Development of Motion Control Method for Laser Soldering Process

Federal Manufacturing & Technologies

Scott S. Yerganian

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P. M. Biggs, Project Leader

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ABSTRACT

Development of a method to generate the motion control data for sealing an electronic housing using laser soldering is described. The motion required to move the housing under the laser is a nonstandard application and was performed with a four-axis system using the timed data streaming mode capabilities of a Compumotor AT6400 indexer. A Microsoft Excel 5.0 spreadsheet (named lsrauto.xls) was created to calculate the movement of the part under the laser, and macros were written into the spreadsheet to allow the user to easily create this data. A data verification method was developed for simulating the motion data. The geometry of the assembly was generated using Parametric Technology Corporation Pro/E version 15. This geometry was then converted using Pro/DADS version 3.1 from Computer Aided Design Software Inc. (CADSI), and the simulation was carried out using DADS version 8.0 from CADSI.

SUMMARY

A method was developed for generating the motion of a radar housing under a laser for a laser soldering process. The purpose of this process is to solder a lid to a backing plate in order to seal the hybrid microelectronic circuit assembly from the environment. The design of this housing makes this a nonstandard application in which a two-dimensional table and common contouring motion control operation cannot be used because the laser is not along the axis of rotation of the part. Instead, the laser is along one of the translational axes, and the motion requires a method of driving the assembly under the laser in two dimensions while rotating about the assembly's center.

To further complicate matters, there are coaxial cables which get in the way and shade the assembly from the laser beam. This requires special movements to solder under the cables. To generate the motion, a four-axis system driven by a Compumotor AT6400 indexer was used. The software to program this indexer allows for a timed data streaming mode for nonstandard movements. In this mode, the user picks a streaming update interval, which may be any even number time interval from 10 milliseconds minimum to 50 milliseconds maximum. The user then supplies incremental move distances for each axis at each update point in time. In order to generate the data required for this streaming mode, a Microsoft Excel 5.0 spreadsheet (named lsrauto.xls) was created to calculate the movement of the part under the laser and convert this movement into the incremental step moves required. The amount of data to describe the motion becomes quite large, and macros were written into the spreadsheet to allow the user to easily create this data. A method was also developed for simulating the motion data.

The geometry of the assembly was generated using Parametric Technology Corporation Pro/E version 15. This geometry was then converted using Pro/DADS version 3.1 from Computer Aided Design Software Inc. (CADSI) and the simulation was carried out using DADS version 8.0 from CADSI.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to develop a method for driving a radar housing containing a hybrid microelectronic circuit under a laser to solder it, sealing the assembly from the environment. A Microsoft Excel 5.0 spreadsheet was created to calculate the required movements of the part under the laser and to convert these movements into the incremental step moves required to drive the motion control system. The amount of data to describe the motion becomes quite large, and macros were written into the spreadsheet to allow the user to easily create this data. A method was also developed for simulating the motion data to verify the results of the spreadsheet calculations.

ACTIVITY

Motion Requirements

The design of the radar housing makes its movement under the laser a nonstandard application in which a two-dimensional table and common contouring motion control operation cannot be used because the laser is not along the axis of rotation of the part. Instead, the laser is along one of the translational axes and the motion requires a method of driving the assembly under the laser in two dimensions while rotating about the assembly's center (see Figure 1). To further complicate matters, there are coaxial cables that get in the way and shade the assembly from the laser beam. This requires special movements to solder under the cables. To generate the motion, a four-axis system driven by a Compumotor AT6400 indexer was used. The software to program this indexer allows for a timed data streaming mode for nonstandard movements. In this mode, the user picks a streaming update interval, which may be any even number time interval from 10 milliseconds minimum to 50 milliseconds maximum. The user then supplies incremental move distances for each axis at each update point in time.

Method for Generating Streaming Data to Drive the Motion Control System

The approach to generate the data for the motion control system was to allow the user to describe the desired motion around the part in the body fixed coordinate frame. This data was then to be transformed into incremental moves in the global coordinate frame required by the motion control system. Referring to Figure 2, the motion around the part is defined by the user in terms of the body fixed S' vector. The components of this vector are the distances from the center of the part to the focal point of the laser, as the laser moves around the entire perimeter of the part. The focal point of the laser will always be on the outer surface of the part. Because of this, the

Figure 1. Motion Control System

S' vector (in body fixed coordinates) will have a constant y' coordinate (equal to plus or minus one half the width of the part) and vary in the x' direction, when the laser is shining on the top or bottom of the part. Likewise, when the laser is shining on the right or left sides of the part, the S' vector will have a constant x' coordinate (equal to plus or minus one half the length of the part) and vary in the y' direction. A transformation matrix is then used to convert the S' vector in the body fixed coordinate frame to the S vector in global coordinates. The position of the focal point of the laser is labeled as the r_p vector and is fixed at all times with respect to the global coordinate system. The position of the center of the part (at any point in time, in global coordinates) is labeled as the r_A vector. This vector is found by subtracting the S vector from the r_p vector. The incremental moves used to drive the motion control system are equal to the

Figure 2. Positional Vectors of Part in Body Fixed and Global Coordinate Frames

changes in the global x and y components of the r_A vector. Derivatives of the S vector were taken to determine the velocity and acceleration of the motion control system. If the velocities are too high, whipping of the lead screw will occur. If the accelerations are too high, the stepper or servo motors of the motion control system will not have enough power and torque to create the motion.

$\vec{s}'$ = vector in body fixed coordinates from the part center to the focal point of the laser

$\vec{s} = A\vec{s}'$ where A is the transformation matrix

$$A = \begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$$

Expanding $\vec{s}$ in terms of its components in the $\hat{i}$ and $\hat{j}$ directions:

$$\vec{s} = (s'_x \cos \beta - s'_y \sin \beta) \hat{i} + (s'_x \sin \beta + s'_y \cos \beta) \hat{j} \quad (\text{equation 1})$$

$$\vec{r}_A = \vec{r}_p - \vec{s}$$

Because $\vec{r}_p$ is a fixed point in the global coordinate system, the velocity of the center of the part $\dot{\vec{r}}_A = -\dot{\vec{s}}$. Likewise, the acceleration of the center of the part $\ddot{\vec{r}}_A = -\ddot{\vec{s}}$.

Taking the derivatives of (equation 1) to find the general relationship for the part velocity:

$$\begin{aligned} \dot{\vec{s}} = & (-s'_x \dot{\beta} \sin \beta + \dot{s}'_x \cos \beta - s'_y \dot{\beta} \cos \beta - \dot{s}'_y \sin \beta) \hat{i} \\ & + \\ & (s'_x \dot{\beta} \cos \beta + \dot{s}'_x \sin \beta - s'_y \dot{\beta} \sin \beta + \dot{s}'_y \cos \beta) \hat{j} \end{aligned} \quad (\text{equation 2})$$

Differentiating (equation 2) to find the general relationship for the part acceleration:

$$\begin{aligned} \ddot{\vec{s}} = & (-s'_x \dot{\beta}^2 \cos \beta - s'_x \ddot{\beta} \sin \beta - 2\dot{s}'_x \dot{\beta} \sin \beta + \ddot{s}'_x \cos \beta + s'_y \dot{\beta}^2 \sin \beta - s'_y \ddot{\beta} \cos \beta - 2\dot{s}'_y \dot{\beta} \cos \beta - \ddot{s}'_y \sin \beta) \hat{i} \\ & + \\ & (-s'_x \dot{\beta}^2 \sin \beta + s'_x \ddot{\beta} \cos \beta + 2\dot{s}'_x \dot{\beta} \cos \beta + \ddot{s}'_x \sin \beta - s'_y \dot{\beta}^2 \cos \beta - s'_y \ddot{\beta} \sin \beta - 2\dot{s}'_y \dot{\beta} \sin \beta + \ddot{s}'_y \cos \beta) \hat{j} \end{aligned} \quad (\text{equation 3})$$

Derivation of Velocity and Acceleration for Constant Travel Speed While Rotating Through Corner

If the laser is to move at a constant travel speed, remain perpendicular to the edge of the part, and the part rotations begin and end with the beginning and ending of each corner, the velocities and accelerations in the corners become very large. The smaller the corner radius, the higher these velocities and accelerations become. The reason for this is that, for this type of motion, the angular velocity around the corner is the travel speed (tangential velocity) divided by the radius. For a constant travel velocity, this angular velocity, and consequently the velocities of the part to correct for the off-radius rotation, become larger as the radius becomes smaller. In the limit, the velocities and accelerations approach infinity for a zero radius (perfectly sharp corner). Deriving the magnitude of the part velocity and accelerations, for this motion in a corner, as a function of the travel speed and part geometry (referring to Figure 3):

