

Astronomical Routines

Introduction

These MMBasic routines are to support users that may require astronomical support, such as a weather station. Due to their size they are targeted at the CMM2 and H7 systems and its recommended to use it as an include file. All routines are based on Astronomical Algorithms by Jean Meeus, First Edition (1991).

Period Limits

This will give correct results for any date between 01 Jan 1961 and Feb 28 2100, although dates from March 1 1900 to 1961 would be reasonably accurate with an additional error of no greater than one minute of time. These limits have been set as it simplifies some of the calculations and would not affect most uses of these routines.

Algorithms Supported

1. Sun, Moon and visible planets Transit, Rise and Set. These also include altitude at transit and azimuth of rise. For the sun it also includes civil, nautical and astronomical twilight/dusk times.
2. Equinox and Solstices.
3. Moon Phases.
4. Instant Sun, Moon and visible planet position.

All input times are local and must factor in daylight savings. All output times returned are local and corrected for daylight savings time for the specific location. Distance, Right Ascension and Declination are geocentric.

Managing Daylight Savings Time (DST)

These routines were written for a weather station where daily astronomical information is returned to the user in their local time thus negating the user sorting out correct time zones depending on whether DST is active or not. The Initialisation Command defines all the information required by the routines to resolve correct time zones. Times for change in DST status are all based on local times, see Initialise Command below.

The MMBasic command Yearly Task One should be called just after the Initialisation Command and then just after rollover into 01 January for future years. This sets up the DST change over times for the year to ensure all times are properly corrected for DST. This command also calculates Delta Time for the year, which is used in some of the routines for converting between UT1 and Terrestrial time.

Some commands return dates and times that span more than a day, such as the Moon Phases Command or Seasons Command, and as such may span changes in DST, however times will be correctly adjusted for DST depending on when they occur using the previously yearly calculated DST start and end times. In addition, Planet and Moon rise, set and transit times may span a DST change, these will be correctly adjusted. If you need to use any Commands where the requested date and time may be outside the current

calculated DST start and end times just run the Yearly Task One for the required year prior to running the other Command.

Commands

The command string determines what is to be undertaken by the astronomical program. Commands are listed below, and users should note that some commands must be called on initialisation. The command string consists of comma delimited fields with the first field always being the command number that may then be followed by additional fields that are used by the command, such as dates or times. Any dates and times in the command are assumed to be local and for ease of use match the same format as MMBasic DATE\$ and TIME\$ commands and functions. White spaces are ignored. Returned times generally do not include seconds and are in the format of “HH:MM”

Initialise.

Command String.	
FIELD	DATA
1	Command Number = 1
2	Site Latitude. Negative number indicates southern hemisphere
3	Site Longitude. Negative number is West.
4	Time Zone Hour
5	Daylight Saving Time (DST) Zone Hour *
6	DST Start Month
7	DST Start Week
8	DST Start Day (Sunday is 0)
9	DST Start Hour (24 hour clock)
10	DST End Month
11	DST End Week
12	DST End Day (Sunday is 0)
13	DST End Hour (24 hour clock)

*Note.

1. All DST times and dates are local times and dates.
2. If the site does not have Daylight Savings Time then set the Daylight Saving Time (DST) Zone Hour (field 5) to the same value as Time Zone Hour (field 4) and ignore populating any of the DST start and End fields (field 6 to 13).

For example,

"1,-34.76639,138.5367,9.5,10.5,10,1,0,2,4,1,0,3"

Return string will be “00” if all OK else an error number (see Errors)

Yearly Task

This command should be called once for the year that astronomical information is required before any other commands to calculate the Daylight Savings start and end Julian Date and Delta Time for that year. It undertakes the following tasks,

1. Calculates DST start (DST.UTC_START_JD) and DST end (DST.UTC_END_JD).
2. Calculates Delta Time for defining relationship between Terrestrial Time and Universal Time 1 (UT1).

Command String.

FIELD	DATA
1	Command Number = 2
2	Local Date as "DD-MM-YYYY"

For example,

"2,23-05-2023".

Return string will be "00" if all OK else an error number (see Errors)

Sun and Moon Transit, Rise Set Times (TRS)

This is normally called once per day, but of course you can request any day within the past or future as long as it's within the period limits and correct DST change-over dates and times have been calculated (Managing DST above).

Command String

FIELD	DATA
1	Command Number = 3
2	Local Date as "DD-MM-YYYY"

For example,

"3,23-05-2023".

