PURE SINE WAVE INVERTER USING SINUSOIDAL PULSE WIDTH MODULATION
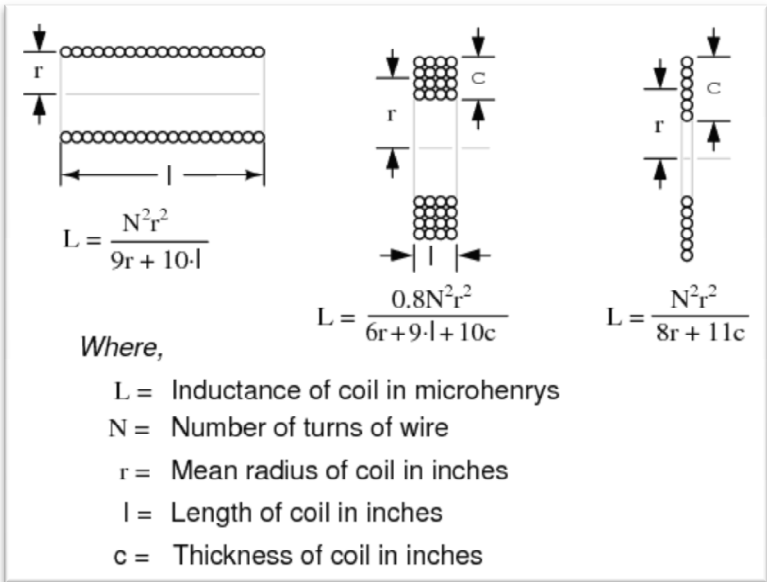
Written by

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This inverter is based on full bridge configuration with sinusoidal PWM modulation. PIC16F886 is used to generate required control signals. ECCP module of PIC16F886 is used in half bridge mode. TLP250 is used as IGBT driver as well as electrical isolation. The circuit is designed to deliver 230V, 50Hz, 1.5KVA output. 325V DC input should not be grounded and it should be floating supply. 18V DC auxiliary supply is also floating used as Vcc for TLP250.

During +ve half cycle T3 conducts continuously and T1's conduction is modulated. During –ve half cycle T4 conducts continuously and T2's conduction is modulated. Dead time is implemented in the program to avoid shoot through current.

The output filter is low pass LC filter consist of 3 milli-henry air cored inductor and 5 MFD capacitor. The cut-off frequency of LC filter is 1300Hz which is far below switching frequency of 19.53 KHz and above the output fundamental frequency of 50 Hz. Air cored inductor is preferred because core saturation does not arise while supplying peak currents, makes it suitable for RCD loads such as computer SPMS etc. But copper loss is somewhat more compared to ferrite cored inductor which can be tolerated.

$$L = \frac{N^2 r^2}{9r + 10 \cdot l}$$

$$L = \frac{0.8 N^2 r^2}{6r + 9 \cdot l + 10c}$$

$$L = \frac{N^2 r^2}{8r + 11c}$$

Where,

L = Inductance of coil in microhenrys
N = Number of turns of wire
r = Mean radius of coil in inches
l = Length of coil in inches
c = Thickness of coil in inches

The inductance of multilayer air cored inductor can be calculated using the formula as given in the diagram. For typical 3 milli-henry inductance, 330 Turns of 19 SWG enameled copper wire wound over a bobbin of 1 inch diameter and 1 inch length.

IGBT FGA25N120 has built in anti parallel diode so no need of providing external diodes. TLP250 driving low side directly receives power from 18 V auxiliary supply while TLP250 driving high side receives power through BA159 diode and stored in 100MFD capacitor. Polyester capacitor of 0.1MFD is connected across 100MFD electrolytic capacitors to overcome high inductance of electrolytic capacitors.