Figure 3. Motion Around Corner With Laser Perpendicular to Surface

$$s'_x = \frac{L}{2} - r + r \sin \beta \quad (\text{equation 4})$$

$$s'_y = \frac{W}{2} - r + r \cos \beta \quad (\text{equation 5})$$

$$\dot{s}'_x = r \dot{\beta} \cos \beta \quad (\text{equation 6})$$

$$\dot{s}'_y = -r \dot{\beta} \sin \beta \quad (\text{equation 7})$$

For constant travel speed V around the corner:

$$\dot{\beta} = \frac{V}{r} \quad \text{and} \quad \ddot{\beta} = 0$$

Plugging the above relationships for $\dot{\beta}$ into (equations 6 and 7):

$$\dot{s}'_x = V \cos \beta \quad (\text{equation 8})$$

$$\dot{s}'_y = -V \sin \beta \quad (\text{equation 9})$$

Plugging the relationship $\dot{\beta} = \frac{V}{r}$ and (equations 8 and 9) into (equation 2):

$$\begin{aligned} \dot{\mathbf{s}} = & \left[-\left(\frac{L}{2} - r + r \sin \beta\right) \frac{V}{r} \sin \beta + V \cos^2 \beta - \left(\frac{W}{2} - r + r \cos \beta\right) \frac{V}{r} \cos \beta + V \sin^2 \beta \right] \hat{\mathbf{i}} \\ & + \\ & \left[\left(\frac{L}{2} - r + r \sin \beta\right) \frac{V}{r} \cos \beta + V \cos \beta \sin \beta - \left(\frac{W}{2} - r + r \cos \beta\right) \frac{V}{r} \sin \beta - V \sin \beta \cos \beta \right] \hat{\mathbf{j}} \end{aligned}$$

Simplifying and using the identity $\sin^2 \beta + \cos^2 \beta = 1$:

$$\begin{aligned} \dot{\mathbf{s}} = & \left[-\frac{V}{r} \left\{ \left(\frac{L}{2} - r\right) \sin \beta + \left(\frac{W}{2} - r\right) \cos \beta \right\} \right] \hat{\mathbf{i}} \\ & + \\ & \left[\frac{V}{r} \left\{ \left(\frac{L}{2} - r\right) \cos \beta - \left(\frac{W}{2} - r\right) \sin \beta \right\} \right] \hat{\mathbf{j}} \end{aligned} \quad (\text{equation 10})$$

Differentiating (equation 10) to find the acceleration, and using the relationship $\dot{\beta} = \frac{V}{r}$:

$$\ddot{\mathbf{s}} = \left[-\left(\frac{V}{r}\right)^2 \left\{ \left(\frac{L}{2} - r\right) \cos\beta - \left(\frac{W}{2} - r\right) \sin\beta \right\} \right] \hat{\mathbf{i}} + \left[-\left(\frac{V}{r}\right)^2 \left\{ \left(\frac{L}{2} - r\right) \sin\beta + \left(\frac{W}{2} - r\right) \cos\beta \right\} \right] \hat{\mathbf{j}} \quad (\text{equation 11})$$

The maximum velocity in the corner occurs when its derivative is zero. For the non-trivial solution, the bracketed term of (equation 11) in the x and y direction are set equal to zero:

$$\dot{s}_{x \max} \text{ occurs when } \left\{ \left(\frac{L}{2} - r\right) \cos\beta - \left(\frac{W}{2} - r\right) \sin\beta \right\} = 0 \quad \text{or} \quad \tan\beta = \frac{\left(\frac{L}{2} - r\right)}{\left(\frac{W}{2} - r\right)} \quad (\text{equation 12})$$

$$\dot{s}_{y \max} \text{ occurs when } \left\{ \left(\frac{L}{2} - r\right) \sin\beta + \left(\frac{W}{2} - r\right) \cos\beta \right\} = 0 \quad \text{or} \quad -\tan\beta = \frac{\left(\frac{W}{2} - r\right)}{\left(\frac{L}{2} - r\right)} \quad (\text{equation 13})$$

The maximum acceleration in the corner occurs when its derivative is zero. Taking the derivative of (equation 11) and using the relationship $\dot{\beta} = \frac{V}{r}$:

$$\ddot{\mathbf{s}} = \left[\left(\frac{V}{r}\right)^3 \left\{ \left(\frac{L}{2} - r\right) \sin\beta + \left(\frac{W}{2} - r\right) \cos\beta \right\} \right] \hat{\mathbf{i}} + \left[-\left(\frac{V}{r}\right)^3 \left\{ \left(\frac{L}{2} - r\right) \cos\beta - \left(\frac{W}{2} - r\right) \sin\beta \right\} \right] \hat{\mathbf{j}} \quad (\text{equation 14})$$

For the non-trivial solution, the bracketed term of the components in the x and y direction of (equation 14) are set equal to zero:

$$\ddot{s}_{x \max} \text{ occurs when } \left\{ \left(\frac{L}{2} - r \right) \sin \beta + \left(\frac{W}{2} - r \right) \cos \beta \right\} = 0 \quad \text{or} \quad -\tan \beta = \frac{\left(\frac{W}{2} - r \right)}{\left(\frac{L}{2} - r \right)}$$

(equation 15)

$$\ddot{s}_{y \max} \text{ occurs when } \left\{ \left(\frac{L}{2} - r \right) \cos \beta - \left(\frac{W}{2} - r \right) \sin \beta \right\} = 0 \quad \text{or} \quad \tan \beta = \frac{\left(\frac{L}{2} - r \right)}{\left(\frac{W}{2} - r \right)}$$

(equation 16)

The use of these relationships allows the user to determine the requirements on a motion control system if this motion is desired in the corners. To find the maximum velocities through the corner in global coordinates, equation 10 is evaluated at the angles described by equations 12 and 13. To find the maximum accelerations through the corner in global coordinates, equation 11 is evaluated at the angles described by equations 15 and 16.

The demands on the motion control system, for a part with a small corner radius, may be significantly reduced, if the constraint of holding the part perpendicular to the laser is relaxed when nearing and exiting a corner. This allows the rotation of the part to be spread over a greater distance (beginning rotation at a small distance before reaching the corner radius, and ending rotation at a small distance after the corner radius).

Method for Soldering Under Coaxial Cables

A method was developed to allow the laser to solder under the area shaded by a cable. In this method, the laser is brought up to the edge of the cable diameter, or the diameter of a tolerance "keep out" zone around the cable. The edge of the laser then "hugs" this diameter as the part is rotated, to allow the beam to move under the cable. Since the angle beta is used to describe the absolute rotation of the part, the angle alpha is used to describe the angle of the laser as it moves under the cable. The angle alpha must be solved for as a function of the distance of the centerline of the laser under the cable. The absolute rotation beta of the part is then either increased or decreased by the alpha angle, depending on the direction of movement around the part. For deriving the angle alpha as the laser is moved under a cable, see Figure 4.

Figure 4. Method of Rotating Part to Allow Laser to Solder Under Cable

From the distances defined in Figure 4:

$$\Delta s = \left(\frac{D+B}{2} \right) - \left(\frac{D+B}{2} \right) \cos \alpha + \left(H - \left(\frac{D+B}{2} \right) \sin \alpha \right) \tan \alpha$$

Writing the $\tan \alpha$ as the $\frac{\sin \alpha}{\cos \alpha}$:

$$\Delta s = \left(\frac{D+B}{2} \right) - \left(\frac{D+B}{2} \right) \cos \alpha + H \frac{\sin \alpha}{\cos \alpha} - \left(\frac{D+B}{2} \right) \frac{\sin^2 \alpha}{\cos \alpha}$$

Multiplying both sides by $\cos \alpha$:

$$\Delta s \cos \alpha = \left(\frac{D+B}{2} \right) \cos \alpha - \left(\frac{D+B}{2} \right) \cos^2 \alpha + H \sin \alpha - \left(\frac{D+B}{2} \right) \sin^2 \alpha$$

Using the identity $\sin^2 \alpha + \cos^2 \alpha = 1$:

$$\Delta s \cos \alpha = \left(\frac{D+B}{2} \right) \cos \alpha - \left(\frac{D+B}{2} \right) + H \sin \alpha$$

Rearranging terms:

$$\left[\Delta s - \left(\frac{D+B}{2} \right) \right] \cos \alpha + \left(\frac{D+B}{2} \right) = H \sin \alpha$$

Squaring both sides:

$$\left[\Delta s - \left(\frac{D+B}{2} \right) \right]^2 \cos^2 \alpha + 2 \left(\frac{D+B}{2} \right) \left[\Delta s - \left(\frac{D+B}{2} \right) \right] \cos \alpha + \left(\frac{D+B}{2} \right)^2 = H^2 \sin^2 \alpha$$

Using the identity $\sin^2 \alpha = 1 - \cos^2 \alpha$:

$$\left[\Delta s - \left(\frac{D+B}{2} \right) \right]^2 \cos^2 \alpha + 2 \left(\frac{D+B}{2} \right) \left[\Delta s - \left(\frac{D+B}{2} \right) \right] \cos \alpha + \left(\frac{D+B}{2} \right)^2 = H^2 - H^2 \cos^2 \alpha$$

Rearranging:

$$\left\{ \left[\Delta s - \left(\frac{D+B}{2} \right) \right]^2 + H^2 \right\} \cos^2 \alpha + \left\{ 2 \left(\frac{D+B}{2} \right) \left[\Delta s - \left(\frac{D+B}{2} \right) \right] \right\} \cos \alpha + \left\{ \left(\frac{D+B}{2} \right)^2 - H^2 \right\} = 0$$

This equation is now a quadratic equation of the form $ax^2 + bx + c = 0$ where $x = \cos \alpha$ and may be solved using the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ (with the angle alpha equal to the arc cosine of the solution) where:

$$a = \left\{ \left[\Delta s - \left(\frac{D+B}{2} \right) \right]^2 + H^2 \right\}$$

$$b = \left\{ 2 \left(\frac{D+B}{2} \right) \left[\Delta s - \left(\frac{D+B}{2} \right) \right] \right\}$$

$$c = \left\{ \left(\frac{D+B}{2} \right)^2 - H^2 \right\}$$

Development of Spreadsheet and Macros

Because the data streaming mode used with the motion control system requires incremental move data every 10 to 50 milliseconds (depending on the streaming update interval chosen), the amount of data required for the full motion of the housing under the laser becomes quite large. A Microsoft Excel 5.0 spreadsheet was created containing macros to enable a user to easily generate the data required for the streaming mode of the motion control system. The macros of this spreadsheet are contained within three modules which are included in the Appendix. The macros take advantage of the method discussed earlier for converting the body fixed coordinates of the part to the incremental moves required by the motion control system. They also incorporate the solution of the quadratic equation used to define movements under the cables.

