AN543

Tone Generation

INTRODUCTION

A general purpose resonator routine is implemented using PIC17C42. This routine is used to generate multiple tones. A tone signal is normally generated using extensive table lookup schemes. When a multiple tone signal is desired, each tone must have its own lookup table, thus requiring a large amount of storage space, especially when various frequencies are to be generated. This application note implements a tone generation using recursive techniques. The algorithm for a resonator is developed and implemented using PIC17C42.

THEORY

Generation of a single tone basically implies generating samples of a sine/cosine wave. The Z-Transform of a sine wave is given as follows :

$$Z\{\sin (wt)\} = \frac{Y(z)}{X(z)} = \frac{z*\sin (wT)}{z^2 - 2*z*\cos(wT) + 1}$$

The impulse response of the above transform (i.e. for X(z) = 1) will generate a sine wave of frequency w sampled at a rate of T (= 1/fs). Thus the above equation is translated to:

$$Y(z) = \frac{z^{-1}*\sin (wT)}{1 - 2*z^{-1}*\cos (wT) + z^{-2}}$$

The above equation can be rewritten in a difference equation form as follows:

$$y(n) - 2y(n-1)\cos(wT) + y(n-2) = x(n-1)\sin(wT)$$

Rearranging the above equation and setting, x(n) as an impulse sequence, the following recursive equations are obtained.

$y(n) = 2*K_1*y(n-1)-y(n-2)$

$y(n-2) = y(n-1)$

$y(n-1) = y(n)$

with the following conditions:

$K_1 = \cos(wT)$

$K_2 = \text{initial } y(n-1) = \sin(wT)$

$K_3 = \text{initial } y(n-2) = 0$

IMPLEMENTATION

The above developed algorithm is implemented as a subroutine using PIC17C42. All computations are performed using double precision arithmetic (16/32-bits). The recursive tone generation algorithm is implemented as a subroutine (labelled as “Resonator”). This subroutine generates samples of a single tone. To generate multiple frequencies, simply call this resonator routine for the desired frequencies and sum the outputs. The three tone co-efficients are stored in program memory and are read into the data memory using TABLRD instructions.

The fully commented code is listed in Appendix A. The timing and memory requirements are included in the comment sections of the code. For a listing of the header file "17C42.h" and the macro definition file "17C42.mac" please refer to Appendices C and D respectively of the application note ANDS00540. This code can be easily modified and used in various applications like DTMF generation, sound generation, etc. The tones generated can easily be output to an on chip PWM channel which in turn can drive a speaker for producing various sounds. If using a PWM channel, it is suggested to set the PWM frequency much higher than the sampling frequency used (in the example code, for 8 KHz sampling frequency, use at least 20 KHz PWM frequency).

As an example, a dual tone is generated and the resulting digital wave form is analyzed. The main program calls the function “Resonator” twice for generating the two desired tones and the two outputs are summed. A sampling frequency of 8 KHz was used to generate a dual tone of 800 Hz and 1.10 KHz. The resulting wave form is shown in Figure 1. The spectrum of the signal shown in Figure 2 shows two peaks corresponding to the two desired tones (800 Hz & 1.10 KHz). The assembly code was tested using PICMASTER™ (Microchip’s Universal In-Circuit Emulator System).

The generated tones were captured into the PICMASTER’s trace buffer and then transferred to Microsoft Excel® using Dynamic Data Exchange (DDE). Once the data is in Excel™ it is analyzed using Excel's FFT utility.

FIGURE 1 - DUAL TONE WAVE FORM CAPTURED BY PICMASTER

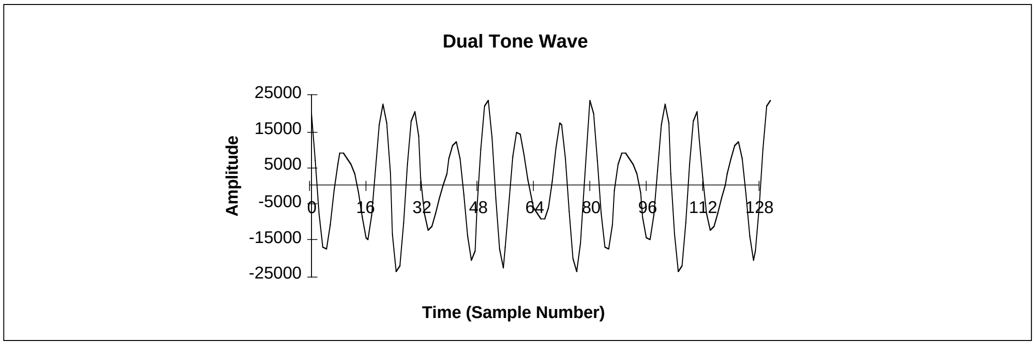
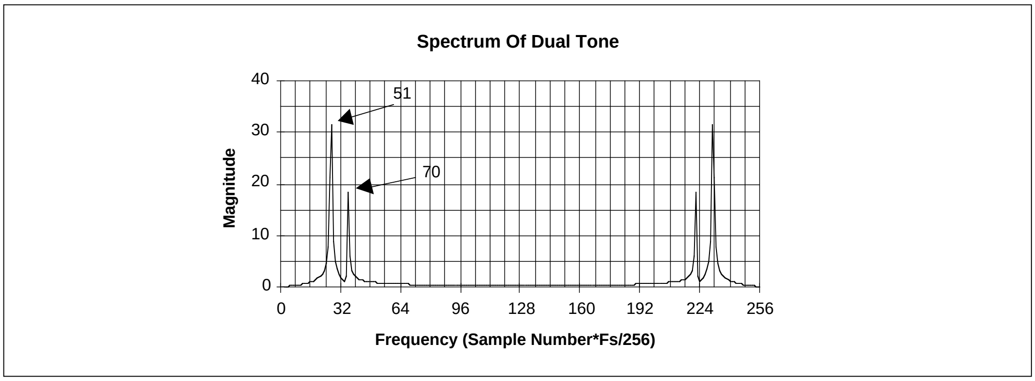


FIGURE 2 - FREQUENCY SPECTRUM OF FIG. 1.1 SHOWING THE DUAL TONE FREQUENCIES



PERFORMANCE

Table 1 below provides the performance of the resonator (labeled in the source code as “Resonator”) in terms of both timing and memory requirements. Since a double precision multiplier is used (software implementation), the multiplier timing is not always constant. Therefore the timings are given for the worst case. Note that irrespective of the frequency and the sampling (resolution) of the tone, program memory requirements is only 54 locations which in case of table lookup could be very large.

