Use of BF3 Sunshine Sensor for Building Control

Rev	Date	By	Reason
1	15 Nov 02	John	Creation
2	12 Dec 02	John	Rearranged order of material

Introduction

The BF3 Sunshine Sensor has applications in building control, particularly for control of blinds, or for measurement of radiation load on any arbitrary surface.

The BF3 measures the Global (Total) and Diffuse radiation incident on a flat surface. The difference between these is therefore the amount of Direct beam solar radiation incident on the surface. This value can be used for the control of blinds, or heating and cooling systems.

This application note describes various different ways of doing this.

At the end is a description of the calculations required using (relatively!) simple approximations.

Separate BF3s

If the BF3 is mounted in the same plane as the surface of interest, it will give a direct output of the Global and Diffuse, and hence also Direct, radiation on that surface. These could be used to directly control blinds on that building face. For a relatively small number of faces, it may be simpler or more economical to use a BF3 for each face of interest, rather than integrate the calculations into a central system.

BF3 control box

The calculations below may be within the capability of the more powerful building management systems. Where this is not possible, or the user needs a system which is already programmed and validated, a control box is available for the BF3. This is powered from a standard “wall brick” and provides serial connections to the BF3 and BMS.

The control box contains an embedded PC, and runs full accuracy versions of the solar position algorithms. The control box drives the BF3 via its RS232 port, and provides solar radiation values for any surface via simple commands on either RS232 or RS485 links to the BMS. This system can be customised if required to suit the BMS protocol. If the BMS does not support a serial interface, a customised system could be made with voltage or digital outputs for the required surfaces.

Single BF3, calculate for multiple faces

If the solar Global and Diffuse are measured with a single BF3, then from a knowledge of the solar position and building orientation, it is possible to calculate the radiation load on any building face. These calculations are detailed below, and could be incorporated into the more sophisticated building management systems

Solar position

All angles are given in degrees, and the trigonometry works in degrees. These may need to be converted to radians, depending on your application. Accuracy will be better than 1 degree.

LAT = site latitude +ve North

LON = site longitude +ve East

DOY = Day of Year, ie 1 Jan = 1, 31 Dec = 365 (or 366 if leap year)

DEC = Solar Declination

$$DEC = \sin^{-1}[22.8 * \cos((DOY + 10) * 360 / 365.25)]$$

EOT = Equation of Time (difference between solar time (sundial time) and clock time

$$EOT = -0.1236 * \sin(x) + 0.0043 * \cos(x) - 0.1538 * \sin(2x) - 0.0608 * \cos(2x)$$

Where $x = (DOY – 1) * 360 / 365.25$ and EOT is in hours.

LSM = the longitude of the local standard meridian, ie the longitude of the centre of the local time zone.

LSM = (difference from GMT or UT) * 15°

If your system clock implements a summer time correction, remove this first.

AST = apparent solar time, (ie time as shown by a sundial at your site), in hours (0 – 24)

AST = local time + EOT + (LON – LSM) / 15

SolZ = solar zenith angle, ie angle between sun and vertically upwards

SolA = solar azimuth angle, ie angle of from North in direction NESW

$SolZ = \cos^{-1}(\sin(LAT) * \sin(DEC) + \cos(LAT) * \cos(DEC) * \cos(15 * AST - 180)$

$SolA = \tan^{-1}[-\cos(DEC) * \cos(LAT) * \sin(15 * AST – 180) / (\sin(DEC) - \sin(LAT) * \cos(SolZ))]$

NB you will need to use the four-quadrant rules for $\tan^{-1}$ to correctly resolve the azimuth angle.

Direct beam strength

The BF2 measures the Global and Diffuse radiation on a horizontal surface, so to get the power in the Direct solar beam, divide by the cosine of the solar zenith angle:

DIRnorm = (Global – Diffuse) / cos(SolZ)

This can give very high values when the sun is near the horizon, because we are dividing small values by small values, so truncate these calculated values to the maximum likely beam strength at that time

DIRmax = 1370 $W.m^{-2}$ * (0.9) ^ (1 / cos(SolZ)) (for SolZ < 90°, otherwise DIRmax = 0)

This assumes the site is near sea level, with a clear day atmospheric transmittivity of 0.9

If (DIRnorm > DIRmax) then DIRnorm = DIRmax

Direct beam strength on any surface

SurfA = the azimuth angle of the perpendicular to the surface from North in direction NESW

SurfZ = the zenith angle of the perpendicular to the surface, ie SurfZ = 0 is a horizontal surface, SurfZ = 90 is a vertical surface.

AngIn = the angle of incidence of the sun to the surface, ie AngIn = 0 means that the sun is perpendicular to the surface, and the surface receives the full power of the sun's rays.

$$\cos(AngIn) = \cos(SolZ) * \cos(SurfZ) + \sin (SolZ) * \sin(SurfZ) * \cos(SolA – SurfA)$$

DIRsurf = Direct solar beam power on the surface

DIRsurf = DIRnorm * cos(AngIn)

Other possibilities

Look-up tables

For some BMS controllers, it may be simpler to tabulate the solar position data for the site of interest, and use look-up tables and interpolation to return the required values. Contact us if you need help in designing these tables.

END