The spreadsheet (called lsrauto.xls) consists of four sheets and three modules of macros written in the Visual Basic version contained within the Excel 5.0 program. To make use of the spreadsheet, the user must also have two additional Excel files in the same directory that contain the lsrauto.xls file. These additional files are labeled dads_dat.xls and mtn_dad.csv. The dads_dat.xls file is an Excel 5.0 spreadsheet containing only one sheet. The macros of the lsrauto.xls spreadsheet open this spreadsheet and use it to create the rax.txt, ray.txt, beta.txt, and shutter.txt files required to perform the DADS simulation. The mtn_dad.csv file is the comma delimited file data used to drive the motion control system. The macros of the lsrauto.xls spreadsheet open this file, to create the required file. The user may then rename the file when saving to another desired file name for the data.

The approach used in the spreadsheet and macros is for the user to define the minimum data required for the desired motion of the part under the laser on the first sheet of the spreadsheet. The macros then expand upon this data in creating the second and third sheets. The definition data supplied by the user consists of the major points around the part geometry where an event is to occur. Examples of the points that the user defines on the first sheet are the starting and ending points, the corners, the cables, and any other points in which a specific travel speed under the laser or part rotation angle is desired. To make this definition easier for the user, the method for defining the moves through corners and under cables on the first sheet of the spreadsheet was simplified. The user simply makes a notation designating the corner number to define a corner move. Likewise, the user provides the minimum data required to define a cable move. The macros within the spreadsheet copy the data on the first sheet and create a second sheet where the

movements through the corners and under the cables are more fully defined. The only thing lacking on the second sheet for the full definition of the moves through the corners and under the cables is the desired travel speed under the laser. The user must then edit the second sheet to include the desired travel speed for these few additional points around the part. It is important to note that the user must make sure that all rows of data on the second sheet contain values for the travel speed but that all rows do not require values for the angle beta.

Because the motion definition thus far is only of some major points around the part, the spreadsheet must now generate the large amount of data that defines each incremental move at every time step that occurs between any two major points. This full definition of the entire motion around the part is performed on the third sheet of the spreadsheet. The data on the third sheet is entirely created by the macros of the spreadsheet. The macros within the spreadsheet copy the data on the second sheet and create the third sheet.

To generate the full data that exists on the third sheet, macros scan down the data copied over from the second sheet and insert rows to define all of the incremental moves that exist between each pair of major points that the user defined on the first and second sheets. Each pair of major points defined by the user is treated as an interval in which the starting and ending coordinates and travel speed are defined. To create the data for the rows inserted within this interval, the travel speeds defined by the user at the beginning and at the end of the interval are compared. The macros then change the travel speed from the beginning value to the ending value linearly over the interval (constant acceleration or deceleration).

There is a slight difference in the way that changes in the rotation angle beta for the part are handled. Once the macros have inserted all of the additional rows, into the third sheet, for the entire motion around the part, the macros will go back and scan through the data to generate the values for the beta angle. A macro counts the number of rows, not containing beta values, existing in an interval between any two defined beta values. It then changes the beta angle from the beginning value to the ending value linearly over the interval. The advantage to this method is that the user is not required to define a beta angle for most of the major points defined on the first and second sheets. The user then only defines a beta angle at a point in which a specific value is desired. The macros that create the third sheet will then gradually vary the beta angle over all of the moves that exist between any two defined beta values.

This method is especially useful to allow a gradual rotation around a corner. To do this, the user defines a point on the first sheet where the start of rotation is desired before a corner. The beta angle at this point is defined as the angle before rotation (the last point that will have this beta angle). The user then defines the corner on the first sheet using the corner notation. Finally, the user defines a point on the first sheet where the end of rotation is desired after the corner. The beta value at this point is the angle at the end of rotation. A similar "scan and fill in" method is used for the shutter values on the third sheet. The macro that fills in the shutter values on the third sheet simply scans down the rows of inserted data and fills in any missing shutter value as

Sheet 1[illegible]

Figure 5. Sheet 1 of Spreadsheet

Summary of Definition From User on the First Sheet:

- Starting point definition
- Corners (defined by corner designator c1, c2, c3, or c4)

- Cables (defined by definitions in cable data fields)
- Definition of other points to make changes in travel speed or angle
- Ending point definition

Sheet 1 Definition Notes:

1. The user must define a starting point as the first line of data that includes sx' , sy' , beta, travel speed, and shutter values. For this entry, any notation may be written, if desired, in the "Point in Time" field. The only exception to defining the starting point in this manner would be if the user specifically wants to start the motion at a corner or cable. To do this, the first line of data would be a corner or cable definition.
2. All points defined on Sheet 1 must be in the sequential order that the movement is to occur around the part. The user may define a movement clockwise or counterclockwise around the part. The beta angles defined are always positive angles from 0 to 360 degrees. If the part is to rotate counterclockwise under the laser, the beta angle, at the first point defined, will usually be 0 degrees, with 360 degrees as the angle for last point defined. If the part is to rotate clockwise under the laser, the beta angle will usually start at 360 degrees and end at 0 degrees.
3. To define a corner, all fields are left blank, with the exception that the corner designator $c1$, $c2$, $c3$, or $c4$, must be typed into the "Point in Time" field. This designator must be typed in exactly including using the lowercase letter "c".
4. To define a cable, the sx' , sy' , and beta fields are left blank. The travel speed definition is optional. The user must define the size of the "keep out diameter" around the cable, the sx' and sy' coordinates to the center of the cable, the distance for the laser to move forward under the cable (if desired), the distance for the laser to move backward under the cable (if desired), and the time in which the shutter turns the laser off while the part is moved and rotated into a position on the other side of the cable. The user may have the laser move both forward and backward under the cable by filling in the distances under the respective columns, but at least one of these distances (forward or backward) must be defined. For a cable entry, any notation may be written, if desired, in the "Point in Time" field.
5. Any other point may be defined, as long as it is in the sequential order that the movement is to occur around the part. Examples of such points included in the motion definition include points at which a specific velocity or angle is desired. To define such a point, the sx' , sy' , and travel speed values are required. Values for beta and shutter are optional.
6. The user must define an ending point as the last line of data that includes sx' , sy' , beta, travel speed, and shutter values. For this entry, any notation may be written, if desired, in the "Point in Time" field. The only exception to defining the ending point in this manner would be if the user specifically wants to end the motion at a corner or cable. To do this, the last line of data would be a corner or cable definition.

7. The macros were made general enough to allow the travel speed around the part to increase or decrease over any interval (including movements under cables or movements around corners). To accomplish this, constant acceleration or deceleration is used in an interval (the velocity is linearly ramped up or down).

Sheet 2

Sheet 2 (see Figure 6) is a copy of sheet 1 that is then expanded to include additional definition data required for movement around the corners and under the cables. The additions on sheet 2 relating to the corners do not contain any data defining the beta angle or the travel speed under the laser at these positions. The user may choose to define the angles at these points but is required to fill in the travel speed data at these points. The additions on sheet 2 relating to the cables do contain data defining the beta angle but not the travel speed under the laser at these positions. The user may choose to edit the angles at these points but is required to fill in the travel speed data at these points. Once the editing is finished to sheet 2, the user makes a mouse click on the button labeled "Create Full Motion Control Data on Sheet3." This runs the macros that delete the old sheet 3 and create a new one.

Summary of Definition From User on the Second Sheet:

- Travel speeds are required (the macro will stop with an error if all definition rows do not contain travel speed data).
- Angle changes if desired for corners and under cable moves.