Return String

FIELD	DATA
1	Error number, 00 if no error
2	Sun Transit Hour as HH:MM
3	Sun Transit Altitude (whole degrees)
4	Sun Rise Hour as HH:MM
5	Sun Rise Azimuth (whole degrees)
6	Sun Set Hour as HH:MM
7	Sun Set Azimuth (whole degrees)
8	Civil Twilight Hour as HH:MM
9	Civil Dusk Hour as HH:MM
10	Nautical Twilight Hour as HH:MM
11	Nautical Dusk Hour as HH:MM
12	Astronomical Twilight Hour as HH:MM
13	Astronomical Dusk Hour as HH:MM
14	Day Length as HH:MM:SS
15	Sun Distance at Transit (millions of KM to nearest 1000km)
16	Moon Transit Hour as HH:MM
17	Moon Transit Altitude(whole degrees)
18	Moon Rise Hour as HH:MM
19	Moon Rise Azimuth (whole degrees)
20	Moon Set Hour as HH:MM
21	Moon Set Azimuth (whole degrees)
22	Moon Distance at Transit in km. If no Transit then distance at Rise.

Notes

1. The actual times returned in the above are the local times of the event and factor in the Daylight Saving Time (DST) depending on when the event occurred. For example, if the date requested for this command fell on a DST change day and the Moon rise was to occur during the DST period then it would be adjusted for the DST Time Zone hours but if in the same command request the Moon Set occurred in the non DST period its time would be adjusted for Time Zone hours.
2. As per standard practice all times returned are rounded to the nearest minute and in the format of HH:MM.
3. The routines do not take into account local elevation or local obstructions such as hills.
4. Where there is no Moon transit or rise or set the relevant hour will be set to 00 and the transit Altitude (Transit) or Azimuth (Rise and Set) will be set to "NIL".

To UTC

Will convert the date and times in command string to UTC factoring in DST based around the initialisation command information.

Command String

FIELD	DATA
1	Command Number = 4
2	Local Date to convert to UTC as "DD-MM-YYYY"
	Local Time to convert to UTC as "HH:MM:SS" (24 hour format)

"4,23-05-2023,02:05:00".

Return String

FIELD	DATA
1	Error number, 00 if no error
2	UTC Date as "DD-MM-YYYY"
3	UTC Time as "HH:MM:SS" (24 hour format)

To Local

Will convert the date and times in command string to UTC factoring in DST based around the initialisation command information.

Command String

FIELD	DATA
1	Command Number = 5
2	UTC Date to convert to Local as "DD-MM-YYYY"
	UTC Time to convert to Local as "HH:MM:SS" (24 hour format)

"4,23-05-2023,02:05:00".

Return String

FIELD	DATA
1	Error number, 00 if no error
2	Local Date as "DD-MM-YYYY"
3	Local Time as "HH:MM:SS" (24 hour format)

Moon Phases

Will return the dates and times of the Moon Phases for a specified month. If THERE IS a fifth phase (i.e 'blue moon') it will also be calculated.

Command String

FIELD	DATA
1	Command Number = 6
2	UTC Date of the required month as "DD-MM-YYYY"

"6,23-05-2023".

Note that the date is ignored as calculations are based on the middle of the month.

Return String

FIELD	DATA
1	Error number, 00 if no error
2	New Moon Date as "DD-MM-YYYY"
3	New Moon Time as "HH:MM:SS" (24 hour format)
4	First Quarter Date as "DD-MM-YYYY"
5	First Quarter Time as "HH:MM:SS" (24 hour format)
6	Full Moon Date as "DD-MM-YYYY"
7	Full Moon Time as "HH:MM:SS" (24 hour format)
8	Last Quarter Date as "DD-MM-YYYY"
9	Last Quarter Time as "HH:MM:SS" (24 hour format)
10	Additional Phase Type, Nil =0, New=1, First Qtr=2, Full = 3, Last Qtr=4
11	Additional Phase Date as "DD-MM-YYYY" Note if Field 10 is 0 (No Additional Phase) this should be ignored.
12	Additional Phase Time as "HH:MM:SS" " Note if Field 10 is 0 (No Additional Phase) this defaults to 00:00 Hrs
13 to ??	Lunar Eclipse data (see below)

The Lunar Eclipse information will only be present if an eclipse (Penumbra or Umbra) is occurring on the full moon. Depending on what type of eclipse is occurring will define what data is returned.

