

A Program listing¹

Program: Modulated UV-B system
 Version 10.1: switch (delayed), hysteresis, temp cal BW
 Date: 1-6,12,14,15,18-22,29 Aug 1997, 4(,16) Sep 1997
 EMERGENCY VERSION: less dimming 1800-5000 mv only
 Date: 18,20-22 May 98, 6,8,22 Jul 98, 2,23 Oct 98
 Date: 18 Jan 99, 16,18,20 Apr 99, 24 May 99

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Logger: CR10 (4k program memory)
 Sensors: 1 50Y, 1 107, 2 LI-190, 2 BW-20
 Peripherals: 1 SDM-A04

Flag Usage: 1 lamps,2 init,3 DEBUG,4 ON,5 OFF, 6 scrat.
 Input Channel Usage: diff 4,5 single 1,2,3,11,12
 Excitation Channel Usage: 1, (3)
 Control Port Usage: 1,2,3 -> SDM, 7 -> lamps, 8 -> 12V
 Pulse Input Channel Usage: none
 Output Array Definitions: none

* 1 Table 1 Programs
 01: 60 Sec. Execution Interval

 Initialize lamps (important on start up)

01: P91 If Flag/Port
 01: 22 Do if flag 2 is low
 02: 30 Then Do
 We make sure that we start with lamps off!

02: P86 Do
 01: 57 Set low Port 7

03: P30 Z=F
 01: 1800 F
 02: 0 Exponent of 10
 03: 16 Z Loc [:dimmer mV]