Sheet 2 Definition Notes:

1. If the cable is close to the start or end of a corner rotation, the user may want the motion to begin or finish the cable move at an angle desirable for entering or exiting the corner area.
2. The macros that create sheet 2 are automated to prevent the operator from needing to put in the coordinates for the corners and the coordinates at the start and stop of cables. To perform this, the macros require the user to designate the corners correctly on sheet 1 (including using the lowercase letter "c") using the notation c1, c2, c3, or c4 where the corner number refers to the quadrant of the body fixed coordinate system (refer to Figure 2). The macros that insert the beginning and ending s_x' and s_y' coordinates for the radiused corners on sheet 2 will not include a beta angle in the angle field. It is up to the user to determine at what point the rotation around a corner should start and end. This allows the user to start a corner rotation early, before encountering the radius, and end the corner after the radius. To make a smooth rotation around a corner, the user would add points to the sheet 1 data before and after the c1, c2, c3, or c4 designator for the corner. The first point (before the upcoming corner

File Edit View Insert Format Tools Data Window Help																
Create Full Motion Control Data on Sheet3																
	RPz (in)	RPx (in)	Laser Beam Width (in)	Length of Part (in)	Width of Part (in)	Corner Radius (in)	Time Step Size (sec)									
	0.0000	0.7925	0.0400	2.4400	1.5850	0.0500	0.030									
	Sx' (in)	Sy' (in)	Beta (deg)	Travel Speed Under Laser (in/sec)	Keep Out Dia. for Cable (in)	Sx' to Center of Cable (in)	Sy' to Center of Cable (in)	Delta S' Under Cable (in)	Angle Alpha Under Cable (deg)	Time to Back Under Cable (sec)	Shutter on = 1 off = 0					
Point in Time																
time = zero	0.0000	0.7925	0.0000	0.20							1					
start 1st corner rotation	1.0000	0.7925	0.0000	0.20							1					
beginning of corner c1	1.1700	0.7925		0.20												
end of corner c1	1.2200	0.7425		0.20												
end 1st corner rotation	1.2200	0.6000	90.0000	0.20							1					
start going fast along face 2	1.2200	0.5000	90.0000	0.20							1					
full speed on face 2	1.2200	0.3000	90.0000	0.80							1					
end full speed on face 3	1.2200	-0.3000	90.0000	0.80							1					
stop going fast along face 2	1.2200	-0.5000	90.0000	0.20							1					
start 2nd corner rotation	1.2200	-0.6000	90.0000	0.20							1					
beginning of corner c4	1.2200	-0.7425		0.20												
end of corner c4	1.1700	-0.7925		0.20							1					
end 2nd corner rotation	1.0000	-0.7925	180.0000	0.20							1					
Edge of beam meets cable	0.8430	-0.7925	180.0000	0.20	0.0480	0.7990	-0.9355	0.0000	0.0000		0					
Farthest point bkwd under cal	0.9050	-0.7925	230.8591	0.20	0.0480	0.7990	-0.9355	0.1500	50.8591	0.500	1					
Last contact with cable	0.7550	-0.7925	180.0000	0.20	0.0480	0.7990	-0.9355	0.0000	0.0000		1					
start going slow along face 3	0.5000	-0.7925	180.0000	0.20							1					
go slow along face 3	0.3000	-0.7925	180.0000	0.05							1					
end slowest speed along face	-0.3000	-0.7925	180.0000	0.05							1					
stop going so slow you moro	-0.5000	-0.7925	180.0000	0.20							1					
start 3rd corner rotation	-1.0000	-0.7925	180.0000	0.20							1					
beginning of corner c3	-1.1700	-0.7925		0.20												
end of corner c3	-1.2200	-0.7425		0.20							1					
Edge of beam meets cable	-1.2200	-0.7085	270.0000	0.20	0.0480	-1.4080	-0.6625	0.0000	0.0000							
Farthest point fwd under cable	-1.2200	-0.5685	230.9185	0.20	0.0480	-1.4080	-0.6625	0.1400	39.0815	1.000	0					
Last contact with cable	-1.2200	-0.6185	270.0000	0.20	0.0480	-1.4080	-0.6625	0.0000	0.0000		1					
Edge of beam meets cable	-1.2200	0.6135	270.0000	0.20	0.0480	-1.5760	0.6575	0.0000	0.0000							
Farthest point fwd under cable	-1.2200	0.6835	258.7422	0.20	0.0480	-1.5760	0.6575	0.0700	11.2578	0.500	0					
Farthest point bkwd under cal	-1.2200	0.5615	291.9452	0.20	0.0480	-1.5760	0.6575	0.1400	21.9452	0.500	1					
Last contact with cable	-1.2200	0.7015	270.0000	0.20	0.0480	-1.5760	0.6575	0.0000	0.0000		1					
beginning of corner c2	-1.2200	0.7425		0.20												
end of corner c2	-1.1700	0.7925		0.20							1					
end 4th corner rotation	-1.0000	0.7925	360.0000	0.20							1					
finish move with overlap	0.3000	0.7925	360.0000	0.20							1					

Figure 6. Sheet 2 of Spreadsheet

designator) would define the s_x' and s_y' coordinates for the corner rotation to begin. The angle beta for this point would be the current beta angle. Next would be the corner designator. The last point for the corner would be the s_x' and s_y' coordinates for the corner rotation to end. The angle beta for this point would be the final beta angle for the corner move. The user would then leave the angle fields blank on sheet 2 next to the beginning and ending s_x' and s_y' coordinates created by the macros for the radiused corners.

- To define the movement around a cable, the user must define the size of the "keep out diameter" around the cable, the s_x' and s_y' coordinates to the center of the cable, the distance for the laser to move forward under the cable (if desired), the distance for the laser to move backward under the cable (if desired), and the time in which the shutter turns the laser off while the part is moved and rotated into a position on the other side of the cable. The user may have the laser move both forward and backward under the cable by filling in the distances under the respective columns, but at least one of these distances (forward or backward) must be defined. The macros that create sheet 2 will put in the perpendicular

angles at the start and stop of a cable move. The user may change these angles on sheet 2. Because the motion under a cable is well defined, the macros that create sheet 3 correct for an error in the angle definition to keep the laser from shining on the "keep out dia."

4. The user may rotate the part over any interval, but the user is responsible for making sure that the cable is not rotated into the line of sight of the laser during a non-cable move (error checking to keep the laser from shining in the "keep out dia." of the cable only occurs during a cable move).

Sheet 3

Sheet 3 is a copy of sheet 2 that is expanded to include all of the data calculated to fully define the motion profile and all of the calculations of data needed to create a file for running the motion control system (see Figures 7 and 8).

File Edit View Insert Format Tools Data Window Help													
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Delete This Data Sheet	RPx (in)	RPy (in)	Laser Beam Width (in)		Length of Part (in)	Width of Part (in)	Corner Radius (in)		Time Step Size			
2		0.0000	0.7925	0.0400		2.4400	1.5850	0.0500		0.030			
3	Create CADSI DADS Curve Data Files for Simulation												
4	Create Input File for Drawing Motion Control System												
5					Travel Speed Under Laser (in/sec)	Keep Out Dia. for Cable (in)	Sx' to Center of Cable (in)	Sy' to Center of Cable (in)	Delta S' Under Cable (in)	Angle Alpha Under Cable (deg)	Time to Back Under Cable (sec)	Shutter on = 1 off = 0	
6	Point in Time	Sx' (in)	Sy' (in)	Beta (deg)									
7	time = zero	0.0000	0.7925	0.0000	0.20							1	
8		0.0060	0.7925	0.0000								1	
9		0.0120	0.7925	0.0000								1	
10		0.0180	0.7925	0.0000								1	
11		0.0240	0.7925	0.0000								1	
12		0.0300	0.7925	0.0000								1	
13		0.0360	0.7925	0.0000								1	
14		0.0420	0.7925	0.0000								1	
15		0.0480	0.7925	0.0000								1	
16		0.0540	0.7925	0.0000								1	
17		0.0600	0.7925	0.0000								1	
18		0.0660	0.7925	0.0000								1	
19		0.0720	0.7925	0.0000								1	
20		0.0780	0.7925	0.0000								1	
21		0.0840	0.7925	0.0000								1	
22		0.0900	0.7925	0.0000								1	
23		0.0960	0.7925	0.0000								1	
24		0.1020	0.7925	0.0000								1	
25		0.1080	0.7925	0.0000								1	
26		0.1140	0.7925	0.0000								1	
27		0.1200	0.7925	0.0000								1	
28		0.1260	0.7925	0.0000								1	
29		0.1320	0.7925	0.0000								1	
30		0.1380	0.7925	0.0000								1	
31		0.1440	0.7925	0.0000								1	
32		0.1500	0.7925	0.0000								1	
33		0.1560	0.7925	0.0000								1	

Figure 7. Sheet 3 of Spreadsheet

[illegible]

20

Sheet Four—Setup Help

The fourth sheet is labeled “Setup Help” (see Figure 9) and contains a figure and notes to aid the user in defining the motion profile required on sheet 1.

Figure 9. Fourth Sheet of Spreadsheet Labeled “Setup Help”

Simulation of Motion Using DADS

A verification method was developed by simulating the motion data. The geometry of the assembly was generated using Parametric Technology Corporation Pro/E version 15. This geometry was then converted using Pro/DADS version 3.1 from Computer Aided Design Software Inc. (CADSI) and the simulation was carried out using DADS version 8.0 from CADSI. This process animated the results of the motion of the part on the computer screen. This was extremely useful in catching and correcting errors in the Excel spreadsheet (see Figure 10).

Figure 10. Motion Simulation Using DADS 8.0

Notes on Method Used to Verify Spreadsheet Data

The following are notes of the method that was used to verify the data from the Excel spreadsheet.

Create Hybrid Geometry in Pro/E:

1. Create default datums.
2. Create a protrusion from both sides of the sketching plane.
3. Sketch a block shape of part on Datum 3, and when prompted for a horizontal or vertical reference for sketching, pick **Top** and then Datum 2.