TABLE 1

Cycles	235 Cycles
Time @ 16 MHz	58.75 µs
Time @ 25 MHz	47 µs
Data Memory	9 + 9*(# of tones to be generated)
Program memory	54 locations

APPLICATIONS

Tone generation is required in many applications. The code provided in this application note may be used as a general purpose routine to generate desired tones. It can be used in applications involving secure off-site control, where commands/data in the format of tones are transmitted over a telephone line. The tone generation finds applications involving signal modulations as well. The routine can be used to generate audible tones and output to a speaker connected to an I/O Port or a PWM channel.

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APPENDIX A: TONE.LST

```
MPASM B0.54                                                         PAGE  1



                     ;************************************************************************
                     ;                       Dual Tone Generation
                     ;
                     ;       A generic resonator subroutine is implemented to generate
                     ; tones. Samples Of A Sin/Cos Wave are generated using
                     ; recursive techniques. Table Lookups are thus avoided
                     ; This is especially useful in generating multiple tones
                     ; (e.g. DTMF tone generation, tone signalling, etc.), or programmable
                     ; tone generation which may vary for each application unit.
                     ;
                     ;************************************************************************
                     ;
                             LIST    P=17C42, C=80, T=ON, R=DEC, N=0
                             include “17c42.h”



                             include “17c42.mac”


                     ;
                     ;**********************************************************

                     ;       TBLADDR
                     ;
                     ; DESCRIPTION:
                     ;       Load 16 bit table pointer with specified label
                     ;
                     ; TIMING (in cycles):
                     ;       4
                     ;

                     TBLADDR MACRO   label

                             MOVLW   (label)
                             MOVWF   tblptrl
                             MOVLW   page    (label)
                             MOVWF   tblptrh

                             ENDM

                     ;**********************************************************

                     ;       ADDLBL
                     ;
                     ; DESCRIPTION:
                     ;       Add A Label (16 bit constant) To A File Register (1

                     ;
                     ; TIMING (in cycles):
                     ;       4
                     ;

                     ADDLBL  MACRO   label,f

                             MOVLW   (label)
                             ADDWF   f+B0
                             MOVLW   page    (label)
                             ADDWFC  f+B1

                             ENDM
```

