRECTION
  127 022C 30              ASC
  128 022D 4A              ADT
  129 022E 04              XIS                     ;STORE DIGIT AND POINT TO NEXT DIGIT
  130 022F EA              JP      ADD1L
  131 0230 3C              LBI     SCR0            ;STORE VALUE TO CHECK FOR MAX VALUE
  132 0231 79              STII    9
  133 0232 74              STII    4
  134 0233 76              STII    6
  135 0234 6A53            JSR     ADDLIM
  136 0236 20              SKC                     ;IF CARRY IS SET ON RETURN FROM
  137 0237 48              RET                     ;ADDLIM THEN THE VARIABLE IS LARGER
  138 0238 1C              LBI     VLD             ;THEN ITS MAXIMIUM VALUE
  139 0239 70              STII    0               ;SO RESET IT TO ITS MAX VALUE
  140 023A 75              STII    5
  141 023B 73              STII    3
  142 023C 48              RET
  143                      ;
  144                      ;********
  145                      ;
  146                      ;SUBTRACT ONE FROM THE VARIABLE AND CHECK FOR
  147                      ;IT BEING GREATER THEN THE MINIMIUM VALUE.
  148                      ;
  149                      ;********
  150                      ;
  151              SUB1:
  152 023D 1C              LBI     VLD     ;SUBTRACT 1 BY FORCING A BORROW
  153 023E 32              RC
```