4. Create vertical and horizontal centerlines and align them to Datum 1 and Datum 2.
5. Draw a rectangle centered around the centerlines, and dimension the length along the x direction and the width along the y.
6. Radius the corners by creating a round and selecting the edge of each corner.
7. Create a separate circular protrusion for each cable, pick **Both Sides** and again sketch on Datum 3 with Top as Datum 2. Sketch a circle and dimension the diameter and the center of the circle from the Datums 1 and 2.

Create Laser Beam Geometry in Pro:

1. Create default datums.
2. Create a protrusion from **One Side** of a sketching plane.
3. Sketch on Datum 2 with feature creation up, and when prompted for a horizontal or vertical reference for sketching, pick **Bottom** and then Datum 3.
4. Sketch a circle with the diameter of the laser beam and the center aligned with Datum 3 and Datum 1.

Create Assembly of Hybrid and Laser Beam and Export Geometry Using Pro/DADS:

1. Assemble the laser beam to the hybrid. It doesn't matter how the parts are assembled together (the important thing is to include the hybrid and laser parts into an assembly together). No matter how the parts were assembled, they will both come into DADS with their datum planes aligned to the global coordinate system in DADS.
2. Save the assembly file.
3. From the Assembly choose **DADS**, then **File**, then **Write geo**, then **All parts**. Type the highest number allowable for the quality of the geometry on the Pro/E command line.
4. Now exit without saving (the part geometry slp files have already been saved to disk).

Start DADS and Import the Geometry Files:

1. Start DADS and choose a two-dimensional analysis.
2. Pick **File**, **Save_as**, and name the project definition file **hybrid**.
3. Pick **File**, **Import**, **Geometry**, and then **slp**. Go to the directory with the .slp file for the hybrid and select it. Repeat for the .slp file for the laser.
4. Create a Body for the Hybrid and Assign to it the Hybrid Geometry:
5. Pick **Body** and then **Create**.

6. Highlight the part name and change the name to **hybrid**.
7. Pick **Use** on the Geometry row, **Use GeomShell**, and pick **hybrid**.
8. Change from **Wireframe** to **Solid** (if desired) and change colors using slide bars next to red, green, and blue colors (if desired).
9. There are three labels and triads attached to the part. To turn them off, select the **Body** submenu, and toggle the "Enable" to "Disable" next to the wording labeled "Show Triad & Label." The first selection is located under **Body**, the next is under **Center of Gravity**, and the last selection is located by picking **Rotate/Translate** under "Geometry" **Edit**.
10. Choose **Accept**.

Create a Body for the Laser and Assign to it the Laser Geometry:

1. Pick **Body** and then **Create**.
2. Change the name to **laser**.
3. Pick **Use** on the Geometry row, **Use GeomShell**, and pick **laser**.
4. Change from **Wireframe** to **Solid** (if desired) and change colors using slide bars next to red, green, and blue colors (if desired).
5. Translate the laser beam by picking **Rotate/Trans** and type in a value equal to 1/2 the width of the part for the y coordinate (coordinates are in the format x,y,z). This will put the end of the laser beam on the top edge of the hybrid.
6. There are three labels and triads attached to the part. To turn them off, select the **Body** submenu, and toggle the "Enable" to "Disable" next to the wording labeled "Show Triad & Label." The first selection is located under **Body**, the next is under **Center of Gravity**, and the last selection is located by picking **Rotate/Translate** under "Geometry" **Edit**.

Creating Curves and Drivers for Defining the Motion of the Hybrid and Laser Beam

The purpose of the next steps is to satisfy the definition of the three degrees of freedom (of a two-dimensional analysis) for both the hybrid and laser. To satisfy the definition requirements, the x, y, and angle degrees of freedom will be defined as a function of time for both the hybrid and laser. The hybrid will move in the x, y directions and rotate. The laser will not move in the x direction or rotate, but to animate the effect of shuttering off the laser, it will be almost instantaneously "jerked" out of the field of view in the y direction whenever the laser is shuttered off.

The definition of the movements of the hybrid and laser is accomplished in DADS by first creating curves consisting of time versus position data, and then creating drivers that will use the

curves to move the part according to the specified curve. To create the curves, two lines of data will be typed in. This data corresponds to a position of zero at time zero and also a position of zero at time one second. This data is all that is needed for the curves used by the drivers that keep the laser from moving in the x direction and rotation. For the rest of the movements needed, this data will be edited by using a text editor to paste in the Excel file data (rax.txt, ray.txt, beta.txt, and shutter.txt) on top of it.

Create Curves to Drive Hybrid and Laser:

1. From the DADS Modeling dialog box, pick **Other, Curve, SplineCurve, Create**.
2. Rename the curve to **rax**.
3. Make sure the Type of Data is **Spline.Explicit**.
4. Click on **Interpolation** and pick **Linear**.
5. Click on **DATA Edit** and then click in the editor window. Make an array of numbers such as follows and then click **Done**.

0	0
1	0

6. **Accept** the Curve form.
7. Click **copy**, make a copy of the previously defined curve, and then edit the new curve, changing its name to **ray**.
8. Make another copy of a previously defined curve, and then edit the new curve, changing its name to **beta**.
9. Make another copy of a previously defined curve, and then edit the new curve, changing its name to **lsr_fixed**.
10. Make another copy of a previously defined curve, and then edit the new curve, changing its name to **shutter**.

Create Drivers for the Hybrid:

1. From the DADS Modeling dialog box, pick **Constraint, Driver, One-Body, Create**.
2. Rename the Driver to **hybrid_x**.
3. Toggle the Type to **X**.
4. Toggle the Body Name to **hybrid**.
5. Toggle the Triad on Body to either **hybrid_cg** or **hybrid** (they are both at the center of the hybrid).
6. Toggle the Function Type to **General**.

7. Toggle the Curve Driver to **rax**.
8. **Accept** the Driver form.
9. Click **copy**, make a copy of the **hybrid_x** driver, and then edit the new Driver, changing its name to **hybrid_y**, toggle the Type to **Y**, and toggle the Curve Driver to **ray**.
10. Make a copy of one of the previous drivers, and then edit the new Driver, changing its name to **hybrid_beta**, toggle the Type to **PHI**, toggle the Curve Driver to **beta**, and toggle the Angular Units to **Radians**.

Create Drivers for the Laser:

1. From the DADS Modeling dialog box, pick **Constraint, Driver, One-Body, Create**.
2. Rename the Driver to **laser_x**.
3. Toggle the Type to **X**.
4. Toggle the Body Name to **laser**.
5. Toggle the Triad on Body to either **laser_cg** or **laser** (they are both at the center of the laser).
6. Toggle the Function Type to **General**.
7. Toggle the Curve Driver to **lsr_fixed**.
8. **Accept** the Driver form.
9. Make a copy of the **laser_x** driver, and then edit the last Driver, changing its name to **laser_y**, toggle the Type to **Y**, and toggle the Curve Driver to **shutter**.
10. Make a copy of the **laser_x** driver, and then edit the new Driver, changing its name to **laser_beta**, toggle the type to **PHI**, and make sure the Curve Driver is **lsr_fixed**.

Save and Then Edit the .def File:

1. Pick **File and Save** to save the project definition file **hybrid.def**.
2. Using the FTP utility, copy the ASCII files **rax.txt**, **ray.txt**, **beta.txt**, and **shutter.txt** from the directory containing the Excel 5.0 spreadsheet to the workstation used for the DADS simulation.
3. Using a text editor, copy the data from the **rax.txt** file (created by the spreadsheet) into the clipboard, and then paste this data on top of the data for the **rax** curve in the **hybrid.def** file.
4. Repeat copying and pasting of the **ray.txt** file to the data for the **ray** curve, **beta.txt** to the data for the **beta** curve, and **shutter.txt** to the data for the **shutter** curve in the **hybrid.def** file.
5. Now the corrected **hybrid.def** file is the edited version on disk, not the version currently running in memory. To bring the corrected version from disk into the current DADS session, pick **File, Open**. Pick the **hybrid.def** file, and then choose **Load without Saving** (this is

very important, because if you choose Save Current Project, it will write over the corrected file on the disk).

Run the Analysis and Animate the Results:

1. Pick **Solve** from the title bar, toggle the Analysis Type to **Kinematic**, and set the End Time to slightly greater than the largest elapsed time in the rax, ray, beta, and shutter files.
2. Pick **Animate** from the title bar, pick **Load a File** and choose the **hybrid.bin** file, and then pick **Execute Animation**.

ACCOMPLISHMENTS

A method was developed for creating the motion control data for sealing an electronic housing using laser soldering. The motion required to move the housing under the laser is a nonstandard application and was performed with a four-axis system using the timed data streaming mode capabilities of a Compumotor AT6400 indexer. A Microsoft Excel 5.0 spreadsheet was created to calculate the movement of the part under the laser, and macros were written into the spreadsheet to allow the user to easily create this data. A data verification method was developed for simulating the motion data. The method for driving the housing and spreadsheet were verified by simulating the housing movement using DADS version 8.0 from Computer Aided Design Software Inc. (CADSI).