4

```
                     ;**********************************************************


                     ;
                              CBLOCK  0
0000 0004                     B0,B1,B2,B3       ; RAM offset constants
                              ENDC
                     ;
                              CBLOCK  0x18
0018 0002                     AARG,AARG1        ; 16 bit multiplier A
001A 0002                     BARG,BARG1        ; 16 bit multiplicand B
001C 0004                     DPX,DPX1,DPX2,DPX3; 32 bit multiplier result = A*B

                              ENDC
                                                ;
                              CBLOCK            ; Generic Resonator

0020 0002                     K1,K11            ; K1
0022 0003                     SinCos_2C,SinCos_2,SinCos1_2
                                                ; y(n-2), Init Value = K3

0025 0002                     SinCos_1,SinCos1_1; y(n-1), Init Value = K2

0027 0002                     SinCos,SinCos1    ; y(n)
0029 0000
                              ENDC

                              CBLOCK
0029 0002                     tone1K1,tone1K11  ; Tone 1 variables
002B 0003                     tone1_2C,tone1_2,tone11_2
002E 0002                     tone1_1,tone11_1
0030 0002                     tone1,tone11
0032 0000
0032 0002                     tone2K1,tone2K11  ; Tone 2 variables
0034 0003                     tone2_2C,tone2_2,tone21_2
0037 0002                     tone2_1,tone21_1
0039 0002                     tone2,tone21
003B 0000
003B 0002                     dualTone,dualTone1; tone1+tone2
       ENDC


                     ;**********************************************************


005A                         #define ADD_OFFSET  FALSE

005B                         #define coeff_addr  0x0030 ; prog mem addr of

005C                         #define DummyAddr   0x0A00

                     ;**********************************************************

                     ;              Test Routine For Sin Wave Generation
                     ;
                     ;       (a) Call Initialization Subroutine to read desired s

                     ;              freq from prog mem to data mem.
                     ;       (b) Call the resonator subroutine to generate sampl

                     ;              sine wave.
                     ;       (c) Perform a Dummy Table Write of The Sine Wave Da

                     ;              PICMASTER emulator can capture the data in

                     ;
                     ;**********************************************************
```

```
                                   ORG     0x0000
0000 C040                          goto    start

                          ;*********************************************************

                                            ;Resonator Co-efficients For Desired Tones

                                   ORG     coeff_addr

                                            ; Tone 1 Resonator Constants
                                            ;Sample Rate = fs = 8 kHz, Tone Freq = f = 0.800 Khz

0030 678E                          DATA    26510   ; K1 = COS(wT) = COS(360*f/

0031 259E                          DATA    9630    ; K2 = SIN(wT) = SIN(360*f/

0032 0000                          DATA    0       ; K3 is init value of y(n-2


                                            ; Tone 2 Resonator Constants
                                            ; Sample Rate = fs = 8 khz, Tone Freq = f = 1.10 Khz

0033 5321                          DATA    21281   ; K1 = COS(wT) = COS(360*f/

0034 1855                          DATA    6229    ; K2 = SIN(wT) = SIN(360*f/

0035 0000                          DATA    0       ; K3 is init value of y(n-2


                          ;*********************************************************


                                   ORG     0x0040
                          start
0040 E057                          call    Coeff_Read
                                                              ; load table pointers with a dummy  addr

                                   MOVK16  DummyAddr,tblptrl

0041 B000                          MOVLW   (0x0A00) & 0xff
0042 010D                          MOVWF   tblptrl+B0
0043 B00A                          MOVLW   ((0x0A00) >> 8)
0044 010E                          MOVWF   tblptrl+B1


                          NextSample
0045 0000                          nop
0046 A43B                          tlwt    0,dualTone
                          capture
0047 AE3C                          tablwt  1,0,dualTone+B1    ; for PICMASTER tr

0048 0000                          nop

0049 B029                          movlw   tone1K1            ; load indirect add

004A 0101                          movwf   fsr0               ; for Tone 1
004B E06C                          call    Resonator          ; Compute next samp


004C B032                          movlw   tone2K1            ; load indirect add

004D 0101                          movwf   fsr0               ; for Tone 2
004E E06C                          call    Resonator          ; compute next samp


                                                               ; Compute Tone1 + Tone2 for dual tone

                                   ADD16ACC        tone1,tone2,dualTone
```

```
                                                              ; dualTone = tone1
004F 6030                     movfp   tone1+B0,wreg
0050 0E39                     addwf   tone2+B0,w
0051 013B                     movwf   dualTone+B0
0052 6031                     movfp   tone1+B1,wreg
0053 103A                     addwfc  tone2+B1,w
0054 013C                     movwf   dualTone+B1
0055 C045                     goto    NextSample

0056 C056             self    goto    self

                      ;***********************************************************

                      ; Initialization routine :
                      ; Read Tone 1 & Tone 2 Resonator Frequencies from Program M

                      ; Data Memory
                      ;
                      ;       Program Memory  :       3 + 8*(#of tones to be gene

                      ;       Timing          :       4 + 11*(#of tones to be gen

                      ;***********************************************************
                      Coeff_Read

                              TBLADDR coeff_addr
0057 B030                     MOVLW   (0x0030)
0058 010D                     MOVWF   tblptrl
0059 B000                     MOVLW   page    (0x0030)
005A 010E                     MOVWF   tblptrh
005B A929                     tablrd  0,1,tone1K1
005C A029                     tlrd    0,tone1K1
005D AB2A                     tablrd  1,1,tone1K1+B1  ; read K1
005E A02E                     tlrd    0,tone1_1
005F AB2F                     tablrd  1,1,tone1_1+B1  ; read K2
0060 A02C                     tlrd    0,tone1_2
0061 A22D                     tlrd    1,tone1_2+B1    ; read K3
0062 292B                     clrf    tone1_2C
0063 A932                     tablrd  0,1,tone2K1
0064 A032                     tlrd    0,tone2K1
0065 AB33                     tablrd  1,1,tone2K1+B1  ; read K1
0066 A037                     tlrd    0,tone2_1
0067 AB38                     tablrd  1,1,tone2_1+B1  ; read K2
0068 A035                     tlrd    0,tone2_2
0069 A236                     tlrd    1,tone2_2+B1    ; read K3
006A 2934                     clrf    tone2_2C
006B 0002                     return

                      ;***********************************************************
                      ;                       Resonator Subroutine
                      ;
                      ; Before calling this routine, load the indirect register,
                      ; with the starting RAM address of the desired Tone Variabl
                      ; ( eg. For Tone1 Generation, load FSR0 with “Tone1K1” addr
                      ;
                      ;
                      ;
                      ; Timing (worst case) :
                      ;               20 + 36 + (worst case multiplier time)
                      ;               = 56 + 179 = 235 cycles
                      ;               = 58.75 uS @ 16Mhz
                      ;               = 47.00 uS @ 20Mhz
                      ;               = 37.60 uS @ 25 Mhz
                      ;
                      ; Memory Requirements :
                      ;               Program Memory  : 54 locations
                      ;               Data Memory     : 9 + 9*(#of tones to be ge
                      ;
                      ;***********************************************************
```

```
                     ;
                     Resonator
                     ;
                     ; Transfer tone varialbles to resonator’s variables using i
                     ; This is necessary for making the “Resonator” a generic
                     ; subroutine, so that the same code can be called for vario
                     ; tones.
                     ;  Indirect addressing mode can be used throught the code i