04: P103 SDM-A04
 01: 1 Reps
 02: 00 Address

¹Not intended for publication. Provided as additional information for the referees and editor. The listing of the program will be available for download from one of our university's web servers.

```
03: 16      Loc dimmer mV

05:  P86      Do
01:  12      Set high Flag 2

06:  P95      End
end if then do

*****
Read sensors
*****

07:  P10      Battery Voltage
01:  10      Loc [:Battery ]

08:  P86      Do
01:  2       Call Subroutine 2
Measure air temp and RH and calculate VPD

09:  P11      Temp 107 Probe
01:  1       Rep
02:  3       IN Chan
03:  1       Excite all reps w/EXchan 1
04:  4       Loc [:Temp_soil]
05:  1       Mult
06:  0       Offset

10:  P86      Do
01:  3       Call Subroutine 3
Measure PAR

11:  P86      Do
01:  1       Call Subroutine 1
Measure UV-B

move initial values (read before adjusting dimmer)
to prevent overwriting

12:  P54      Block Move
01:  4       No. of Values
02:  6       First Source Loc UVB-acet
03:  1       Source Step
04:  17      First Destination Loc [:UVB_ace_i]
05:  1       Destination Step

*****
Switch lamps off or on and adjust dimmer
*****
```

```
13: P91      If Flag/Port
    01: 11    Do if flag 1 is high
    02: 6     Call Subroutine 6

14: P91      If Flag/Port
    01: 21    Do if flag 1 is low
    02: 7     Call Subroutine 7

15: P89      If X<=>F
    01: 1     X Loc Temp_air
    02: 4     <
    03: 1     F
    04: 15    Set high Flag 5

16: P91      If Flag/Port
    01: 15    Do if flag 5 is high
    02: 30    Then Do

17: P86      Do
    01: 25    Set low Flag 5

18: P30      Z=F
    01: 0     F
    02: 0     Exponent of 10
    03: 34    Z Loc [:delay ON ]

19: P86      Do
    01: 57    Set low Port 7
Switch lamps off

20: P86      Do
    01: 21    Set low Flag 1

21: P30      Z=F
    01: 0     F
    02: 0     Exponent of 10
    03: 14    Z Loc [:iteration]
needed only for logging

22: P30      Z=F
    01: 1800  F
    02: 0     Exponent of 10
    03: 16    Z Loc [:dimmer mV]

23: P86      Do
    01: 8     Call Subroutine 8

24: P95      End
end if then do
```

```
25: P89      If X<=>F
    01: 1      X Loc Temp_air
    02: 4      <
    03: 3      F
    04: 24     Set low Flag 4

26: P91      If Flag/Port
    01: 14     Do if flag 4 is high
    02: 30     Then Do

27: P86      Do
    01: 24     Set low Flag 4

28: P30      Z=F
    01: 0      F
    02: 0      Exponent of 10
    03: 33     Z Loc [:delay OFF]

29: P86      Do
    01: 11     Set high Flag 1

30: P86      Do
    01: 47     Set high Port 7

31: P32      Z=Z+1
    01: 13     Z Loc [:on count ]

32: P22      Excitation with Delay
    01: 3      EX Chan
    02: 0      Delay w/EX (units=.01sec)
    03: 300    Delay after EX (units=.01sec)
    04: 0      mV Excitation

33: P86      Do
    01: 1      Call Subroutine 1

34: P95      End
end if flag 4 then do

35: P91      If Flag/Port
    01: 11     Do if flag 1 is high
    02: 9      Call Subroutine 9
*****
output
*****

36: P92      If time is
    01: 0      minutes into a
```

```
02: 60      minute interval
03: 10      Set high Flag 0 (output)

37: P77     Real Time
01: 1210    Year,Day,Hour-Minute

38: P71     Average
01: 10      Reps
02: 1       Loc Temp_air

39: P71     Average
01: 2       Reps
02: 35      Loc PAR 1

40: P71     Average
01: 5       Reps
02: 16      Loc dimmer mV

41: P73     Maximize
01: 3       Reps
02: 10      Value with Hr-Min
03: 5       Loc PAR max12

42: P73     Maximize
01: 5       Reps
02: 10      Value with Hr-Min
03: 16      Loc dimmer mV

43: P74     Minimize
01: 3       Reps
02: 10      Value with Hr-Min
03: 5       Loc PAR max12

44: P74     Minimize
01: 5       Reps
02: 10      Value with Hr-Min
03: 16      Loc dimmer mV

45: P70     Sample
01: 1       Reps
02: 13      Loc on count

46: P91     If Flag/Port
01: 13      Do if flag 3 is high
02: 30      Then Do
manually set flag 3 high for performance monitoring

47: P75     Histogram
01: 1       Rep
```

```
02: 10      No. of Bins
03: 1       Closed form
04: 9       Bin Select Value Loc UVB-achie
05: 0       Frequency Distribution
06: .5      Low Limit
07: 1.5     High Limit

48: P75     Histogram
01: 1       Rep
02: 10      No. of Bins
03: 1       Closed form
04: 20      Bin Select Value Loc UVB_ach_i
05: 0       Frequency Distribution
06: .5      Low Limit
07: 1.5     High Limit

49: P82     Standard Deviation
01: 1       Rep
02: 9       Sample Loc UVB-achie

50: P82     Standard Deviation
01: 1       Rep
02: 20      Sample Loc UVB_ach_i

51: P71     Average
01: 1       Rep
02: 14      Loc iteration

52: P95     End
end if then do

53: P91     If Flag/Port
01: 10      Do if flag 0 (output) is high
02: 30      Then Do

54: P30     Z=F
01: 0       F
02: 0       Exponent of 10