"Sample mains in" voltage in microcontroller circuit is an isolated reduced and calibrated DC voltage in terms of AC mains voltage. The calibration may be done as 2.5V DC for 230V AC mains in. It is used for automatic changeover from mains to inverter and vice-versa.
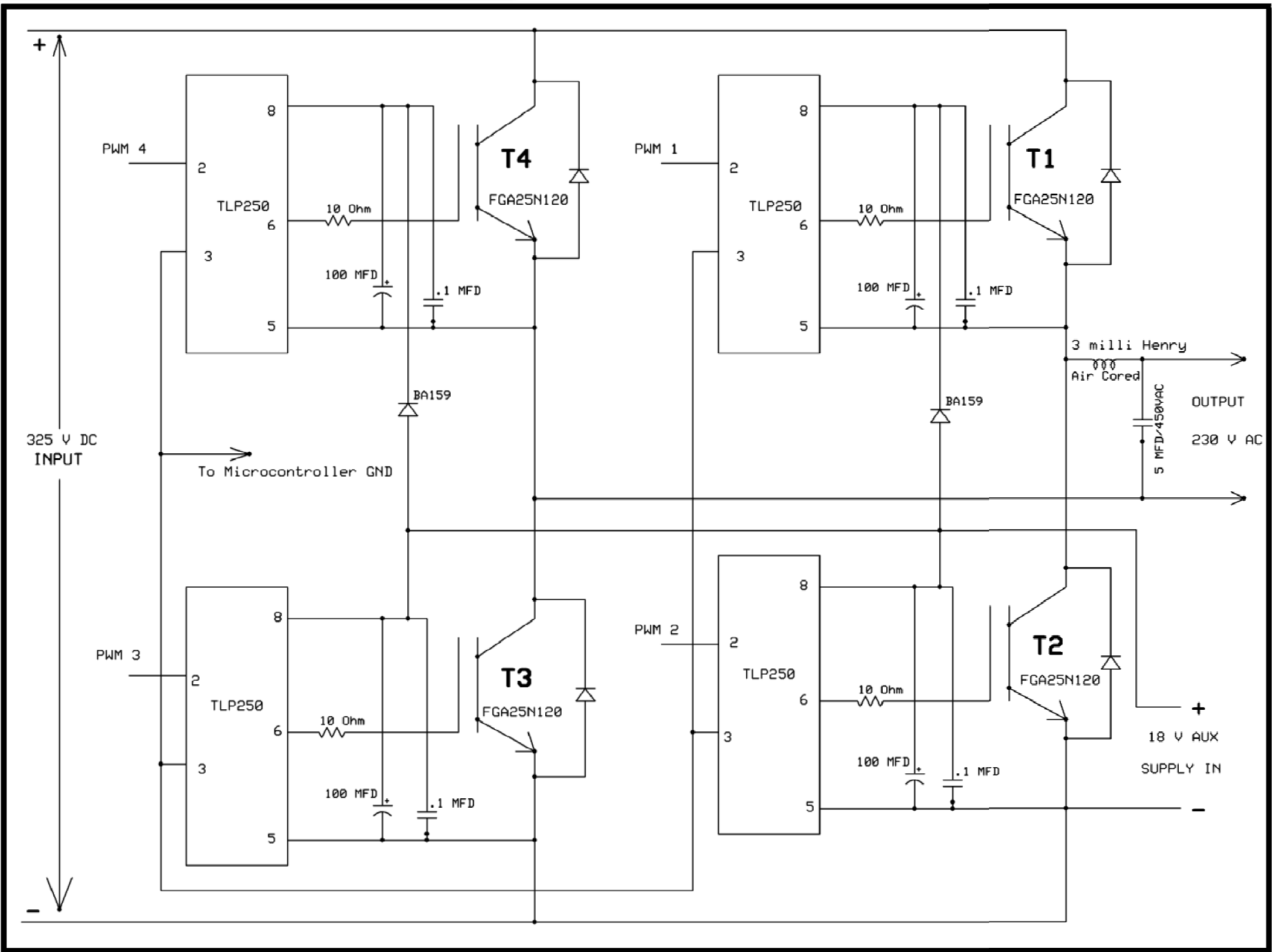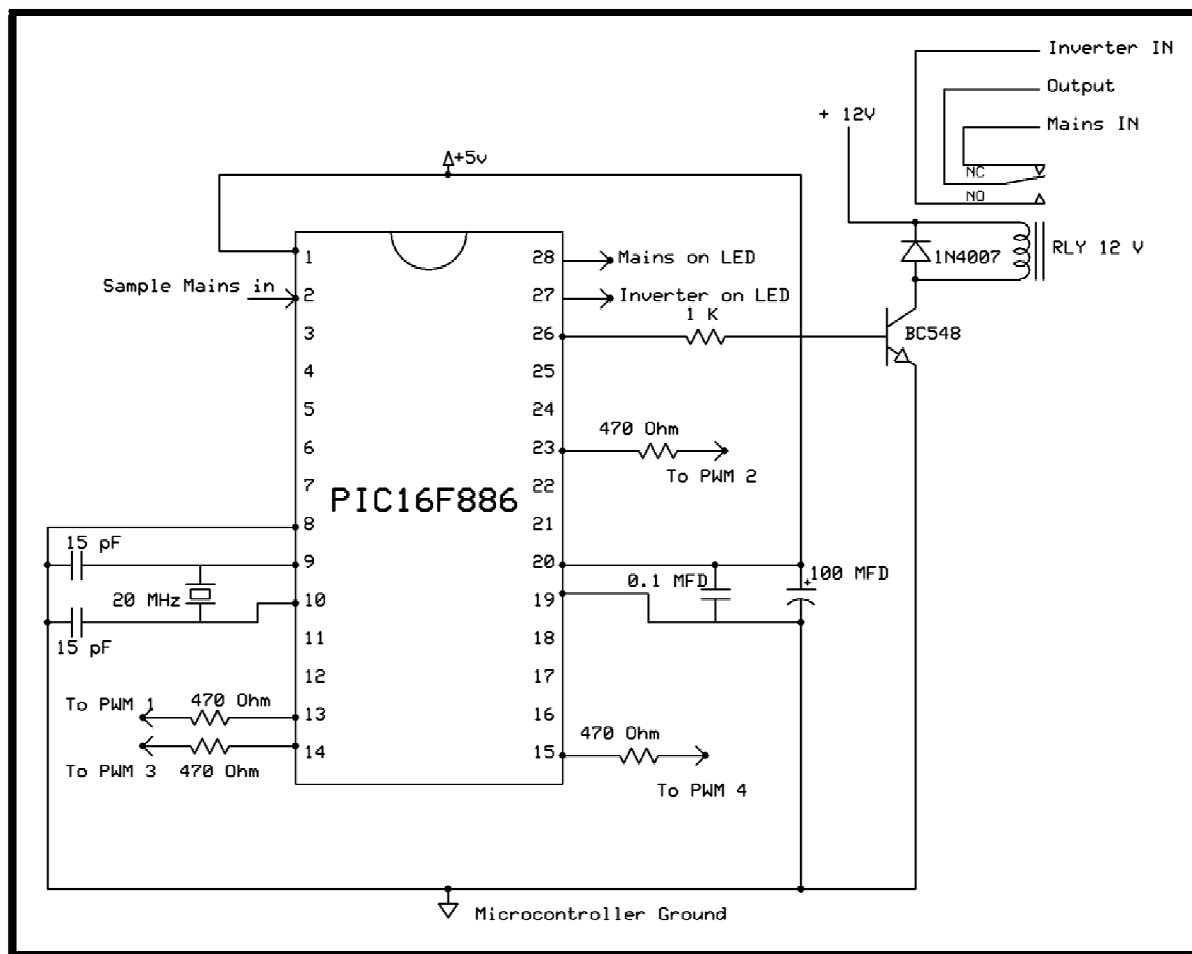
Program written in assembly language for PIC16F886 microcontroller is given below which is fully tested. The HEX file generated for the assembly program is also given at the end of this document. The HEX file may be directly loaded into PIC16F886. The program can be modified to add features such as low battery cutoff, over load protection, Short circuit protection, and High heat sink temperature protection by using LM35 sensor.