                     ; subroutine, but is less efficient.
                     ;
006C 8D04                    bcf     _fs1
006D 8404                    bsf     _fs0               ; auto increment FSR0
006E 4020                    movpf   indf0,K1+B0
006F 4021                    movpf   indf0,K1+B1
0070 4022                    movpf   indf0,SinCos_2C
0071 4023                    movpf   indf0,SinCos_2+B0
0072 4024                    movpf   indf0,SinCos_2+B1
0073 4025                    movpf   indf0,SinCos_1+B0
0074 4026                    movpf   indf0,SinCos_1+B1
0075 4027                    movpf   indf0,SinCos+B0
0076 4028                    movpf   indf0,SinCos+B1
                                           ;
                     ; Compute 2*K1*y(n-1)
                     ;
                             MOVFP16 K1,BARG
0077 7A20                    MOVFP   K1+B0,BARG+B0      ; move K1(B0) t
0078 7B21                    MOVFP   K1+B1,BARG+B1      ; move K1(B1) t
                             MOVFP16 SinCos_1,AARG
0079 7825                    MOVFP   SinCos_1+B0,AARG+B0; move Si
007A 7926                    MOVFP   SinCos_1+B1,AARG+B1; move Si
007B E0A2                    call    DblMult
007C 8804                    BCF     _carry
007D 1B1C                    RLCF    DPX+B0
007E 1B1D                    RLCF    DPX+B1
007F 1B1E                    RLCF    DPX+B2
0080 1B1F                    RLCF    DPX+B3             ;
                     ; subtract y(n-2)*(2**15)          ;
0081 2922                    clrf    SinCos_2C
                             RRC24   SinCos_2C
0082 1A24                    RLCF    SinCos_2C+B2,W     ; move sign
0083 1924                    RRCF    SinCos_2C+B2
0084 1923                    RRCF    SinCos_2C+B1
0085 1922                    RRCF    SinCos_2C+B0
                             SUB24   SinCos_2C,DPX1     ; DPX = 2*K1*y(n-1) - y(n-
0086 6022                    MOVFP   SinCos_2C+B0,wreg  ; get lowes
0087 051D                    SUBWF   DPX1+B0            ; sub lowest byt
0088 6023                    MOVFP   SinCos_2C+B1,wreg  ; get 2nd b
0089 031E                    SUBWFB  DPX1+B1            ; sub 2nd byte o
008A 6024                    MOVFP   SinCos_2C+B2,wreg  ; get 3rd b
008B 031F                    SUBWFB  DPX1+B2            ; sub 3rd byte o
                             RLC24   DPX1               ; adjust decimal point
008C 8804                    BCF     _carry
008D 1B1D                    RLCF    DPX1+B0
008E 1B1E                    RLCF    DPX1+B1
008F 1B1F                    RLCF    DPX1+B2
                     ;
                     ; update past samples with newly computed values
                     ;
                             MOVPF16 DPX2,SinCos        ; y(n) = 2*K1*y(n-1) - y(n
0090 5E27                    MOVPF   DPX2+B0,SinCos+B0  ; move DPX2
0091 5F28                    MOVPF   DPX2+B1,SinCos+B1  ; move DPX2
                             MOV16   SinCos_1,SinCos_2  ; y(n-2) = y(n-1)
0092 6025                    MOVFP   SinCos_1+B0,wreg   ; get byte o
0093 0123                    MOVWF   SinCos_2+B0        ; move to Si
0094 6026                    MOVFP   SinCos_1+B1,wreg   ; get byte o
0095 0124                    MOVWF   SinCos_2+B1        ; move to Si
                             MOVPF16 DPX2,SinCos_1      ; y(n-1) = y(n)
0096 5E25                    MOVPF   DPX2+B0,SinCos_1+B0; move DP
0097 5F26                    MOVPF   DPX2+B1,SinCos_1+B1; move DP
```

```
                    ;
                    ; Generation Of The Next Sample Of The Resonator (sine wave
                    ; The 16 bit result is stored in location "SinCos" (low Byt
                    ; "SinCos+1" (High Byte)
                    ;
                    ; write back all the computed values to respective tone var
                    ;
0098 0701                   decf    fsr0
0099 8D04                   bcf     _fs1
009A 8C04                   bcf     _fs0
009B 6028                   movfp   SinCos+B1,indf0
009C 6027                   movfp   SinCos+B0,indf0
009D 6026                   movfp   SinCos_1+B1,indf0
009E 6025                   movfp   SinCos_1+B0,indf0
009F 6024                   movfp   SinCos_2C+B2,indf0
00A0 6023                   movfp   SinCos_2C+B1,indf0                      ;
00A1 0002                   return
                    ;
                    ;*********************************************************

                    ;       Include Double Precision Multiplication Routine
                    ;*********************************************************
0001                SIGNED  equ     TRUE
                            include "17c42mpy.mac"
                    ;       NOLIST
                    ;*********************************************************
                    ;
                    ;*********************************************************
                    ;              Double Precision Multiplier For PIC17C42
                    ;
                    ;       Dmult
                    ;
                    ; DESCRIPTION:
                    ;
                    ;   Multiplication : AARG (16 bits) * BARG (16 bits) -> DPX
                    ;
                    ;      (a) Load the 1st operand in locations AARG+B0 & AARG
                    ;      (b) Load the 2nd operand in locations BARG+B0 & BARG
                    ;      (c) CALL Dmult
                    ;      (d) The 32 bit result is in locations ( DPX+B0,DPX+B
                    ;
                    ;       In the signed case, a savings of 9 clks can be real
                    ;       BARG as the positive factor in the product when pos
                    ;
                    ; TIMING (worst case):
                    ;                       unsigned:                       17
                    ;
                    ;                       signed:                  BARG+  17
                    ;                                                BARG-  17
                    ;
                    ;   NOTE :   Define SIGNED/UNSIGNED To 1/0 before including
                    ;               this file in your program
                    ;
                    ;*********************************************************
                    ;               Multiplication Macro
                    ;*********************************************************
                    ;
                    ; TIMING:       unsigned:     11+7*10+8*11   = 169 clks
                    ;(worst case)   signed:       11+7*10+7*11+5 = 163 clks
                    ;
                    MULTMAC  MACRO
                             variable i
                             i = 0
                             if   SIGNED
                             while i < 15
                             else
                             while i < 16
                             endif
                             if i < 8              ; test low byte
```

```
          btfsc      BARG+B0,i
            else                  ; test high byte
          btfsc      BARG+B1,i-8
       fi
          goto    add#v(i)
       if i < 8

          rlcf    DPX+B3,W        ; rotate sign into carry bit
          rrcf    DPX+B3          ; for i < 8, no meaningful bits
          rrcf    DPX+B2          ; are in DPX+B0
          rrcf    DPX+B1
       else
          rlcf    DPX+B3,W        ; rotate sign into carry bit
          rrcf    DPX+B3
          rrcf    DPX+B2
          rrcf    DPX+B1
          rrcf    DPX+B0
       fi
          i = i+1
       endw
          clrf    DPX+B0          ; if we get here, BARG = 0
          return
                add0
          movfp   AARG+B0,WREG
          addwf   DPX+B2          ;add lsb
          movfp   AARG+B1,WREG
          addwfc  DPX+B3          ;add msb
          rlcf    AARG+B1,W       ; rotate sign into carry bit
          rrcf    DPX+B3          ; for i < 8, no meaningful bits
          rrcf    DPX+B2          ; are in DPX+B0
          rrcf    DPX+B1
    i = 1
    if   SIGNED
            while i < 15
    else
       while i < 16
    endif
       if i < 8
          btfss      BARG+B0,i   ;test low byte
       else
          btfss      BARG+B1,i-8  ; test high byte
       fi
          goto    noadd#v(i)
                add#v(i)
          movfp   AARG+B0,WREG
          addwf   DPX+B2          ;add lsb
          movfp   AARG+B1,WREG
          addwfc  DPX+B3          ;add msb
                noadd#v(i)
       if i < 8
          rlcf    AARG+B1,W       ; rotate sign into carry bit
          rrcf    DPX+B3          ; for i < 8, no meaningful bits
          rrcf    DPX+B2          ; are in DPX+B0
          rrcf    DPX+B1
       else
          rlcf    AARG+B1,W       ; rotate sign into carry bit
          rrcf    DPX+B3
          rrcf    DPX+B2
          rrcf    DPX+B1
          rrcf    DPX+B0
            fi
          i = i+1
            endw
    if   SIGNED
          rlcf    AARG+B1,W       ; since BARG is always made posit
          rrcf    DPX+B3          ; the last bit is known to be zer
          rrcf    DPX+B2
          rrcf    DPX+B1
          rrcf    DPX+B0
```