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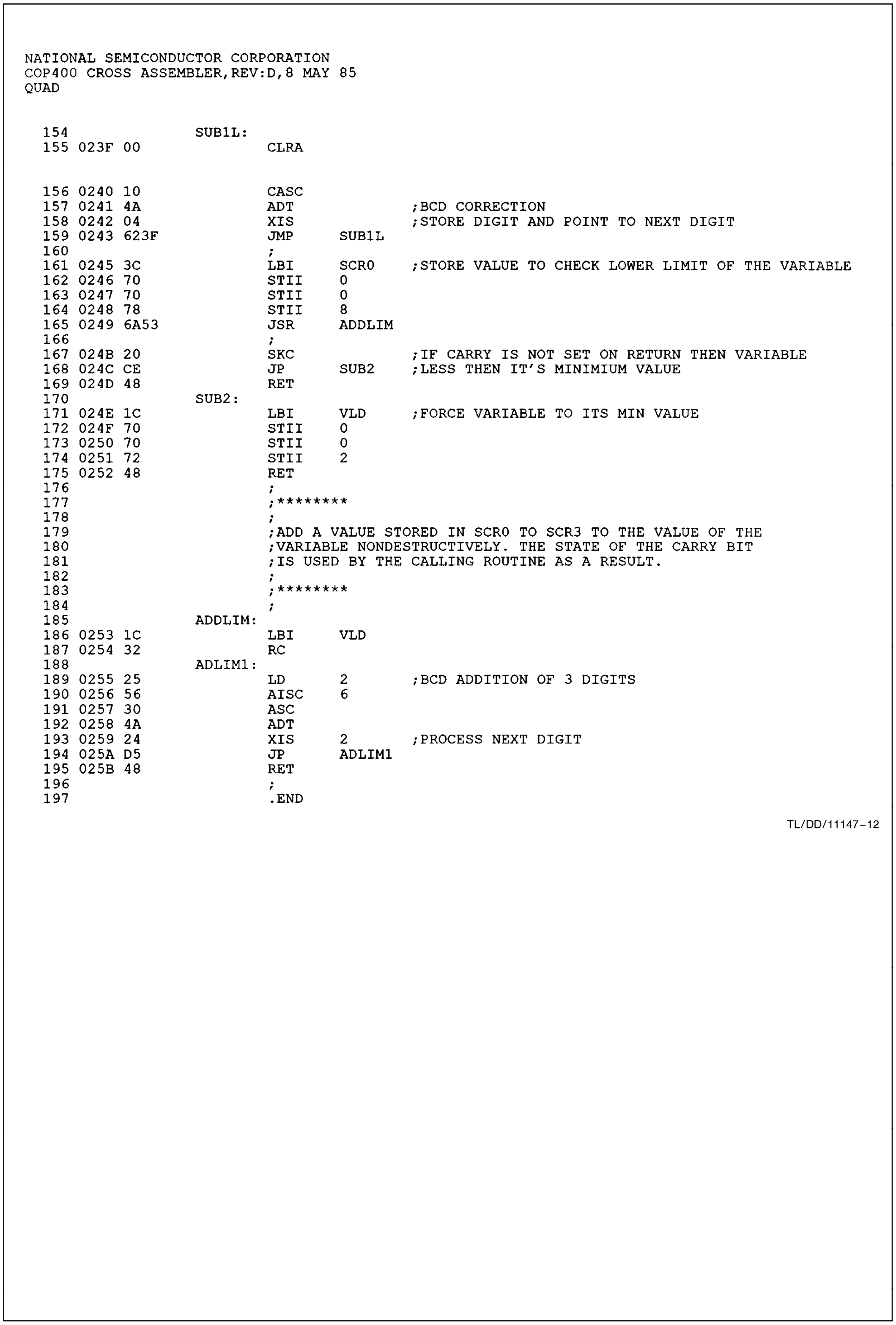

NATIONAL SEMICONDUCTOR CORPORATION
COP400 CROSS ASSEMBLER,REV:D,8 MAY 85
QUAD

```
             SUB1L:
023F 00              CLRA


0240 10              CASC
0241 4A              ADT             ;BCD CORRECTION
0242 04              XIS             ;STORE DIGIT AND POINT TO NEXT DIGIT
0243 623F            JMP     SUB1L
                     ;
0245 3C              LBI     SCR0    ;STORE VALUE TO CHECK LOWER LIMIT OF THE VARIABLE
0246 70              STII    0
0247 70              STII    0
0248 78              STII    8
0249 6A53            JSR     ADDLIM
                     ;
024B 20              SKC             ;IF CARRY IS NOT SET ON RETURN THEN VARIABLE
024C CE              JP      SUB2    ;LESS THEN IT'S MINIMIUM VALUE
024D 48              RET
             SUB2:
024E 1C              LBI     VLD     ;FORCE VARIABLE TO ITS MIN VALUE
024F 70              STII    0
0250 70              STII    0
0251 72              STII    2
0252 48              RET
                     ;
                     ;********
                     ;
                     ;ADD A VALUE STORED IN SCR0 TO SCR3 TO THE VALUE OF THE
                     ;VARIABLE NONDESTRUCTIVELY. THE STATE OF THE CARRY BIT
                     ;IS USED BY THE CALLING ROUTINE AS A RESULT.
                     ;
                     ;********