03: 13      Z Loc [:on count ]

55: P95     End
end if flag 0 then do

56: P       End Table 1

*          2       Table 2 Programs
01: 0.0000   Sec. Execution Interval
```

```
01: P      End Table 2

*      3      Table 3 Subroutines

*****
Measure UV-B
*****

measure sensors 4 times, calculate average and then
use average reading for each sensor in calculations

sensor callibration is temperature dependent:
  offset is calculated using a 3rd degree polynomial

01: P85      Beginning of Subroutine
  01: 1      Subroutine Number

02: P55      Polynomial
  01: 1      Rep
  02: 1      X Loc Temp_air
  03: 29     F(X) Loc [:offset_ac]
  04: 22.557 C0
  05: -.1445 C1
  06: .01391 C2
  07: -.00353 C3
  08: 0      C4
  09: 0      C5

03: P55      Polynomial
  01: 1      Rep
  02: 1      X Loc Temp_air
  03: 30     F(X) Loc [:offset_po]
  04: -28.328 C0
  05: -1.0404 C1
  06: -.03933 C2
  07: -.00020 C3
  08: 0.0000 C4
  09: 0.0000 C5

04: P30      Z=F
  01: 0.2    F
  02: 0      Exponent of 10
  03: 31     Z Loc [:mult_ac ]

05: P30      Z=F
  01: 0.22   F
  02: 0      Exponent of 10
  03: 32     Z Loc [:mult_pol ]
```

```
06: P87      Beginning of Loop
    01: 0      Delay
    02: 4      Loop Count

07: P1       Volt (SE)
    01: 1      Rep
    02: 5      2500 mV slow Range
    03: 11     IN Chan
    04: 21--   Loc [:UVB-a_raw]
    05: 1      Mult
    06: 0      Offset

08: P1       Volt (SE)
    01: 1      Rep
    02: 5      2500 mV slow Range
    03: 12     IN Chan
    04: 25--   Loc [:UVB-p_raw]
    05: 1      Mult
    06: 0      Offset

09: P35      Z=X-Y
    01: 21--   X Loc UVB-a_raw
    02: 29     Y Loc offset_ac
    03: 21--   Z Loc [:UVB-a_raw]

10: P36      Z=X*Y
    01: 21--   X Loc UVB-a_raw
    02: 31     Y Loc mult_ac
    03: 21--   Z Loc [:UVB-a_raw]

11: P35      Z=X-Y
    01: 25--   X Loc UVB-p_raw
    02: 30     Y Loc offset_po
    03: 25--   Z Loc [:UVB-p_raw]

12: P36      Z=X*Y
    01: 25--   X Loc UVB-p_raw
    02: 32     Y Loc mult_pol
    03: 25--   Z Loc [:UVB-p_raw]

13: P95      End
end loop

14: P51      Spatial Average
    01: 4      Swath
    02: 21     First Loc UVB-a_raw
    03: 6      Avg Loc [:UVB-acet ]
```

```
15: P51      Spatial Average
    01: 4      Swath
    02: 25     First Loc UVB-p_raw
    03: 7      Avg Loc [:UVB-poly ]

16: P35      Z=X-Y
    01: 6      X Loc UVB-acet
    02: 7      Y Loc UVB-poly
    03: 8      Z Loc [:UVB-dif_m]

17: P37      Z=X*F
    01: 7      X Loc UVB-poly
    02: 1.5    F
Change this value for adjusting UV-B increase:
1.5 means 50% increase in UV-B as measured by
the sensors!
    03: 12     Z Loc [:UVB_targ ]

18: P89      If X<=>F
    01: 12     X Loc UVB_targ
    02: 4      <
    03: 0.000  F
    04: 30     Then Do

19: P30      Z=F
    01: 0.00   F
    02: 0      Exponent of 10
    03: 12     Z Loc [:UVB_targ ]

20: P95      End

21: P91      If Flag/Port
    01: 11     Do if flag 1 is high
    02: 30     Then Do

22: P38      Z=X/Y
    01: 6      X Loc UVB-acet
    02: 12     Y Loc UVB_targ
    03: 9      Z Loc [:UVB-achie]

23: P94      Else

24: P30      Z=F
    01: 1      F
    02: 0      Exponent of 10
    03: 9      Z Loc [:UVB-achie]

25: P95      End
end if then do else
```

```
26: P95      End
end subroutine
```

```
*****
Measure temperature and RH and calculate VPD
*****
```

```
27: P85      Beginning of Subroutine
    01: 2      Subroutine Number
```

```
28: P86      Do
    01: 48     Set high Port 8
```

```
29: P22      Excitation with Delay
    01: 3      EX Chan
    02: 0      Delay w/EX (units=.01sec)
    03: 10     Delay after EX (units=.01sec)
    04: 0      mV Excitation
```

```
30: P1       Volt (SE)
    01: 1      Rep
    02: 5      2500 mV slow Range
    03: 1      IN Chan
    04: 1      Loc [:Temp_air ]
    05: .1     Mult
    06: -40    Offset
```

```
31: P1       Volt (SE)
    01: 1      Rep
    02: 5      2500 mV slow Range
    03: 2      IN Chan
    04: 2      Loc [:RH_air  ]
    05: .1     Mult
    06: 0      Offset
```

```
32: P86      Do
    01: 58     Set low Port 8
```

```
33: P56      Saturation Vapor Pressure
    01: 1      Temperature Loc Temp_air
    02: 11     Loc [:VPsat_air]
```

```
34: P30      Z=F
    01: 100    F
    02: 0      Exponent of 10
    03: 15     Z Loc [:scratch ]
```

```
35: P35      Z=X-Y
```

```
01: 15      X Loc scratch
02: 2       Y Loc RH_air
03: 15      Z Loc [:scratch ]

36: P37     Z=X*F
01: 15      X Loc scratch
02: .01     F
03: 15      Z Loc [:scratch ]

37: P36     Z=X*Y
01: 15      X Loc scratch
02: 11      Y Loc VPsat_air
03: 3       Z Loc [:VPD_air ]

38: P95     End

*****
Measure PAR
*****

39: P85     Beginning of Subroutine
01: 3       Subroutine Number

40: P2      Volt (DIFF)
01: 1       Rep