4

```
                          endif

                             ENDM

                     ;               Double Precision Multiply ( 16x16 -> 32 )
                     ;         ( AARG*BARG -> : 32 bit output in DPX
                     ;
                             DblMult
                          if   SIGNED

00A2 971B                    btfss   BARG+B1,MSB        ; test sign of BARG

00A3 C0AE                    goto    argsok             ; if positive, ok
                     NEG16   AARG+B0                    ; if negative, then negate


00A4 1318                    COMF    AARG+B0+B0
00A5 1319                    COMF    AARG+B0+B1
00A6 2900                    CLRF    wreg
00A7 1518                    INCF    AARG+B0+B0
00A8 1119                    ADDWFC  AARG+B0+B1


                     NEG16   BARG+B0                    ; AARG and BARG

00A9 131A                    COMF    BARG+B0+B0
00AA 131B                    COMF    BARG+B0+B1
00AB 2900                    CLRF    wreg
00AC 151A                    INCF    BARG+B0+B0
00AD 111B                    ADDWFC  BARG+B0+B1



                          endif

                     argsok
                             CLR16   DPX+B2             ; clear initial partial pr


00AE 291E                    CLRF    DPX+B2+B0
00AF 291F                    CLRF    DPX+B2+B1

                             MULTMAC                    ; use macro for multiplica

0000                         variable i

0000                         i = 0

                             if   SIGNED

                             while i < 15

                          else

                             while i < 16

                          endif
                             if i < 8                   ; test low byte

                             btfsc      BARG+B0,i

                          else                          ; test high byte
                             btfsc      BARG+B1,i-8
                         fi
                             goto    add#v(i)
                             if i < 8
                             rlcf    DPX+B3,W           ; rotate sign into carry bit
                             rrcf    DPX+B3             ; for i < 8, no meaningful bits
```

```
                                   rrcf    DPX+B2     ; are in DPX+B0
                                   rrcf    DPX+B1
                                else
                                   rlcf    DPX+B3,W   ; rotate sign into carry bit
                                   rrcf    DPX+B3
                                   rrcf    DPX+B2
                                   rrcf    DPX+B1
                                   rrcf    DPX+B0
                                fi
                                   i = i+1
                                    endw
                                if i < 8              ; test low byte
00B0 981A                          btfsc   BARG+B0,i
                                   else               ; test high byte
                                   btfsc   BARG+B1,i-8
                                fi
00B1 C113                          goto    add0
                                if i < 8
00B2 1A1F                          rlcf    DPX+B3,W   ; rotate sign into
00B3 191F                          rrcf    DPX+B3     ; for i < 8, no mea
00B4 191E                          rrcf    DPX+B2     ; are in DPX+B0
00B5 191D                          rrcf    DPX+B1
                                else
                                   rlcf    DPX+B3,W   ; rotate sign into carry bit
                                   rrcf    DPX+B3
                                   rrcf    DPX+B2
                                   rrcf    DPX+B1
                                   rrcf    DPX+B0
                                fi
0001                               i = i+1
                                if i < 8              ; test low byte
00B6 991A                          btfsc   BARG+B0,i
                                else                  ; test high byte
                                   btfsc   BARG+B1,i-8
                                fi
00B7 C11D                          goto    add1
                                if i < 8
00B8 1A1F                          rlcf    DPX+B3,W   ; rotate sign into
00B9 191F                          rrcf    DPX+B3     ; for i < 8, no mea
00BA 191E                          rrcf    DPX+B2     ; are in DPX+B0
00BB 191D                          rrcf    DPX+B1
                                else
                                   rlcf    DPX+B3,W   ; rotate sign into carry bit
                                   rrcf    DPX+B3
                                   rrcf    DPX+B2
                                   rrcf    DPX+B1
                                   rrcf    DPX+B0
                                fi
0002                               i = i+1
                                if i < 8              ; test low byte
00BC 9A1A                          btfsc      BARG+B0,i
                                else                  ; test high byte
                                   btfsc      BARG+B1,i-8
                                fi
00BD C127                          goto    add2
                                if i < 8
00BE 1A1F                          rlcf    DPX+B3,W   ; rotate sign into
00BF 191F                          rrcf    DPX+B3     ; for i < 8, no mea
00C0 191E                          rrcf    DPX+B2     ; are in DPX+B0
00C1 191D                          rrcf    DPX+B1
                                else
                                   rlcf    DPX+B3,W   ; rotate sign into carry bit
                                   rrcf    DPX+B3
                                   rrcf    DPX+B2
                                   rrcf    DPX+B1
                                   rrcf    DPX+B0
                                fi
0003                               i = i+1
                                if i < 8              ; test low byte
```

```
00C2 9B1A                            btfsc      BARG+B0,i
                                     else               ; test high byte
                                     btfsc      BARG+B1,i-8
                                  fi
00C3 C131                            goto    add3
                                  if i < 8
00C4 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00C5 191F                            rrcf    DPX+B3     ; for i < 8, no mea
00C6 191E                            rrcf    DPX+B2     ; are in DPX+B0
00C7 191D                            rrcf    DPX+B1
                                     else
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                  fi
0004                                 i = i+1
                                  if i < 8              ; test low byte
00C8 9C1A                            btfsc      BARG+B0,i
                                     else               ; test high byte
                                     btfsc      BARG+B1,i-8
                                  fi
00C9 C13B                            goto    add4
                                  if i < 8
00CA 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00CB 191F                            rrcf    DPX+B3     ; for i < 8, no mea
00CC 191E                            rrcf    DPX+B2     ; are in DPX+B0
00CD 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                  fi
0005                                 i = i+1
                                  if i < 8              ; test low byte
00CE 9D1A                            btfsc      BARG+B0,i
                                       else             ; test high byte
                                     btfsc      BARG+B1,i-8
                                  fi
00CF C145                            goto    add5
                                  if i < 8
00D0 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00D1 191F                            rrcf    DPX+B3     ; for i < 8, no mea
00D2 191E                            rrcf    DPX+B2     ; are in DPX+B0
00D3 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                 fi
006                                 i = i+1
                                if i < 8                ; test low byte
00D4 9E1A                            btfsc   BARG+B0,i
                                      else               ; test high byte
                                     btfsc   BARG+B1,i-8
                                 fi
0D5 C14F                             goto    add6
                                  if i < 8