For deriving +5V for microcontroller use 7805 regulator. When using 12V / 24V batteries suitable push-pull DC-DC converter may be designed to step up to 325V DC. The changeover circuit shown is for phase only. Neutral may be connected commonly.

```
;*********************************************************************************************
;                          PURE SINE WAVE INVERTER USING PIC16F886
;*********************************************************************************************
;THIS IS PROGRAM TO INVERT 325 V DC TO 230 V 50 HZ AC OF PURE SINE WAVE.
;USE 20 MHZ CRYSTAL.
;USE MPLAB X IDE v2.26
;TIMER 2 IS USED BY ECCP MODULE TO GENERATE PWM.
;TIMER 0 IS USED TO INTERRUPT FOR EVERY 166 MICRO SECONDS TO UPDATE DUTY CYCLE
;FROM LOOKUP TABLE, AND FOR ONE CYCLE 120 LOOKUP TABE VALUES ARE USED.
; 0 TO 59 OF LOOKUP TABLE IS FOR +VE HALF CYCLE AND 60 TO 119 FOR -VE HALF CYCLE.
; -VE HALF CYCLE VALUES ARE (255 - POSITIVE HALF CYCLE VALUES).
;USE TLP250 MOSFET DRIVER, 3 MILLI HENRY AIR CORED INDUCTOR AND 4.7 MFD CAPACITOR AS OUTPUT FILTER
;*****************************************************************************
list p=16f886

list n=0

#include p16f886.inc

;FOR CONFIG BITS REFER Program Files->Microchip->MPLABX->mpasmx->concerned header file

__config _CONFIG1, _DEBUG_OFF & _LVP_OFF & _FCMEN_OFF & _IESO_OFF & _BOR_OFF & _CPD_OFF & _MCLRE_OFF & _PWRTE_OFF & _WDT_OFF & _HS_OSC

__config _CONFIG2, _WRT_OFF

;*********** I/O PORTS DEFINITION ******************

#DEFINE LED_MO PORTB,7          ;LED MAINS ON

#DEFINE LED_IO PORTB,6          ;LED INVERTER ON

#DEFINE OPREL PORTB,5           ;OUTPUT CHANGE OVER RELAY
```

```
#DEFINE MOSF3 PORTC,3          ;MOSFET PORT

#DEFINE MOSF4 PORTC,4          ;MOSFET PORT

;***************** FLAGS DEFINITION *****************

#DEFINE FMO 0X3A,0             ;FLAG MAINS ON

#DEFINE FIO 0X3A,1             ;FLAG INVERTER ON

#DEFINE FHSEC 0X3A,2           ;FLAG HALF SECOND

#DEFINE FINSHD 0X3A,3          ;FLAG INVERTER TO BE SHUTDOWN

#DEFINE F20MS 0X3A,4           ;FLAG 20 MILLI SECONDS

;********** VARIABLE DEFINITION *********************

DCOU1   EQU 0X21   ;DELAY COUNTER 1

DCOU2   EQU 0X22   ;DELAY COUNTER 2

DCOU3   EQU 0X23   ;DELAY COUNTER 3

PWCOU   EQU 0X24   ;PULSE WIDTH COUNTER

TMCOU   EQU 0X25   ;TIME COUNTER

MSTBC   EQU 0X26   ;MAINS STABILIZATION COUNTER

W_TEMP1 EQU 0X27   ;TEMPORARY WORKING REGISTER 1

AD_RES  EQU 0X28   ;A/D CONVERTER RESULT

CHN_NO  EQU 0X29   ;CHANNEL NUMBER

W_TEMP  EQU 0X70   ;BACKUP REGISTER FOR W mirrored in all 4 banks

STATUS_TEMP EQU 0X71   ;BACKUP FOR STATUS REGISTER


;********** MAIN PROGRAM STARTS *********************
;
                ORG 0x0000     ;RESET VECTOR

                GOTO START

                ORG 0X0004     ;INTERRUPT VECTOR

                 GOTO ISR

                ORG 0X0005

TABLE           ADDWF PCL,F   ;LOOK UP TABLE SHOULD BE LOCATED IN FIRST ;BECAUSE LAST MEMORY OF TABLE SHOULD NOT EXCEED 256

                 RETLW .0      ;0  LOOK UP TABLE FOR PURE SINE WAVE

                RETLW .13      ;1

                RETLW .27      ;2

                RETLW .40

                RETLW .53

                RETLW .66

                RETLW .79

                RETLW .91

                RETLW .104

                RETLW .116

                RETLW .127

                RETLW .139

                RETLW .150
```