                     ;
             ADDLIM:
0253 1C              LBI     VLD
0254 32              RC
             ADLIM1:
0255 25              LD      2       ;BCD ADDITION OF 3 DIGITS
0256 56              AISC    6
0257 30              ASC
0258 4A              ADT
0259 24              XIS     2       ;PROCESS NEXT DIGIT
025A D5              JP      ADLIM1
025B 48              RET
                     ;
                     .END
```

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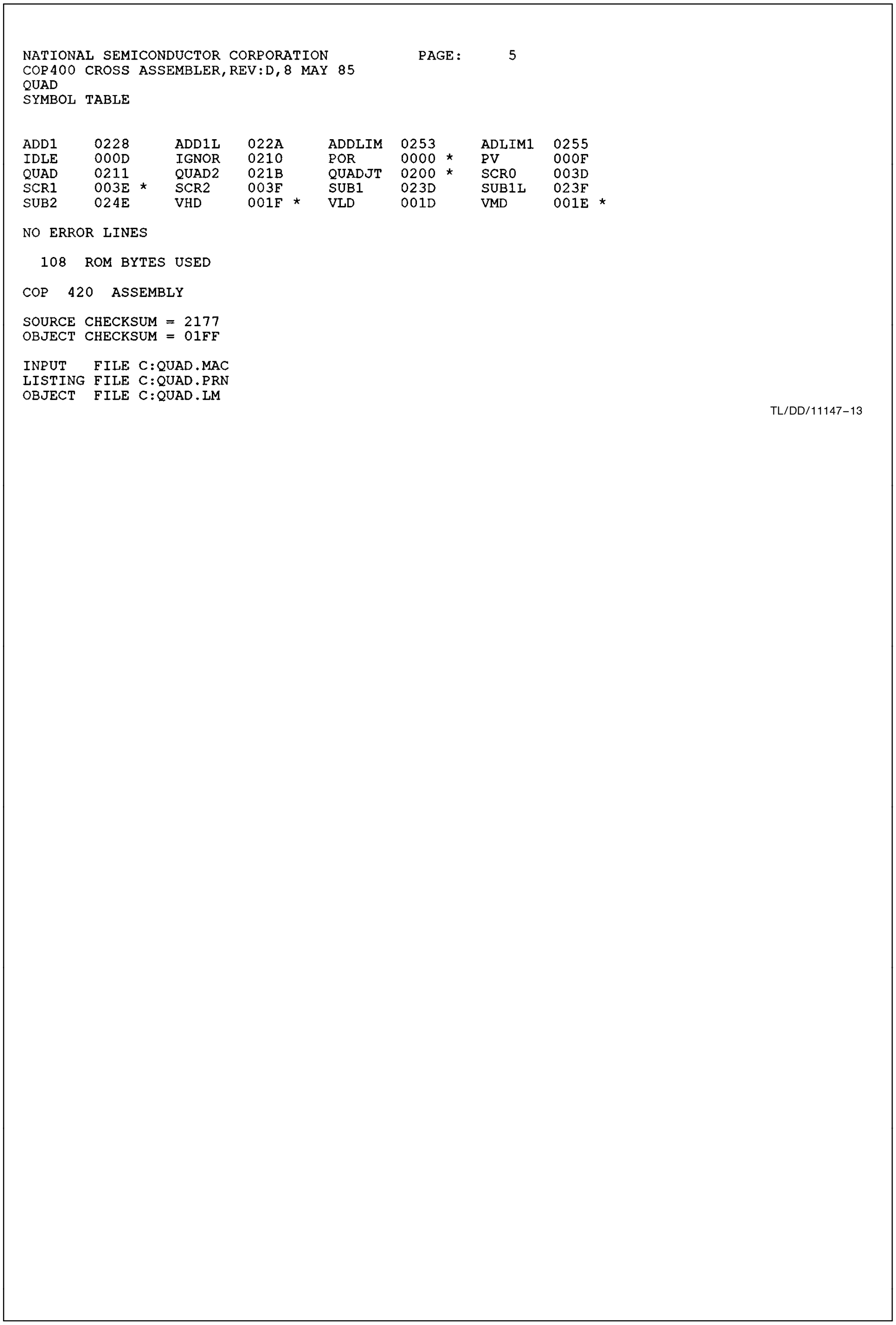

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NATIONAL SEMICONDUCTOR CORPORATION          PAGE:     5
COP400 CROSS ASSEMBLER,REV:D,8 MAY 85
QUAD
SYMBOL TABLE


ADD1    0228     ADD1L   022A     ADDLIM  0253     ADLIM1  0255
IDLE    000D     IGNOR   0210     POR     0000 *   PV      000F
QUAD    0211     QUAD2   021B     QUADJT  0200 *   SCR0    003D
SCR1    003E *   SCR2    003F     SUB1    023D     SUB1L   023F
SUB2    024E     VHD     001F *   VLD     001D     VMD     001E *

NO ERROR LINES

  108  ROM BYTES USED

COP  420  ASSEMBLY

SOURCE CHECKSUM = 2177
OBJECT CHECKSUM = 01FF

INPUT   FILE C:QUAD.MAC
LISTING FILE C:QUAD.PRN
OBJECT  FILE C:QUAD.LM
```

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AN-749 Quadrature Signal Interface to a COP400 Microcontroller

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