00D6 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00D7 191F                            rrcf    DPX+B3     ; for i < 8, no mea
00D8 191E                            rrcf    DPX+B2     ; are in DPX+B0
00D9 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
```

```
                                      rrcf    DPX+B3
                                      rrcf    DPX+B2
                                      rrcf    DPX+B1
                                      rrcf    DPX+B0
                                   fi
0007                                  i = i+1
                                   if i < 8              ; test low byte
00DA 9F1A                             btfsc   BARG+B0,i
                                        else             ; test high byte
                                      btfsc   BARG+B1,i-8
                                   fi
00DB C159                             goto    add7
                                   if i < 8
00DC 1A1F                             rlcf    DPX+B3,W   ; rotate sign into
00DD 191F                             rrcf    DPX+B3     ; for i < 8, no mea
00DE 191E                             rrcf    DPX+B2     ; are in DPX+B0
00DF 191D                             rrcf    DPX+B1
                                   else
                                      rlcf    DPX+B3,W   ; rotate sign into carry bit
                                      rrcf    DPX+B3
                                      rrcf    DPX+B2
                                      rrcf    DPX+B1
                                      rrcf    DPX+B0
                                   fi
0008                                  i = i+1
                                   if i < 8              ; test low byte
                                      btfsc   BARG+B0,i
                                        else             ; test high byte
00E0 981B                             btfsc   BARG+B1,i-8
                                   fi
00E1 C163                             goto    add8
                                   if i < 8
                                      rlcf    DPX+B3,W   ; rotate sign into carry bit
                                      rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                      rrcf    DPX+B2     ; are in DPX+B0
                                      rrcf    DPX+B1
                                   else
00E2 1A1F                             rlcf    DPX+B3,W   ; rotate sign into
00E3 191F                             rrcf    DPX+B3
00E4 191E                             rrcf    DPX+B2
00E5 191D                             rrcf    DPX+B1
00E6 191C                             rrcf    DPX+B0
                                   fi
0009                                  i = i+1
                                   if i < 8              ; test low byte
                                      btfsc   BARG+B0,i
                                        else             ; test high byte
00E7 991B                             btfsc   BARG+B1,i-8
                                   fi
00E8 C16E                             goto    add9
                                   if i < 8
                                      rlcf    DPX+B3,W   ; rotate sign into carry bit
                                      rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                      rrcf    DPX+B2     ; are in DPX+B0
                                      rrcf    DPX+B1
                                   else
00E9 1A1F                             rlcf    DPX+B3,W   ; rotate sign into
00EA 191F                             rrcf    DPX+B3
00EB 191E                             rrcf    DPX+B2
00EC 191D                             rrcf    DPX+B1
00ED 191C                             rrcf    DPX+B0
                                   fi
000A                                  i = i+1
                                   if i < 8              ; test low byte
                                      btfsc   BARG+B0,i
                                        else             ; test high byte
00EE 9A1B                             btfsc   BARG+B1,i-8
                                   fi
00EF C179                             goto    add10
```

```
                                  if i < 8
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
00F0 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00F1 191F                            rrcf    DPX+B3
00F2 191E                            rrcf    DPX+B2
00F3 191D                            rrcf    DPX+B1
00F4 191C                            rrcf    DPX+B0
                                  fi
000B                                 i = i+1
                                  if i < 8              ; test low byte
                                     btfsc      BARG+B0,i
                                       else             ; test high byte
00F5 9B1B                            btfsc      BARG+B1,i-8
                                  fi
00F6 C184                            goto    add11
                                  if i < 8
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
00F7 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00F8 191F                            rrcf    DPX+B3
00F9 191E                            rrcf    DPX+B2
00FA 191D                            rrcf    DPX+B1
00FB 191C                            rrcf    DPX+B0
                                  fi
000C                                 i = i+1
                                  if i < 8              ; test low byte
                                     btfsc      BARG+B0,i
                                       else             ; test high byte
00FC 9C1B                            btfsc      BARG+B1,i-8
                                  fi
00FD C18F                            goto    add12

                                  if i < 8
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
00FE 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
00FF 191F                            rrcf    DPX+B3
0100 191E                            rrcf    DPX+B2
0101 191D                            rrcf    DPX+B1
0102 191C                            rrcf    DPX+B0
                                  fi
000D                                 i = i+1
                                  if i < 8              ; test low byte
                                     btfsc      BARG+B0,i
                                       else             ; test high byte
0103 9D1B                            btfsc      BARG+B1,i-8
                                  fi
0104 C19A                            goto    add13
                                  if i < 8
                                     rlcf    DPX+B3,W   ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
0105 1A1F                            rlcf    DPX+B3,W   ; rotate sign into
0106 191F                            rrcf    DPX+B3
0107 191E                            rrcf    DPX+B2
0108 191D                            rrcf    DPX+B1
0109 191C                            rrcf    DPX+B0
```

```
                                  fi
000E                                 i = i+1
                                  if i < 8                   ; test low byte
                                     btfsc   BARG+B0,i
                                     else                  ; test high byte
010A 9E1B                            btfsc   BARG+B1,i-8
                                  fi
010B C1A5                            goto    add14
                                  if i < 8
                                     rlcf    DPX+B3,W        ; rotate sign into carry bit
                                     rrcf    DPX+B3          ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2          ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
010C 1A1F                            rlcf    DPX+B3,W        ; rotate sign into
010D 191F                            rrcf    DPX+B3
010E 191E                            rrcf    DPX+B2
010F 191D                            rrcf    DPX+B1
0110 191C                            rrcf    DPX+B0
                                  fi
000F                                 i = i+1
0111 291C                            clrf    DPX+B0          ; if we get here, B
0112 0002                            return
                                  add0
0113 6018                            movfp   AARG+B0,WREG
0114 0F1E                            addwf   DPX+B2          ;add lsb
0115 6019                            movfp   AARG+B1,WREG