APPENDIX

Exel 5.0 Macros to Generate Motion Control Data

Module1

```

*****
*****
EXCELS.0 MACROS FOR GENERATING SPREADSHEETS FOR LASER SOLDERING
MOTION CONTROL SYSTEM (MODULE1)
SCOTT YERGANIAN 11-11-96
*****
*****

Const first_row = 7
Dim current_row As Integer
Dim lngth As Single
Dim wdth As Single
Dim radius As Single
Dim beam As Single
Dim time_step As Single
Dim dia As Single
Dim ave_speed As Single
Dim sxb_initial As Single
Dim syb_initial As Single
Dim sxb_final As Single
Dim syb_final As Single
Dim sxc As Single
Dim syb As Single
Dim time_shutter_off As Single
Dim half_beam_and_cable As Single
Dim delta_s_fwd As Single
Dim delta_s_bkwd As Single
Dim syb As Single
Dim sxb As Single
Dim cntclock As Integer
Dim direction As Integer

Sub EXPAND_INPUT_DATA()
*****
This subroutine is called by the button on Sheet1. It runs the subroutine "Recreate_Sheet2" and
then the subroutines used to generate the coordinates of the starting and stopping points of the
corners and the coordinates which define the movement under the cable.
*****
Recreate_Sheet2
Fill_in_corner_points
Fill_in_cable_points
End Sub

Sub Recreate_Sheet2()
*****
This subroutine looks for the old Sheet2 (expanded data) and Sheet3 (full data) and deletes them
if they exist it then recreates Sheet2 by making a copy of Sheet1. Copying Sheet1 also copies the
button from the top of Sheet1 called "Expand User Input Data on Sheet 2" on Sheet1. This button is
then modified to become the button at the top of Sheet2 called "Create Full Motion Control Data on
Sheet3". Sheet2 is then modified to include the column labels called "Cosine of Angle Alpha Under
Cable" and "Angle Alpha Under Cable (rad)". These are the columns where the angle alpha will be
calculated for use in the subroutines used for movement under the cables.
*****
Look for the sheets called Sheet2 (expanded data) and Sheet3 (full data) and delete them if they
exist.
*****
If Sheets(2).Name = "Sheet2" Then Sheets(2).Delete
If Sheets(2).Name = "Sheet3" Then Sheets(2).Delete
*****
Create a copy of Sheet1 (user input data) and name it Sheet2
*****
Sheets(1).Copy After:=Sheets(1)
Sheets(2).Name = "Sheet2"
*****
Change the button at the top of Sheet2 and assign the macro called "COPY_AND_CREATE_FULL_DATA" to
it.
*****
Sheets(2).Activate
ActiveSheet.DrawingObjects("Button 11").Select
Selection.Characters.Text = "Create Full Motion Control Data on Sheet3"
Selection.OnAction = "COPY_AND_CREATE_FULL_DATA"
Range("A1").Select
*****
Set up the cells on Sheet2 for labeling the Cosine of Alpha and Alpha Angle columns
*****
Cells(first_row - 1, 19) = "Cosine of Angle Alpha Under Cable"
Cells(first_row - 1, 20) = "Angle Alpha Under Cable (rad)"

```

Module1

```

*****
' Read in the values of some of the variables used in the rest of the macros
*****
    lngth = Cells(2, 7)           'total length of the part along its body fixed x axis
    wtdth = Cells(2, 8)           'total width of the part along its body fixed y axis
    radius = Cells(2, 9)          'corner radius of the part
    beam = Cells(2, 5)            'width of the laser beam
    time_step = Cells(2, 11)      'time step in seconds (the motion control system requires the time
                                'step to be an even number in the range of 10 to 50 milliseconds)

End Sub

Sub Fill_in_corner_points()
*****
' This subroutine inserts lines into Sheet2 for the sx' and sy' coordinates at the starting point
' and ending point of each radiused corner. The order in which these coordinates are inserted
' (for each corner) is dependent on the direction of rotation of the part under the laser. This
' subroutine is dependent on the user identifying each corner in the Sheet1 input data by the
' notation of "c1", "c2", "c3", or "c4" in the first column.
' The designation "c1" refers to the corner that lies within the first quadrant of the body fixed
' coordinate system ("c3" refers to the corner that lies within the third quadrant etc). The user
' must input these corner designators exactly (including using a lower case "c"). After the
' direction of rotation of the part is found, the variable called "direction" is set as either 1
' (for counterclockwise rotation) or -1 (for clockwise rotation) and a separate subroutine is run
' for each corner. Each of these subroutines finds its respective corner and fills in the corner
' points at the beginning and end of the radius and then writes a designator in the first column
' for the beginning and ending points of each radiused corner.
*****
' Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
' Find the direction of movement around the part by starting at the beginning and searching for
' each corner by looking for the "c1", "c2", "c3", or "c4" label. Increment a weighting factor called
' "w" each time a corner is found. If the corner found happens to be "c1" or "c2", then set a
' variable called "c1" or "c2" to be equal to the current value of the weighting factor "w".
*****
    current_row = first_row
    w = 0
    Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) + Abs(Cells(current_row, 8)) +
    Abs(Cells(current_row, 9)) > 0 Or Cells(current_row, 1) = "c1" Or Cells(current_row, 1) = "c2" _
    Or Cells(current_row, 1) = "c3" Or Cells(current_row, 1) = "c4"

        If Cells(current_row, 1) = "c1" Or Cells(current_row, 1) = "c2" Or Cells(current_row, 1) = "c3" _
        Or Cells(current_row, 1) = "c4" Then w = w + 1

        If Cells(current_row, 1) = "c1" Then c1 = w
        If Cells(current_row, 1) = "c2" Then c2 = w
        current_row = current_row + 1
    Loop

' Compare the variables called "c1" and "c2" to determine the direction of rotation of the part. If
' the direction is found to be counterclockwise set the variable called "direction" equal to 1.
' If clockwise, set "direction" equal to -1. In most cases, if c1 > c2 the part is moving
' counterclockwise and if c1 < c2 the part is moving clockwise. There is a special case for
' counterclockwise movement where c1 < c2 if c1 is the first corner while c2 is the last. There is
' another special case for clockwise movement where c1 > c2 if c2 is the first corner while c1 is
' the last.
*****
    If c1 > c2 Then direction = 1
    If c1 < c2 Then direction = -1
    If c1 < c2 And c1 = 1 And c2 = 4 Then direction = 1
    If c1 > c2 And c2 = 1 And c1 = 4 Then direction = -1
*****
' Run each corner point subroutine to fill in the corner points
*****
    corner_1_points
    corner_2_points
    corner_3_points
    corner_4_points
    Cells(1, 1).Select
End Sub

```


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```

Sub corner_1_points()
*****
'   Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
'   Find corner 1
*****
current_row = first_row
Do Until Cells(current_row, 1) = "c1" Or current_row = 1000
current_row = current_row + 1
Loop
*****
'   Insert a cell for the first corner point, calculate its value (based on direction of rotation)
'   fill in the data, and label the row as the "beginning of corner c1"
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
If direction = 1 Then Cells(current_row, 3) = lngth / 2 - radius _
Else Cells(current_row, 3) = lngth / 2

If direction = 1 Then Cells(current_row, 4) = width / 2 Else _
Cells(current_row, 4) = width / 2 - radius

Cells(current_row, 1) = "beginning of corner c1"
*****
'   Go to the cell for the last corner point, calculate its value (based on direction of rotation)
'   fill in the data, and label the row as the "end of corner c1"
*****
current_row = current_row + 1
If direction = 1 Then Cells(current_row, 3) = lngth / 2 Else _
Cells(current_row, 3) = lngth / 2 - radius

If direction = 1 Then Cells(current_row, 4) = width / 2 - radius Else _
Cells(current_row, 4) = width / 2

Cells(current_row, 1) = "end of corner c1"
End Sub

Sub corner_2_points()
*****
'   Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
'   Find corner 2
*****
current_row = first_row
Do Until Cells(current_row, 1) = "c2" Or current_row = 1000
current_row = current_row + 1
Loop
*****
'   Insert a cell for the first corner point, calculate its value (based on direction of rotation)
'   fill in the data, and label the row as the "beginning of corner c2"
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
If direction = 1 Then Cells(current_row, 3) = -lngth / 2 Else _
Cells(current_row, 3) = -(lngth / 2 - radius)

If direction = 1 Then Cells(current_row, 4) = width / 2 - radius Else _
Cells(current_row, 4) = width / 2

Cells(current_row, 1) = "beginning of corner c2"
*****
'   Go to the cell for the last corner point, calculate its value (based on direction of rotation)
'   fill in the data, and label the row as the "end of corner c2"
*****
current_row = current_row + 1
If direction = 1 Then Cells(current_row, 3) = -(lngth / 2 - radius) Else _
Cells(current_row, 3) = -lngth / 2

If direction = 1 Then Cells(current_row, 4) = width / 2 Else _
Cells(current_row, 4) = width / 2 - radius

Cells(current_row, 1) = "end of corner c2"
End Sub

```

Module1

```

Sub corner_3_points()
'*****
'  Activate Sheet2
'*****
Worksheets("Sheet2").Activate