If no eclipse then field is NIL else in all other cases where an eclipse occurs the first three fields are,

Eclipse Return String

FIELD	DATA
13	Eclipse Date "DD-MM-YYYY". This is the date of the full moon and hence maximum eclipse. It is possible that first or last contacts may occur on days after or before if the maximum eclipse is close to a day rollover. The day can easily be evaluated by checking if there is a significant hour change between each first or last contact. For example if the maximum penumbra occurs at 00.42 hours and the penumbra contact is 22:38 hours then the penumbra contact would be on the previous day.
14	Umbra Magnitude (negative number if no Umbra eclipse)
15	Penumbra Magnitude

The magnitudes will define what the rest of the fields will be populated with. The Umbra negative, positive Penumbra negative and positive below refer to their calculated magnitudes.

Penumbra Eclipse: Umbra Negative and Penumbra Positive

FIELD	DATA
16	Time of First Contact with Penumbra as HH:MM
17	Time of Maximum of Penumbra Eclipse as HH:MM
18	Time of Last Contact with Penumbra as HH:MM

Partial Umbra Eclipse: Umbra Positive but less than One

FIELD	DATA
16	Time of First Contact with Penumbra as HH:MM
17	Time of First Contact with Umbra as HH:MM
18	Time of Maximum of Umbra Eclipse as HH:MM
19	Time of Last Contact with Umbra as HH:MM
20	Time of Last Contact with Penumbra as HH:MM

Full Umbra Eclipse: Umbra Greater than One

FIELD	DATA
16	Time of First Contact with Penumbra as HH:MM
17	Time of First Contact with Umbra as HH:MM
18	Time of Start of Total Umbra Eclipse as HH:MM
19	Time of Maximum of Umbra Eclipse as HH:MM
20	Time of End of Total Umbra Eclipse as HH:MM
21	Time of Last Contact with Umbra as HH:MM
22	Time of Last Contact with Penumbra as HH:MM

Notes:

If no Additional Phase in a month then Additional Phase Type is 0 and date is 01-01-1901.

Seasons (Equinoxes and Solstices)

Will calculates the equinoxes and solstices for the required year.

Command String

FIELD	DATA
1	Command Number = 7
2	Local Date for calculation "DD-MM-YYYY"

"7,23-05-2023".

Notes

1. Only the year is used in the calculations.
2. The actual times returned in the above are the local times of the event and factor in the Daylight Saving Time (DST) depending on when the event occurred.

- As per standard practice all times returned are rounded to the nearest minute and in the format of HH:MM.

Return String

FIELD	DATA
1	Error number, 00 if no error
2	March Equinox Date as "DD-MM-YYYY"
3	March Equinox Time as HH:MM
4	June Solstices Date as "DD-MM-YYYY"
5	June Solstices Time as HH:MM
6	September Equinox Date as "DD-MM-YYYY"
7	September Equinox Time as HH:MM
8	December Solstices Date as "DD-MM-YYYY"
9	December Solstices Time as HH:MM
10	June Solstices Total Daylight Hours as HH:MM:SS
11	December Solstices Total Daylight Hours as HH:MML:SS
12	Leap Year ("Y" is true else "N")

Sun Position

This will return the Sun position at the requested local date and time.

Command String

FIELD	DATA
1	Command Number: 8
2	Local Date as "DD-MM-YYYY"
3	Local Time as "HH:MM:SS" (24 hour format)

For example,

"8,23-05-2023, 12:30:00".

Return String

FIELD	DATA
1	Error number, 00 if no error)
2	Azimuth Degree (2 Decimal Places)
3	Altitude Degree (2 Decimal Places)
4	Distance (millions of KM to nearest 1000km)
5	Right Ascension Hours (3 decimal places)
6	Declination Degrees (3 decimal places)

Moon Position

This will return the Planets position at the requested local date and time.

Command String

FIELD	DATA
1	Command Number: 9
2	Local Date as "DD-MM-YYYY"
3	Local Time as "HH:MM:SS" (24 hour format)

For example,
 "9,23-05-2023, 12:30:00".

Return String

FIELD	DATA
1	Error number, 00 if no error)
2	Azimuth Degree (2 Decimal Places)
3	Altitude Degree (2 Decimal Places)
4	Distance (KM)
5	Right Ascension Hours (3 decimal places)
6	Declination Degrees (3 decimal places)
7	Illumination Fraction
8	Position Angle (degrees)
9	Moon Heliocentric Ecliptic Longitude Degrees (2 decimal places)
10	Moon Heliocentric Ecliptic Latitude Degrees (2 decimal places)

Notes:

1. The Moon Heliocentric Ecliptic Longitude and Latitude (fields 9 and 10) are corrected for precession. The values in these fields align to the values calculated in MICA 2 Position of Geometric Heliocentric Ecliptic of J2000.

Planet Position

This will return the Planets position at the requested local date and time.