02: 2       7.5 mV slow Range
03: 4       IN Chan
04: 35      Loc [:PAR 1   ]
05: -329.51 Mult
06: 0       Offset

41: P2      Volt (DIFF)
01: 1       Rep
02: 2       7.5 mV slow Range
03: 5       IN Chan
04: 36      Loc [:PAR 2   ]
05: -337.13 Mult
06: 0       Offset

42: P49     Spatial Maximum
01: 2       Swath
02: 35      First Loc PAR 1
03: 5       Max Value Loc [:PAR max12]

43: P95     End
end subroutine

*****
ON check
```

```
*****  
  
44: P85      Beginning of Subroutine  
    01: 6      Subroutine Number  
  
45: P89      If X<=>F  
    01: 7      X Loc UVB-poly  
    02: 4      <  
    03: 25     F  
    04: 30     Then Do  
  
46: P32      Z=Z+1  
    01: 34     Z Loc [:delay ON ]  
  
47: P89      If X<=>F  
    01: 34     X Loc delay ON  
    02: 3      >=  
    03: 30     F  
    04: 30     Then Do  
  
48: P86      Do  
    01: 15     Set high Flag 5  
  
49: P95      End  
end if then do  
  
50: P94      Else  
  
51: P30      Z=F  
    01: 0      F  
    02: 0      Exponent of 10  
    03: 34     Z Loc [:delay ON ]  
  
52: P95      End  
end if then do else  
  
53: P95      End  
end subroutine  
  
*****  
OFF check  
*****  
  
54: P85      Beginning of Subroutine  
    01: 7      Subroutine Number  
  
55: P89      If X<=>F  
    01: 5      X Loc PAR max12  
    02: 3      >=
```

```
03: 200      F
04: 30      Then Do

56: P32      Z=Z+1
01: 33      Z Loc [:delay OFF]

57: P89      If X<=>F
01: 33      X Loc delay OFF
02: 3       >=
03: 15      F
04: 30      Then Do

58: P89      If X<=>F
01: 7       X Loc UVB-poly
02: 3       >=
03: 25      F
04: 30      Then Do

59: P86      Do
01: 14      Set high Flag 4

60: P95      End
end if then do

61: P95      End
end if then do

62: P94      Else

63: P30      Z=F
01: 0       F
02: 0       Exponent of 10
03: 33      Z Loc [:delay OFF]

64: P95      End
end if then do else

65: P95      End
end subroutine

*****
Iterative procedure to adjust dimmer mV to target
*****

66: P85      Beginning of Subroutine
01: 8       Subroutine Number

67: P103     SDM-A04
01: 1       Reps
```

```
02: 0      Address
03: 16     Loc dimmer mV

68: P22    Excitation with Delay
01: 3      EX Chan
02: 0      Delay w/EX (units=.01sec)
03: 150    Delay after EX (units=.01sec)
04: 0      mV Excitation

69: P86    Do
01: 1      Call Subroutine 1

70: P95    End

*****

71: P85    Beginning of Subroutine
01: 9      Subroutine Number

72: P30    Z=F
01: 0      F
02: 0      Exponent of 10
03: 14     Z Loc [:iteration]

73: P87    Beginning of Loop
01: 0      Delay
02: 30     Loop Count
could be 0 but we use 30 to prevent an endless loop

adjust dimmer voltage

** if UVB is below target increase voltage
   but if voltage reaches maximum then exit
   the loop

74: P32    Z=Z+1
01: 14     Z Loc [:iteration]

75: P89    If X<=>F
01: 9      X Loc UVB-achie
02: 4      <
03: 0.95   F
04: 30     Then Do

76: P34    Z=X+F
01: 16     X Loc dimmer mV
02: 100    F
increase voltage 100 mV
```

```
03: 16      Z Loc [:dimmer mV]

77:  P89      If X<=>F
01:  16      X Loc dimmer mV
02:  3        >=
03:  5000     F
04:  30      Then Do

78:  P30      Z=F
01:  5000     F
02:  0        Exponent of 10
03:  16      Z Loc [:dimmer mV]

79:  P86      Do
01:  8        Call Subroutine 8

80:  P86      Do
01:  31      Exit Loop if true

81:  P95      End
end if then do

82:  P95      End
end if then do

** if UVB is above target then decrease voltage
   but if minimum voltage is reached then
   exit the loop

83:  P89      If X<=>F
01:  9        X Loc UVB-achie
02:  3        >=
03:  1.05     F
04:  30      Then Do

84:  P34      Z=X+F
01:  16      X Loc dimmer mV
02:  -100     F
decrease dimmer output 100 mV
03:  16      Z Loc [:dimmer mV]

85:  P89      If X<=>F
01:  16      X Loc dimmer mV
02:  4        <
03:  1801     F
04:  30      Then Do

86:  P30      Z=F
01:  1800     F
```

```
02: 0      Exponent of 10
03: 16     Z Loc [:dimmer mV]

87: P86    Do
01: 8      Call Subroutine 8

88: P86    Do
01: 31     Exit Loop if true

89: P95    End
end if then do

90: P95    End
end if then do

91: P86    Do
01: 8      Call Subroutine 8

if lamp output is on target then exit the loop

92: P89    If X<=>F
01: 9      X Loc UVB-achie
02: 3      >=
03: .95    F
04: 30     Then Do

93: P89    If X<=>F
01: 9      X Loc UVB-achie
02: 4      <
03: 1.05   F
04: 31     Exit Loop if true

94: P95    End
end if then do

95: P95    End
end loop

96: P95    End
end subroutine

97: P      End Table 3

*      A      Mode 10 Memory Allocation
01: 36     Input Locations
02: 120    Intermediate Locations
03: 0.0000 Final Storage Area 2
Int loc were 100 before
```

```
*      C      Mode 12 Security
01: 0000     LOCK 1
02: 0000     LOCK 2
03: 0000     LOCK 3
```