RETLW .160

RETLW .171

RETLW .180

RETLW .190

RETLW .198

RETLW .206

RETLW .214

RETLW .221

RETLW .227

RETLW .233

RETLW .238

RETLW .243

RETLW .246

RETLW .249

RETLW .252

RETLW .254

RETLW .255

RETLW .255

RETLW .255

RETLW .254

RETLW .252

RETLW .249

RETLW .246

RETLW .243

RETLW .238

RETLW .233

RETLW .227

RETLW .221

RETLW .214

RETLW .206

RETLW .198

RETLW .190

RETLW .180

RETLW .171

RETLW .160

RETLW .150

RETLW .139

RETLW .127

RETLW .116

RETLW .104

RETLW .91

```
RETLW .79

RETLW .66

RETLW .53

RETLW .40

RETLW .27        ;58

RETLW .13        ;59 END OF +VE HALF CYCLE

RETLW .255       ;60 START OF -VE HALF CYCLE

RETLW .242       ;61

RETLW .228       ;62

RETLW .215

RETLW .202

RETLW .189

RETLW .176

RETLW .164

RETLW .151

RETLW .139

RETLW .128

RETLW .116

RETLW .105

RETLW .95

RETLW .84

RETLW .75

RETLW .65

RETLW .57

RETLW .49

RETLW .41

RETLW .34

RETLW .28

RETLW .22

RETLW .17

RETLW .12

RETLW .9

RETLW .6

RETLW .3

RETLW .1

RETLW .0

RETLW .0

RETLW .0

RETLW .1

RETLW .3

RETLW .6
```

```
                RETLW .9

                RETLW .12

                RETLW .17

                RETLW .22

                RETLW .28

                RETLW .34

                RETLW .41

                RETLW .49

                RETLW .57

                RETLW .65

                RETLW .75

                RETLW .84

                RETLW .95

                RETLW .105

                RETLW .116

                RETLW .128

                RETLW .139

                RETLW .151

                RETLW .164

                RETLW .176

                RETLW .189

                RETLW .202

                RETLW .215

                RETLW .228    ;118

                RETLW .242    ;119  END OF -VE HALF CYCLE


START           BSF STATUS,RP0    ;BANK 1 *************************

                MOVLW 0X00

                MOVWF TRISB       ;DEFINE PORTB AS OUTPUT

                MOVLW 0X00

                MOVWF TRISC       ;DEFINE PORTC AS OUTPUT

                MOVLW 0X01

                MOVWF TRISA       ;PORTA,0 AS INPUT FOR MAINS ANALOG INPUT

                MOVLW 0X00                        ;Vref=Vcc and Vss, RESULT LEFT ALIGNED

                MOVWF ADCON1

                MOVLW B'00000000'   ;EXT OSC USED FOR SYSTEM CLOCK

                MOVWF OSCCON

                MOVLW 0X04        ;***** DEAD TIME 800 nS *******

                MOVWF PWM1CON

                MOVLW B'00000001'   ;TMR0 INT CLOCK, PRESCALER 1:4, TMR 0 START ALSO

                MOVWF OPTION_REG
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            MOVLW 0XFF        ;FOR 19.53 KHZ SWITCHING FREQUENCY WITH 20 MHZ CRYSTAL

            MOVWF PR2

            BANKSEL ANSEL     ;BANK 3 ****************************

            MOVLW 0X01        ;PORTA,0 AS ALALOG INPUT

            MOVWF ANSEL

            MOVLW 0X00

            MOVWF ANSELH

            BANKSEL ADCON0    ;BANK 0 **************************

            MOVLW 0X80        ;ADC CLOCK SOURCE FOSC/32

            MOVWF ADCON0

            BSF INTCON,T0IE   ;TIMER 0 INTERRUPT ENABLE

            BCF INTCON,T0IF   ;CLEAR TIMER 0 INTERRUPT FLAG

            CLRF PORTA        ;INITIALLY CLEAR ALL PORTS TO AVOID MALFUNCTION

            CLRF PORTB

            CLRF PORTC

      MOVLW .90                    ;CLEAR 90 REGISTERS FROM 0X21

      MOVWF 0X20

      MOVLW 0X21

      MOVWF FSR

CLRREG      CLRF INDF

      INCF FSR,F

      DECFSZ 0X20,F

      GOTO CLRREG

      CALL HLFSEC       ;INITIAL DELAY FOR CAPACITORS STABILIZATION

       CALL HLFSEC

      CALL HLFSEC


      BSF INTCON,GIE    ;GLOBAL INTERRUPT ENABLE

      BSF FMO           ;MAINS ON FLAG TO AVOID INVERTER TRIGGER WHEN MAINS ALREADY AVAILABLE

      BSF LED_MO        ;MAINS ON LED
;*************** MAIN LOOP STARTS ***************************
LOOP        NOP
;******************* MAINS SENSE PART *********************
;
      MOVLW 0X00            ;MAINS VOLTAGE SENCE PART

      MOVWF CHN_NO

      CALL ANASCAN

      MOVF AD_RES,W

      SUBLW .45             ;VOLTAGE LOWER CUT OUT

      BTFSC STATUS,C

      GOTO MAINOR           ;GOTO MAINS OUT OF RANGE

      MOVF AD_RES,W
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                SUBLW .180              ;VOLTAGE UPPER CUT OUT

                BTFSS STATUS,C

                GOTO MAINOR             ;GOTO MAINS OUT OF RANGE