'*****
'  Find corner 3
'*****
current_row = first_row
Do Until Cells(current_row, 1) = "c3" Or current_row = 1000
current_row = current_row + 1
Loop
'*****
'  Insert a cell for the first corner point, calculate its value (based on direction of rotation)
'  fill in the data, and label the row as the "beginning of corner c3"
'*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
If direction = 1 Then Cells(current_row, 3) = -(length / 2 - radius) Else _
Cells(current_row, 3) = -length / 2

If direction = 1 Then Cells(current_row, 4) = -width / 2 Else _
Cells(current_row, 4) = -(width / 2 - radius)

Cells(current_row, 1) = "beginning of corner c3"
'*****
'  Go to the cell for the last corner point, calculate its value (based on direction of rotation)
'  fill in the data, and label the row as the "end of corner c3"
'*****
current_row = current_row + 1
If direction = 1 Then Cells(current_row, 3) = -length / 2 Else _
Cells(current_row, 3) = -(length / 2 - radius)

If direction = 1 Then Cells(current_row, 4) = -(width / 2 - radius) Else _
Cells(current_row, 4) = -width / 2

Cells(current_row, 1) = "end of corner c3"
End Sub

Sub corner_4_points()
'*****
'  Activate Sheet2
'*****
Worksheets("Sheet2").Activate

'*****
'  Find corner 4
'*****
current_row = first_row
Do Until Cells(current_row, 1) = "c4" Or current_row = 1000
current_row = current_row + 1
Loop
'*****
'  Insert a cell for the first corner point, calculate its value (based on direction of rotation)
'  fill in the data, and label the row as the "beginning of corner c4"
'*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
If direction = 1 Then Cells(current_row, 3) = length / 2 Else _
Cells(current_row, 3) = length / 2 - radius

If direction = 1 Then Cells(current_row, 4) = -(width / 2 - radius) Else _
Cells(current_row, 4) = -width / 2

Cells(current_row, 1) = "beginning of corner c4"
'*****
'  Go to the cell for the last corner point, calculate its value (based on direction of rotation)
'  fill in the data, and label the row as the "end of corner c4"
'*****
current_row = current_row + 1
If direction = 1 Then Cells(current_row, 3) = length / 2 - radius Else _
Cells(current_row, 3) = length / 2

If direction = 1 Then Cells(current_row, 4) = -width / 2 Else _
Cells(current_row, 4) = -(width / 2 - radius)

Cells(current_row, 1) = "end of corner c4"

```

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End Sub

Sub Fill_in_cable_points()

```
*****
This subroutine inserts lines into Sheet2 for the data required for movements around the cables.
To define the movement around a cable, the user must define the size of the "keep out diameter"
around the cable, the sx' and sy' coordinates to the center of the cable, the distance for the
laser to move forward under the cable (if desired), the distance for the laser to move backward
under the cable (if desired), and the time in which the shutter turns the laser off while the part
is moved and rotated into a position on the other side of the cable. The user may have the laser
move both forward and backward under the cable by filling in the distances under the respective
columns, but at least one of these distances (forward or backward) must be defined. The subroutine
scans down the rows in Sheet2 looking for a cable definition row (any row which has a value in the
"keep out diameter around cable" column). Once a cable definition row is found, the data from that
row and the previous row are used to determine which other subroutines will be run for completing
the set up definition of the cable move needed on Sheet2.
*****
Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
Find the cables (or the end of the data area) by looking for a row which contains data for the
"keep out diameter"
*****
current_row = first_row + 1
Do While Abs(Cells(current_row + 1, 3)) + Abs(Cells(current_row + 1, 4)) + _
Abs(Cells(current_row + 1, 8)) + Abs(Cells(current_row + 1, 9)) > 0

If Abs(Cells(current_row, 7)) > 0 Then cable = True Else cable = False
*****
If the current row contains a cable, compare the sx' and sy' coordinates in the previous row to
half of the part width or half of the part length to determine if the movement under the
cable should be in the x direction or the y direction. Run the macro fill_cable_x for
movement in the x direction and the macro fill_cable_y for movement in the y direction.
*****
If cable = True And Abs(Abs(Cells(current_row - 1, 4)) - width / 2) < 0.00001 Then fill_cable_x
If cable = True And Abs(Abs(Cells(current_row - 1, 3)) - length / 2) < 0.00001 Then fill_cable_y
current_row = current_row + 1
Loop
Cells(1, 1).Select
End Sub
```

Sub fill_cable_x()

```
*****
Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
Read in cable definition data from current row. The plus or minus sign of the "delta_s_fwd" and
"delta_s_bkwd" values depends on the direction of movement under the cable. This is checked
by comparing the coordinates at the start and finish ("sxb_initial" and "sxb_final" respectively).
*****
dia = Cells(current_row, 7) 'keep out diameter around cable
sxb_initial = Cells(current_row - 1, 3) 'body fixed sx' coordinate from previous row
syb = Cells(current_row - 1, 4) 'body fixed sy' coordinate from previous row
sxb_final = Cells(current_row + 1, 3) 'body fixed sx' coordinate from next row
sxc_b = Cells(current_row, 8) 'body fixed sx' coordinate to the center of the cable
syc_b = Cells(current_row, 9) 'body fixed sy' coordinate to the center of the cable
If sxb_final > sxb_initial Then delta_s_fwd = Cells(current_row, 10) Else _
delta_s_fwd = -1 * Cells(current_row, 10)

If sxb_final > sxb_initial Then delta_s_bkwd = Cells(current_row, 11) Else _
delta_s_bkwd = -1 * Cells(current_row, 11)

time_shutter_off = Cells(current_row, 12)
*****
After reading in the cable data for the distances forward under the cable and backward under
the cable, the columns containing this data are changed to become "Delta S' Under Cable (in)"
and "Alpha Angle Under Cable (degrees)" respectively.
*****
Cells(first_row - 1, 10) = "Delta S' Under Cable (in)"
Cells(first_row - 1, 11) = "Angle Alpha Under Cable (deg)"
*****
Insert a row, label it "Edge of beam meets cable", calculate the data, and either calculate or
just fill in the data for this row. The sx' coordinate at the point where the laser beam edge
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meets the cable is found by either adding or subtracting half of the laser beam width and half of
the "keep out diameter" from the sx' coordinate of the center of the cable (depending on the
direction of travel found by comparing the values of the sx' coordinates in the previous and next
rows). The values for the distances "Delta S' Under Cable" and "Alpha Angle Under Cable" are zero
by default when the laser beam edge first meets the edge of the "keep out area". The previously
defined values are filled in for the "keep out diameter", body fixed sx' coordinate to the center
of the cable, and body fixed sy' coordinate to the center of the cable. The value for sy' is the
same as the value read in for syb. The angle beta is either 0 degrees or 180 degrees at this point
(depending on which face the movement occurs). If the face has a positive sy' coordinate, the
movement is along the edge defined by sy' = half the width of the part and the beta
angle is 0 degrees. If the face has a negative sy' coordinate, the movement is along the edge
defined by sy' = negative half the width of the part and the beta angle is 180 degrees.
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Edge of beam meets cable"
If sxb_final > sxb_initial Then Cells(current_row, 3) = sxc_b - (beam + dia) / 2 Else _
Cells(current_row, 3) = sxc_b + (beam + dia) / 2

Cells(current_row, 4) = syb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxc_b
Cells(current_row, 9) = sy_c_b
Cells(current_row, 10) = 0
Cells(current_row, 11) = 0
If syb > 0 Then Cells(current_row, 5) = 0 Else Cells(current_row, 5) = 180
*****
Go to the next row. If the value for moving forward under the cable was non-zero, run the
subroutine called "delta_sfx" (this subroutine will insert a row, calculate the data for the
farthest point forward under the cable, and fills in the data for that row). After this, if the
value for moving backward under the cable was non-zero, then run the subroutine called "delta_sbx"
(this subroutine will insert a row, calculate the data for the farthest point backward under the
cable, and fill in the data for that row). The value in the shutter column is always set to zero
at the instant before the cable begins to move through the area under the laser beam. If the
"delta_sfx" subroutine is not run, this point occurs at the edge of the cable and the shutter value
is set to zero on the row labeled "Edge of beam meets cable". If the "delta_sfx" subroutine is run,
this point occurs at the farthest point forward under the cable and the shutter value is set to zero
on the row inserted by the "delta_sfx" subroutine.
*****
current_row = current_row + 1
If Abs(delta_s_fwd) > 0 Then delta_sfx Else Cells(current_row - 1, 13) = 0 'the else statement
                                                                    'turns off the shutter
                                                                    'if delta_sfx is not run

If Abs(delta_s_bkwd) > 0 Then delta_sbx
*****
Label the last row of the cable "Last contact with cable", calculate the data, and either calculate
or just fill in the data for this row. The sx' coordinate at the point where the laser beam edge
last contacts the cable is found by either adding or subtracting half of the laser beam width and
half of the "keep out diameter" from the sx' coordinate of the center of the cable (depending on
the direction of travel found by comparing the values of the sx' coordinates in the previous and
next rows). The values for the distances "Delta S' Under Cable" and "Alpha Angle Under Cable" are
zero by default when the laser beam edge last contacts the edge of the "keep out area". The
previously defined values are filled in for the "keep out diameter", body fixed sx' coordinate to
the center of the cable, and body fixed sy' coordinate to the center of the cable. The value for
sy' is the same as the value read in for syb. The value originally entered by the user in for the
"time to back under cable" is then cleared. The angle beta is either 0 degrees or 180 degrees at
this point (depending on which face the movement occurs). If the face has a positive sy'
coordinate, the movement is along the edge defined by sy' = half the width of the part and the
beta angle is 0 degrees. If the face has a negative sy' coordinate, the movement is along the
edge defined by sy' = negative half the width of the part and the beta angle is 180 degrees.
*****
Cells(current_row, 1) = "Last contact with cable"
If sxb_final > sxb_initial Then Cells(current_row, 3) = sxc_b + (beam + dia) / 2 Else _
Cells(current_row, 3) = sxc_b - (beam + dia) / 2