Command String

FIELD	DATA
1	Command Number: Mercury = 10 Venus = 11 Mars = 12 Jupiter = 13 Saturn = 14
2	Local Date as "DD-MM-YYYY"
3	Local Time as "HH:MM:SS" (24 hour format)

For example Mars position is,
 "12,23-05-2023, 12:30:00".

Return String

FIELD	DATA
1	Error number, 00 if no error)
2	Azimuth Degree (2 Decimal Places)
3	Altitude Degree (2 Decimal Places)
4	Distance (millions of KM to nearest 1000km)
5	Right Ascension Hours (3 decimal places)
6	Declination Degrees (2 decimal places)
7	Magnitude
8	Size in seconds of a degree

9	Planet Heliocentric Ecliptic Longitude Degrees (2 decimal places)
10	Planet Heliocentric Ecliptic Latitude Degrees (2 decimal places)
11	Earth Heliocentric Ecliptic Latitude Degrees (2 decimal places)
12	Planet Distance from Sun in AU.
13	Earth Distance from Sun in AU.

Notes:

1. The Planet Heliocentric Ecliptic Longitude and Latitude (fields 7 and 8) and Earth Heliocentric Ecliptic Longitude (field 9) are corrected for precession. Note that due to the accuracy of this program the Earth Heliocentric Ecliptic Latitude can be regarded as zero and so is not returned (its usually less than 0.01 degrees). The values in these fields and the distances to the Sun (fields 10 and 11) align to the values calculated in MICA 2 Position of Geometric Heliocentric Ecliptic of J2000.

Planet Transit, Rise Set Times (TRS)

This is normally called once per day, but of course it can be requested any day within the past or future as long as it's within the period limits and correct DST change-over dates and times have been calculated (Managing DST above).

Command String

FIELD	DATA
1	Command Number = 15
2	Local Date as "DD-MM-YYYY"

For example,

"15,23-05-2023".

Return String

FIELD	DATA
1	Error number, 00 if no error
2	Mercury Transit Hour as HH:MM
3	Mercury Transit Altitude (whole degrees)
4	Mercury Rise Hour as HH:MM
5	Mercury Rise Azimuth (whole degrees)
6	Mercury Set Hour as HH:MM
7	Mercury Set Azimuth (whole degrees)
8	Mercury Magnitude
9	Mercury Size in seconds of a degree
10	Mercury Transit Distance in millions of KM.
11	Venus Transit Hour as HH:MM
12	Venus Transit Altitude (whole degrees)
13	Venus Rise Hour as HH:MM
14	Venus Rise Azimuth (whole degrees)
15	Venus Set Hour as HH:MM
16	Venus Set Azimuth (whole degrees)
17	Venus Magnitude
18	Venus Size in seconds of a degree

19	Venus Transit Distance in millions of KM.
20	Mars Transit Hour as HH:MM
21	Mars Transit Altitude (whole degrees)
22	Mars Rise Hour as HH:MM
23	Mars Rise Azimuth (whole degrees)
24	Mars Set Hour as HH:MM
25	Mars Set Azimuth (whole degrees)
26	Mars Magnitude
27	Mars Size in seconds of a degree
28	Mars Transit Distance in millions of KM.
29	Jupiter Transit Hour as HH:MM
30	Jupiter Transit Altitude (whole degrees)
31	Jupiter Rise Hour as HH:MM
32	Jupiter Rise Azimuth (whole degrees)
33	Jupiter Set Hour as HH:MM
34	Jupiter Set Azimuth (whole degrees)
35	Jupiter Magnitude
36	Jupiter Size in seconds of a degree
37	Jupiter Transit Distance in millions of KM.
38	Saturn Transit Hour as HH:MM
39	Saturn Transit Altitude (whole degrees)
40	Saturn Rise Hour as HH:MM
41	Saturn Rise Azimuth (whole degrees)
42	Saturn Set Hour as HH:MM
43	Saturn Set Azimuth (whole degrees)
44	Saturn Magnitude
45	Saturn Size in seconds of a degree
46	Saturn Transit Distance in millions of KM.

Notes

1. This return string is 245 characters long as it covers Mercury, Venus, Mars, Jupiter and Saturn.
2. The actual times returned in the above are the local times of the event and factor in the Daylight Saving Time (DST) depending on when the event occurred.
3. As per standard practice all times returned are rounded to the nearest minute and in the format of HH:MM.
4. The routines do not take into account local elevation or local obstructions such as hills.
5. Where there is no Planet transit or rise or set the relevant hour will be set to 00 and the transit Altitude (Transit) or Azimuth (Rise and Set) will be set to "NIL" (the string remains the same length).