                MOVF AD_RES,W

                SUBLW .75               ;VOLTAGE LOWER CUT IN

                BTFSC STATUS,C

                GOTO MAINNC             ;GOTO MAINS NO CHANGE

                MOVF AD_RES,W

                SUBLW .160              ;VOLTAGE UPPER CUT IN

                BTFSS STATUS,C

                GOTO MAINNC

                BTFSC FMO       ;IF MAINS ON FALG NOT SET THEN BLINK MAINS LED

                GOTO MAINNC  ;GOTO MAINS NO CHANGE

                BTFSS FHSEC     ;HALF SECOND FLAG

                GOTO MAINNC

                BTFSS LED_MO  ;JUST ON AND OFF LED DURING MAINS STABILIZATION

                GOTO MLEDON            ;GOTO MAINS LED ON

                BCF LED_MO             ;MAINS ON LED

                GOTO BPMOBLK           ;GOTO BYEPASS MAINS ON BLINK
MLEDON          BSF LED_MO             ;MAINS ON LED
BPMOBLK         INCF MSTBC,F  ;MAINS STABILIZATION COUNTER

                MOVF MSTBC,W

                XORLW .20     ;MAINS STABILIZATION DURATION IN HALF SECONDS

                BTFSS STATUS,Z

                GOTO MAINNC

                BSF FMO                ;MAINS ON FLAG

                BSF LED_MO    ;MAINS ON LED

                CLRF MSTBC    ;MAINS STABILIZATION COUNTER

                BTFSC FIO     ;INVERTER ALREADY OFF ?

                BSF FINSHD    ;INVERTER TO BE SHUTDOWN FLAG

                GOTO MAINNC
MAINOR          BCF FMO                ;MAINS ON FLAG

                BCF LED_MO             ;MAINS ON LED

                CLRF MSTBC             ;RESET MAINS STABILIZATION COUNTER

                BTFSS FIO     ;INVERTER ALREADY ON ?

                CALL INVTGR   ;CALL INVERTER TRIGGER
MAINNC          NOP
;******************* MAINS SENSE PART ENDS *********************
;*************** TIME COUNTER PART *****************************

                BCF FHSEC     ;CLEAR HALF SECOND FLAG

                BTFSS F20MS   ;20 MILLI SECONDS FLAG SET BY ISR ?
```

```
        GOTO LOOP      ;GOTO MAIN LOOP

        BCF F20MS

        INCF TMCOU,F   ;INCREMENT TIME COUNTER

        MOVLW .25      ;HALF SECOND = 25 X 20 MILLISECONDS

        XORWF TMCOU,W

        BTFSS STATUS,Z

        GOTO LOOP

        CLRF TMCOU

    BSF FHSEC      ;SET HALF SECOND FLAG CAN BE USED FOR ANY TIMING

    GOTO LOOP      ;GOTO MAIN LOOP

;*************** MAIN LOOP ENDS ***********************************


;******************* INTERRUPT SERVICE ROUTINE ********************

ISR             MOVWF W_TEMP       ;BACKUP FOR W AND STATUS REG

                SWAPF STATUS,W

                MOVWF STATUS_TEMP

                CLRF STATUS    ;RESTORE TO BANK 0

        INCF PWCOU,F   ;INCREMENT PULSE WIDTH COUNTER

        BTFSS FIO      ;WHEATHER INVERTER ON ?

        GOTO ISRTM     ;GOTO ISR FOR TIME ALONE

            MOVLW .60              ;IF PULSE WIDTH COUNTER REACHES 60 MEANS +VE TO -VE

            XORWF PWCOU,W

            BTFSS STATUS,Z

            GOTO CK120     ;GOTO CHECK FOR 120 ALSO

            BCF MOSF3              ;MOSFET PORT  + VE TO - VE

        MOVLW .255     ;THE INSTRUCTIONS FROM BCF MOSF3 TO BSF MOSF4 FORMS DEAD TIME

        MOVWF CCPR1L      ;PWM DUTY CYCLE

        BCF CCP1CON,DC1B0   ;LSB OF PWM DUTY CYCLE

        BCF CCP1CON,DC1B1   ;LSB OF PWM DUTY CYCLE

        MOVLW 0XFE        ;SINCE THE NEW DUTYCYCLE WILL BE LATCHED WHEN TMR2

        MOVWF TMR2        ;IS EQUAL TO PR2 (0XFF)

        BSF MOSF4      ; - VE HALF CYCLE

        BTFSC FINSHD   ;INVERTER TO BE SHUTDOWN FLAG SET ?

        CALL INVSHD    ;CALL INVERTER SHUTDOWN ( SHUT DOWN INVERTER WHEN O/P VOLTAGE IS ZERO )

        GOTO NOTRN

            CK120   MOVLW .120              ;IF PULSE WIDTH COUNTER REACHES 120 -VE TO +VE

            XORWF PWCOU,W

            BTFSS STATUS,Z

        GOTO NOTRN     ;GOTO NO TRANSITION

        CLRF PWCOU     ;NEXT NEW +VE HALF CYCLE

        BSF F20MS      ;SET 20 MILLI SECONDS FLAG
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            BCF MOSF4               ;MOSFET PORT  - VE TO + VE

        MOVLW .0      ;THE INSTRUCTIONS FROM BCF MOSF4 TO BSF MOSF3 FORMS DEAD TIME

        MOVWF CCPR1L      ;MSB OF PWM DUTY CYCLE

        BSF CCP1CON,DC1B0  ;LSB OF PWM DUTY CYCLE

        BSF CCP1CON,DC1B1  ;LSB OF PWM DUTY CYCLE

        MOVLW 0XFE        ;SINCE THE NEW DUTYCYCLE WILL BE LATCHED WHEN TMR2