0116 111F                            addwfc  DPX+B3          ;add msb
0117 1A19                            rlcf    AARG+B1,W       ; rotate sign into
0118 191F                            rrcf    DPX+B3          ; for i < 8, no mea
0119 191E                            rrcf    DPX+B2          ; are in DPX+B0
011A 191D                            rrcf    DPX+B1
0001                             i = 1
                                 if   SIGNED
                                       while i < 15
                                else
                                     while i < 16
                                 endif
                                 if i < 8
                                      btfss      BARG+B0,i   ;test low byte
                                 else
                                      btfss      BARG+B1,i-8  ; test high byte
                                 fi
                                      goto    noadd#v(i)
                                 add#v(i)
                                     movfp   AARG+B0,WREG
                                     addwf   DPX+B2          ;add lsb
                                     movfp   AARG+B1,WREG
                                     addwfc  DPX+B3          ;add msb
                                     noadd#v(i)
                                  if i < 8
                                     rlcf    AARG+B1,W       ; rotate sign into carry bit
                                     rrcf    DPX+B3          ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2          ; are in DPX+B0
                                     rrcf    DPX+B1
                                else
                                     rlcf    AARG+B1,W       ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                fi
                                i = i+1
                                endw
                                if i < 8                      ;test low byte
011B 911A                            btfss      BARG+B0,i
                                else
                                                              ; test high byte
                                     btfss      BARG+B1,i-8
                                  fi
011C C121                            goto    noadd1
                     add1
011D 6018                            movfp   AARG+B0,WREG
011E 0F1E                            addwf   DPX+B2     ;add lsb
011F 6019                            movfp   AARG+B1,WREG
0120 111F                            addwfc  DPX+B3     ;add msb
                     noadd1
                                  if i < 8
0121 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0122 191F                            rrcf    DPX+B3     ; for i < 8, no mea
0123 191E                            rrcf    DPX+B2     ; are in DPX+B0
0124 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                       fi
0002                                 i = i+1
                                  if i < 8           ;test low byte
0125 921A                            btfss      BARG+B0,i
                                  else                   ; test high byte
                                     btfss      BARG+B1,i-8
                                  fi
0126 C12B                            goto    noadd2
                     add2
0127 6018                            movfp   AARG+B0,WREG
0128 0F1E                            addwf   DPX+B2     ;add lsb
0129 6019                            movfp   AARG+B1,WREG
012A 111F                            addwfc  DPX+B3     ;add msb
                     noadd2
                                  if i < 8
012B 1A19                            rlcf    AARG+B1,W  ; rotate sign into
012C 191F                            rrcf    DPX+B3     ; for i < 8, no mea
012D 191E                            rrcf    DPX+B2     ; are in DPX+B0
012E 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                       fi
0003                                 i = i+1
                                  if i < 8               ;test low byte
012F 931A                            btfss      BARG+B0,i
                                  else
                                                         ; test high byte
                                     btfss      BARG+B1,i-8
                                  fi
0130 C135                            goto    noadd3
                     add3
0131 6018                            movfp   AARG+B0,WREG
0132 0F1E                            addwf   DPX+B2     ;add lsb
0133 6019                            movfp   AARG+B1,WREG
0134 111F                            addwfc  DPX+B3     ;add msb
                     noadd3
                                  if i < 8
0135 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0136 191F                            rrcf    DPX+B3     ; for i < 8, no mea
0137 191E                            rrcf    DPX+B2     ; are in DPX+B0
0138 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                  rrcf    DPX+B0
                                    fi
0004                              i = i+1
                               if i < 8              ;test low byte
0139 941A                         btfss   BARG+B0,i
                               else
                                                     ; test high byte
                                  btfss   BARG+B1,i-8
                               fi
013A C13F                         goto    noadd4
                        add4
013B 6018                         movfp   AARG+B0,WREG
013C 0F1E                         addwf   DPX+B2     ;add lsb
013D 6019                         movfp   AARG+B1,WREG
013E 111F                         addwfc  DPX+B3     ;add msb
                        noadd4
                               if i < 8
013F 1A19                         rlcf    AARG+B1,W  ; rotate sign into
0140 191F                         rrcf    DPX+B3     ; for i < 8, no mea
0141 191E                         rrcf    DPX+B2     ; are in DPX+B0
0142 191D                         rrcf    DPX+B1
                               else
                                  rlcf    AARG+B1,W  ; rotate sign into carry bit
                                  rrcf    DPX+B3
                                  rrcf    DPX+B2
                                  rrcf    DPX+B1
                                  rrcf    DPX+B0
                                    fi
0005                              i = i+1
                               if i < 8              ;test low byte
0143 951A                         btfss   BARG+B0,i
                               else                  ; test high byte
                                 btfss    BARG+B1,i-8
                               fi
0144 C149                         goto    noadd5
                        add5
0145 6018                         movfp   AARG+B0,WREG
0146 0F1E                         addwf   DPX+B2     ;add lsb
0147 6019                         movfp   AARG+B1,WREG
0148 111F                         addwfc  DPX+B3     ;add msb
                        noadd5
                               if i < 8
0149 1A19                         rlcf    AARG+B1,W  ; rotate sign into
014A 191F                         rrcf    DPX+B3     ; for i < 8, no mea
014B 191E                         rrcf    DPX+B2     ; are in DPX+B0
014C 191D                         rrcf    DPX+B1
                               else
                                  rlcf    AARG+B1,W  ; rotate sign into carry bit
                                  rrcf    DPX+B3
                                  rrcf    DPX+B2
                                  rrcf    DPX+B1
                                  rrcf    DPX+B0
                                     fi
0006                              i = i+1
                               if i < 8              ;test low byte
014D 961A                         btfss   BARG+B0,i
                               else                  ; test high byte
                                  btfss   BARG+B1,i-8
                               fi
014E C153                         goto    noadd6
                       add6
014F 6018                         movfp   AARG+B0,WREG
0150 0F1E                         addwf   DPX+B2     ;add lsb
0151 6019                         movfp   AARG+B1,WREG
0152 111F                         addwfc  DPX+B3     ;add msb
                       noadd6
                               if i < 8
0153 1A19                         rlcf    AARG+B1,W  ; rotate sign into
0154 191F                         rrcf    DPX+B3     ; for i < 8, no mea
```