Input Location Assignments (with comments):

Key:

T=Table Number

E=Entry Number

L=Location Number

```
T:  E:  L:
3: 30: 1:  Loc [:Temp_air ]
3: 31: 2:  Loc [:RH_air   ]
3: 37: 3:  Z Loc [:VPD_air  ]
1:  9: 4:  Loc [:Temp_soil]
3: 42: 5:  Max Value Loc [:PAR max12]
3: 14: 6:  Avg Loc [:UVB-acet ]
3: 15: 7:  Avg Loc [:UVB-poly ]
3: 16: 8:  Z Loc [:UVB-dif_m]
3: 22: 9:  Z Loc [:UVB-achie]
3: 24: 9:  Z Loc [:UVB-achie]
1:  7:10:  Loc [:Battery  ]
3: 33:11:  Loc [:VPsat_air]
3: 17:12:  Z Loc [:UVB_targ ]
3: 19:12:  Z Loc [:UVB_targ ]
1: 31:13:  Z Loc [:on count ]
1: 54:13:  Z Loc [:on count ]
1: 21:14:  Z Loc [:iteration]
3: 72:14:  Z Loc [:iteration]
3: 74:14:  Z Loc [:iteration]
3: 34:15:  Z Loc [:scratch  ]
3: 35:15:  Z Loc [:scratch  ]
3: 36:15:  Z Loc [:scratch  ]
1:  3:16:  Z Loc [:dimmer mV]
1: 22:16:  Z Loc [:dimmer mV]
3: 76:16:  Z Loc [:dimmer mV]
3: 78:16:  Z Loc [:dimmer mV]
3: 84:16:  Z Loc [:dimmer mV]
3: 86:16:  Z Loc [:dimmer mV]
1: 12:17:  First Destination Loc [:UVB_ace_i]
3:  7:21:  Loc [:UVB-a_raw]
3:  9:21:  Z Loc [:UVB-a_raw]
3: 10:21:  Z Loc [:UVB-a_raw]
3:  8:25:  Loc [:UVB-p_raw]
```

```

3: 11: 25: Z Loc [:UVB-p_raw]
3: 12: 25: Z Loc [:UVB-p_raw]
3:  2: 29: F(X) Loc [:offset_ac]
3:  3: 30: F(X) Loc [:offset_po]
3:  4: 31: Z Loc [:mult_ac  ]
3:  5: 32: Z Loc [:mult_pol ]
1: 28: 33: Z Loc [:delay OFF]
3: 56: 33: Z Loc [:delay OFF]
3: 63: 33: Z Loc [:delay OFF]
1: 18: 34: Z Loc [:delay ON ]
3: 46: 34: Z Loc [:delay ON ]
3: 51: 34: Z Loc [:delay ON ]
3: 40: 35: Loc [:PAR 1  ]
3: 41: 36: Loc [:PAR 2  ]

```

Input Location Labels:

1:Temp_air	10:Battery	19:UVB_dif_i	28:UVB-p_raw
2:RH_air	11:VPsat_air	20:UVB_ach_i	29:offset_ac
3:VPD_air	12:UVB_targ	21:UVB-a_raw	30:offset_po
4:Temp_soil	13:on count	22:UVB-a_raw	31:mult_ac
5:PAR max12	14:iteration	23:UVB-a_raw	32:mult_pol
6:UVB-acet	15:scratch	24:UVB-a_raw	33:delay OFF
7:UVB-poly	16:dimmer mV	25:UVB-p_raw	34:delay ON
8:UVB-dif_m	17:UVB_ace_i	26:UVB-p_raw	35:PAR 1
9:UVB-achie	18:UVB_pol_i	27:UVB-p_raw	36:PAR 2