        MOVWF TMR2        ;IS EQUAL TO PR2 (0XFF)

        BSF MOSF3          ; + VE HALF CYCLE

NOTRN        MOVF PWCOU,W      ;NO TRANSITION

            CALL TABLE       ;GET PWM DUTY CYCLE FOR PURE SINE WAVE

            MOVWF CCPR1L       ;PWM DUTY CYCLE

        MOVLW .56        ;PERIOD = COUNT X PRE SCALE X TOSC (1/(FOSC/4))

        MOVWF TMR0        ;255 - 199 = 56 FOR 50 HZ (TIME TAKEN BY INSTRUCTIONS IN ISR TO BE DECUCTED)

        BCF INTCON,T0IF    ;CLEAR TIMER 0 INTERRUPT FLAG

            SWAPF STATUS_TEMP,W              ;RESTORE BACKUP

            MOVWF STATUS

            SWAPF W_TEMP,F

            SWAPF W_TEMP,W

            RETFIE       ;RETFIE AUTOMATICALLY ENABLES INTCON,GIE


ISRTM        MOVLW .120            ;ISR WHEN INVERTER NOT RUNNING FOR TIMING PURPOSE ALONE

            XORWF PWCOU,W   ;IF PULSE WIDTH COUNTER REACHES 120 MEANS 20 MILLI SECOND OVER

            BTFSS STATUS,Z

            GOTO ISREXT    ;GOTO ISR EXIT

            CLRF PWCOU    ;CLEAR PWCOU FOR NEXT 120 COUNTS

            BSF F20MS     ;SET 20 MILLI SECONDS FLAG
ISREXT       MOVLW .55      ;PERIOD = COUNT X PRE SCALE X TOSC (1/FOSC/4)

            MOVWF TMR0    ;HERE 55 SINCE INSTRUCTIONS ARE LESS

            BCF INTCON,T0IF       ;CLEAR TIMER 0 INTERRUPT FLAG

            SWAPF STATUS_TEMP,W              ;RESTORE BACKUP

            MOVWF STATUS

            SWAPF W_TEMP,F

            SWAPF W_TEMP,W

            RETFIE       ;RETFIE AUTOMATICALLY ENABLES INTCON,GIE


;***************** INVERTER TRIGGER SUBROUTINE *********************

INVTGR       BSF OPREL       ;OPTPUT CHANGER OVER RELAY

            MOVLW B'10111100'  ;HALF BRIDGE, LSB OF PWM DUTY CYCLE = 11

            MOVWF CCP1CON      ;P1A, P1C active-high; P1B, P1D active-high

            MOVLW 0X01       ;MSB OF DUTY CYCLE

            MOVWF CCPR1L
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                MOVLW B'00000100'  ;TIMER2 ON, PRESCALER 1:1, POSTSCALE 1:1

                MOVWF T2CON

                CLRF PWCOU     ;PULSE WIDTH COUNTER

        BCF MOSF4               ;MOSFET PORT    (START WITH + VE HALF CYCLE)

        BSF MOSF3               ;MOSFET PORT

            BSF FIO      ;SET FLAG INVERTER ON

            BSF LED_IO    ;INVERTER ON LED

            BCF FINSHD    ;INVERTER TO BE SHUTDOWN FLAG

            RETURN



;****************** INVERTER SHTDOWN SUBROUTINE *********************

INVSHD     BCF MOSF3                ;MOSFET PORT

            BCF MOSF4

            CLRF CCP1CON   ;CCPWM OFF

            CLRF T2CON     ;TIMER2 OFF, PRESCALER 1:1, POSTSCALE 1:1

            BCF PORTC,2    ;CCPWM OFF MAY CAUSE ONE O/P TO BE KEPT ON

            BCF PORTB,2    ;SO MANUALLY SWITCH OF BOTH O/P

            BCF FIO       ;CLEAR FLAG INVERTER ON

            BCF LED_IO    ;CLEAR INVERTER ON LED

            BCF FINSHD    ;INVERTER TO BE SHUTDOWN FLAG

            BCF OPREL     ;OPTPUT CHANGER OVER RELAY

            RETURN



;************** ANALOG TO DIGITAL CONVERTER *********************
ANASCAN    MOVF CHN_NO,W              ;ANALOG TO DIGITAL CONVERTER PART

            MOVWF W_TEMP1

            BCF STATUS,C

            RLF W_TEMP1,F             ;TO POSITION FOR CHANNEL SELECT BITS

            RLF W_TEMP1,F

            MOVLW 0X81               ;A/D CLOCK=FOSC/32 AND A/D ON

            IORWF W_TEMP1,F

            MOVF W_TEMP1,W

            MOVWF ADCON0

            MOVLW .20                ;WAIT FOR AQUISITION TIME

            MOVWF 0X20

AQTIME     DECFSZ 0X20,F

            GOTO AQTIME

            BSF ADCON0,1          ;START A/D CONVERSION

ADCONV1    BTFSC ADCON0,1              ;CHECK FOR END OF CONVERSION

            GOTO ADCONV1

            MOVF ADRESH,W
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                    MOVWF AD_RES

                    BCF PIR1,ADIF                    ;CLEAR A/D CONVERTER INT FLAG

                    RETURN


;***************** HALF SECOND DELAY SUBROUTINE********************

HLFSEC          MOVLW 0X50          ;DELAY FOR HALF SECOND

                    MOVWF DCOU3

COU5            MOVWF DCOU2

COU4            MOVWF DCOU1

COU3            DECFSZ DCOU1,F

                    GOTO COU3

                    DECFSZ DCOU2,F

                    GOTO COU4

                    DECFSZ DCOU3,F

                    GOTO COU5

                    RETURN


                    END
```