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0155 191E                            rrcf    DPX+B2     ; are in DPX+B0
0156 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                       fi
0007                                 i = i+1
                                  if i < 8               ;test low byte

0157 971A                            btfss   BARG+B0,i
                                  else                   ; test high byte
                                     btfss   BARG+B1,i-8
                                  fi
0158 C15D                            goto    noadd7
                     add7
0159 6018                            movfp   AARG+B0,WREG
015A 0F1E                            addwf   DPX+B2     ;add lsb
015B 6019                            movfp   AARG+B1,WREG
015C 111F                            addwfc  DPX+B3     ;add msb
                     noadd7
                                  if i < 8
015D 1A19                            rlcf    AARG+B1,W  ; rotate sign into
015E 191F                            rrcf    DPX+B3     ; for i < 8, no mea
015F 191E                            rrcf    DPX+B2     ; are in DPX+B0
0160 191D                            rrcf    DPX+B1
                                  else
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3
                                     rrcf    DPX+B2
                                     rrcf    DPX+B1
                                     rrcf    DPX+B0
                                       fi
0008                                 i = i+1
                                  if i < 8               ;test low byte
                                     btfss   BARG+B0,i
                                  else                   ; test high byte
0161 901B                            btfss   BARG+B1,i-8
                                  fi
0162 C167                            goto    noadd8
                     add8
0163 6018                            movfp   AARG+B0,WREG
0164 0F1E                            addwf   DPX+B2     ;add lsb
0165 6019                            movfp   AARG+B1,WREG
0166 111F                            addwfc  DPX+B3     ;add msb
                     noadd8
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                   else
0167 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0168 191F                            rrcf    DPX+B3
0169 191E                            rrcf    DPX+B2
016A 191D                            rrcf    DPX+B1
016B 191C                            rrcf    DPX+B0
                                       fi
0009                                 i = i+1
                                  if i < 8               ;test low byte
                                     btfss   BARG+B0,i
                                  else                   ; test high byte
016C 911B                            btfss   BARG+B1,i-8
                                  fi
016D C172                            goto    noadd9
                     add9
016E 6018                            movfp   AARG+B0,WREG
```

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016F 0F1E                            addwf   DPX+B2     ;add lsb
0170 6019                            movfp   AARG+B1,WREG
0171 111F                            addwfc  DPX+B3     ;add msb
                     noadd9
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
0172 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0173 191F                            rrcf    DPX+B3
0174 191E                            rrcf    DPX+B2
0175 191D                            rrcf    DPX+B1
0176 191C                            rrcf    DPX+B0
                                       fi
000A                                 i = i+1
                                  if i < 8                ;test low byte
                                     btfss   BARG+B0,i
                                  else
                                                          ; test high byte
0177 921B                            btfss   BARG+B1,i-8
                                  fi
0178 C17D                            goto    noadd10
                     add10
0179 6018                            movfp   AARG+B0,WREG
017A 0F1E                            addwf   DPX+B2     ;add lsb
017B 6019                            movfp   AARG+B1,WREG
017C 111F                            addwfc  DPX+B3     ;add msb
                     noadd10
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
017D 1A19                            rlcf    AARG+B1,W  ; rotate sign into
017E 191F                            rrcf    DPX+B3
017F 191E                            rrcf    DPX+B2
0180 191D                            rrcf    DPX+B1
0181 191C                            rrcf    DPX+B0
                                       fi
000B                                 i = i+1
                                  if i < 8
                                      ;test low byte
                                     btfss   BARG+B0,i
                                  else
                                                          ; test high byte
0182 931B                            btfss   BARG+B1,i-8
                                  fi
0183 C188                            goto    noadd11
                     add11
0184 6018                            movfp   AARG+B0,WREG
0185 0F1E                            addwf   DPX+B2     ;add lsb
0186 6019                            movfp   AARG+B1,WREG
0187 111F                            addwfc  DPX+B3     ;add msb
                     noadd11
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
0188 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0189 191F                            rrcf    DPX+B3
018A 191E                            rrcf    DPX+B2
018B 191D                            rrcf    DPX+B1
018C 191C                            rrcf    DPX+B0
                                       fi
```

```
000C                                 i = i+1
                                  if i < 8
                                      ;test low byte
                                     btfss   BARG+B0,i
                                  else                   ; test high byte
018D 941B                            btfss   BARG+B1,i-8
                                  fi
018E C193                            goto    noadd12
                     add12
018F 6018                            movfp   AARG+B0,WREG
0190 0F1E                            addwf   DPX+B2     ;add lsb
0191 6019                            movfp   AARG+B1,WREG
0192 111F                            addwfc  DPX+B3     ;add msb
                     noadd12
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                   else
0193 1A19                            rlcf    AARG+B1,W  ; rotate sign into
0194 191F                            rrcf    DPX+B3
0195 191E                            rrcf    DPX+B2
0196 191D                            rrcf    DPX+B1
0197 191C                            rrcf    DPX+B0
                                       fi
000D                                 i = i+1
                                  if i < 8               ;test low byte
                                     btfss   BARG+B0,i
                                  else                                                     ;
                                      test high byte
0198 951B                            btfss   BARG+B1,i-8
                                  fi
0199 C19E                            goto    noadd13
                     add13
019A 6018                            movfp   AARG+B0,WREG
019B 0F1E                            addwf   DPX+B2     ;add lsb
019C 6019                            movfp   AARG+B1,WREG
019D 111F                            addwfc  DPX+B3     ;add msb
                     noadd13
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
019E 1A19                            rlcf    AARG+B1,W  ; rotate sign into
019F 191F                            rrcf    DPX+B3
01A0 191E                            rrcf    DPX+B2
01A1 191D                            rrcf    DPX+B1
01A2 191C                            rrcf    DPX+B0
                                       fi
000E                                 i = i+1
                                  if i < 8               ;test low byte
                                     btfss   BARG+B0,i
                                  else                   ; test high byte
01A3 961B                            btfss   BARG+B1,i-8
                                  fi
01A4 C1A9                            goto    noadd14
                     add14
01A5 6018                            movfp   AARG+B0,WREG
01A6 0F1E                            addwf   DPX+B2     ;add lsb
01A7 6019                            movfp   AARG+B1,WREG
01A8 111F                            addwfc  DPX+B3     ;add msb
                     noadd14
                                  if i < 8
                                     rlcf    AARG+B1,W  ; rotate sign into carry bit
                                     rrcf    DPX+B3     ; for i < 8, no meaningful bits
                                     rrcf    DPX+B2     ; are in DPX+B0
                                     rrcf    DPX+B1
                                  else
01A9 1A19                            rlcf    AARG+B1,W  ; rotate sign into
01AA 191F                            rrcf    DPX+B3
01AB 191E                            rrcf    DPX+B2
01AC 191D                            rrcf    DPX+B1
01AD 191C                            rrcf    DPX+B0
                                       fi
000F                                 i = i+1
                               if   SIGNED
01AE 1A19                            rlcf    AARG+B1,W  ; since BARG is alw
01AF 191F                            rrcf    DPX+B3     ; the last bit is k
01B0 191E                            rrcf    DPX+B2
01B1 191D                            rrcf    DPX+B1
01B2 191C                            rrcf    DPX+B0
                               endif
01B3 0002                    return
                     ;
                     ;**********************************************************
                           END

Errors   :    0
Warnings :    0
```

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