;*** ASSEMBLER PROGRAM ENDS***

;***************************** HEX FILE TO BE LOADED IN PIC16F886 **

:020000040000FA

:020000007E2858

:040002000034003492

:02000800E628E8

:06000A00820700340D34F2

:100010001B342834353442344F345B346834743400

:100020007F348B349634A034AB34B434BE34C6340D

:10003000CE34D634DD34E334E934EE34F334F634FC

:10004000F934FC34FE34FF34FF34FF34FE34FC3426

:10005000F934F634F334EE34E934E334DD34D634B1

:10006000CE34C634BE34B434AB34A03496348B347E

:100070007F34743468345B344F344234353428343C

:100080001B340D34FF34F234E434D734CA34BD3475

:10009000B034A43497348B348034743469345F348E

:1000A00054344B34413439343134293422341C34FF

:1000B0001634113410C340934063403340134003A5A

:1000C00000034003401340334063409340C34113460

:1000D00016341C34223429343134393441344B340D

:1000E00054345F346934743480348B349734A4349A

:1000F000B034BD34CA34D734E434F234831600301B

:100100008600003087000130850000309F000030FD

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:100120000317013088000030890083120313038030E8
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:1001700028084B3C0318D9282808A03C031CD92880
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:100230001B29A4013A16373081000B11710E83007F
:10024000F00E700E09008616BC3097000130950044
:1002500004309200A40107128715BA140617BA11C8
:1002600008008711071297019201071110611BA10B1
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