Cells(current_row, 4) = syb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxc_b
Cells(current_row, 9) = sy_c_b
Cells(current_row, 10) = 0
Cells(current_row, 11) = 0
Cells(current_row, 12).Select
Selection.ClearContents
If syb > 0 Then Cells(current_row, 5) = 0 Else Cells(current_row, 5) = 180
End Sub

Sub delta_sfx()
*****
' Activate Sheet2
*****

```

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```
Worksheets("Sheet2").Activate

*****
' Insert a row, label it "Farthest point fwd under cable", calculate the data, and fill in the data
' for this row. The sx' coordinate (in column 3) is equal to the sx' coordinate at the center of
' the cable "sxcb" plus or minus half of the beam and keep out diameter plus or minus the distance
' forward under the cable (depending on the direction of travel).
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Farthest point fwd under cable"
Cells(current_row, 13) = 0
If sxb_final > sxb_initial Then Cells(current_row, 3) = sxcb - (beam + dia) / 2 + delta_s_fwd Else _
Cells(current_row, 3) = sxcb + (beam + dia) / 2 + delta_s_fwd

Cells(current_row, 4) = syb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 12) = time_shutter_off
*****
' Define the parameters and apply them to the quadratic formula for determining the cosine of the
' angle alpha under the cable. Write this value for the cosine of alpha into column 19, and then
' take the arc cosine and write this value as the angle alpha into column 20. Write the distance
' "delta_s" under the cable in column 10, and convert alpha to degrees and write it into column 11.
*****
delta_s = Abs(delta_s_fwd)
H = Abs(sycb - syb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos_alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos_alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
*****
' Determine the angle beta and write it into column 5. The angle beta is either 0 or 180 degrees
' offset by plus or minus alpha (depending on the edge of the part under the cable, and the direction
' of rotation of the part. Then increment the value of "current_row", to go on to the next row.
*****
If syb > 0 Then Cells(current_row, 5) = 0 - direction * Cells(current_row, 11) Else _
Cells(current_row, 5) = 180 - direction * Cells(current_row, 11)

current_row = current_row + 1
End Sub

Sub delta_sbx()
*****
' Activate Sheet2
*****
Worksheets("Sheet2").Activate
*****
' Insert a row, label it "Farthest point bkwd under cable", calculate the data, and fill in the data
' for this row. The sx' coordinate (in column 3) is equal to the sx' coordinate at the center of the
' cable "sxcb" plus or minus half of the beam and keep out diameter plus or minus the distance
' backward under the cable (depending on the direction of travel).
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Farthest point bkwd under cable"
Cells(current_row, 13) = 1
If sxb_final > sxb_initial Then Cells(current_row, 3) = sxcb + (beam + dia) / 2 - delta_s_bkwd Else _
Cells(current_row, 3) = sxcb - (beam + dia) / 2 - delta_s_bkwd

Cells(current_row, 4) = syb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 12) = time_shutter_off
*****
' Define the parameters and apply them to the quadratic formula for determining the cosine of the
' angle alpha under the cable. Write this value for the cosine of alpha into column 19, and then
' take the arc cosine and write this value as the angle alpha into column 20. Write the distance
' "delta_s" under the cable in column 10, and convert alpha to degrees and write it into column 11.
*****
delta_s = Abs(delta_s_bkwd)
H = Abs(sycb - syb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
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b = 2 * (dia + beam) / 2 * (delta s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos alpha
Cells(current_row, 20) = "ACOS(RC[-1])"
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
*****
' Determine the angle beta and write it into column 5. The angle beta is either 0 or 180 degrees
' offset by plus or minus alpha (depending on the edge of the part under the cable, and the direction
' of rotation of the part. Then increment the value of "current_row", to go on to the next row.
*****
If syb > 0 Then Cells(current_row, 5) = 0 + direction * Cells(current_row, 11) Else _
Cells(current_row, 5) = 180 + direction * Cells(current_row, 11)

current_row = current_row + 1
End Sub

Sub fill_cable_y()
*****
' Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
' Read in cable definition data from current row. The plus or minus sign of the "delta_s_fwd" and
' "delta_s_bkwd" values depends on the direction of movement under the cable. This is checked
' by comparing the coordinates at the start and finish ("syb_initial" and "syb_final" respectively).
*****
dia = Cells(current_row, 7)
syb_initial = Cells(current_row - 1, 4)
sxb = Cells(current_row - 1, 3)
syb_final = Cells(current_row + 1, 4)
sxcb = Cells(current_row, 8)
sycb = Cells(current_row, 9)
If syb_final > syb_initial Then delta_s_fwd = Cells(current_row, 10) Else _
delta_s_fwd = -1 * Cells(current_row, 10)

If syb_final > syb_initial Then delta_s_bkwd = Cells(current_row, 11) Else _
delta_s_bkwd = -1 * Cells(current_row, 11)

time_shutter_off = Cells(current_row, 12)
*****
' After reading in the cable data for the distances forward under the cable and backward under
' the cable, the columns containing this data are changed to become "Delta S' Under Cable (in)"
' and "Alpha Angle Under Cable (degrees)" respectively.
*****
Cells(first_row - 1, 10) = "Delta S' Under Cable (in)"
Cells(first_row - 1, 11) = "Angle Alpha Under Cable (deg)"
*****
' Insert a row, label it "Edge of beam meets cable", calculate the data, and either calculate or
' just fill in the data for this row. The sy' coordinate at the point where the laser beam edge
' meets the cable is found by either adding or subtracting half of the laser beam width and half of
' the "keep out diameter" from the sy' coordinate of the center of the cable (depending on the
' direction of travel found by comparing the values of the sx' coordinates in the previous and next
' rows). The values for the distances "Delta S' Under Cable" and "Alpha Angle Under Cable" are zero
' by default when the laser beam edge first meets the edge of the "keep out area". The previously
' defined values are filled in for the "keep out diameter", body fixed sx' coordinate to the center
' of the cable, and body fixed sy' coordinate to the center of the cable. The value for sx' is the
' same as the value read in for sxb. The angle beta is either 90 degrees or 270 degrees at this
' point (depending on which face the movement occurs). If the face has a positive sx' coordinate,
' the movement is along the edge defined by sx' = half the width of the part and the beta angle is
' 90 degrees. If the face has a negative sx' coordinate, the movement is along the edge defined
' by sx' = negative half the width of the part and the beta angle is 270 degrees.
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Edge of beam meets cable"
If syb_final > syb_initial Then Cells(current_row, 4) = sycb - (beam + dia) / 2 Else _
Cells(current_row, 4) = sycb + (beam + dia) / 2

Cells(current_row, 3) = sxb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 10) = 0
Cells(current_row, 11) = 0
If sxb > 0 Then Cells(current_row, 5) = 90 Else Cells(current_row, 5) = 270
*****
' Go to the next row. If the value for moving forward under the cable was non-zero, run the

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subroutine called "delta_sfy" (this subroutine will insert a row, calculate the data for the
farthest point forward under the cable, and fills in the data for that row). After this, if the
value for moving backward under the cable was non-zero, then run the subroutine called "delta_sby"
(this subroutine will insert a row, calculate the data for the farthest point backward under the
cable, and fills in the data for that row). The value in the shutter column is always set to zero
at the instant before the cable begins to move through the area under the laser beam. If the
"delta_sfy" subroutine is not run, this point occurs at the edge of the cable and the shutter value
is set to zero on the row labeled "Edge of beam meets cable". If the "delta_sfy" subroutine is
run, this point occurs at the farthest point forward under the cable and the shutter value is set
to zero on the row inserted by the "delta_sfy" subroutine.
*****
current_row = current_row + 1
If Abs(delta_s_fwd) > 0 Then delta_sfy Else Cells(current_row - 1, 13) = 0 'the else statement
' turns off the shutter
' if delta_sfy is not
' run
If Abs(delta_s_bkwd) > 0 Then delta_sby
*****
Label the last row of the cable "Last contact with cable", calculate the data, and either
calculate or just fill in the data for this row. The sy' coordinate at the point where the laser
beam edge last contacts the cable is found by either adding or subtracting half of the laser beam
width and half of the "keep out diameter" from the sy' coordinate of the center of the cable
(depending on the direction of travel found by comparing the values of the sy' coordinates in the
previous and next rows). The values for the distances "Delta S' Under Cable" and "Alpha Angle
Under Cable" are zero by default when the laser beam edge last contacts the edge of the
"keep out area". The previously defined values are filled in for the "keep out diameter",
body fixed sx' coordinate to the center of the cable, and body fixed sy' coordinate to the center
of the cable. The value for sx' is the same as the value read in for sxb. The value originally
entered by the user in for the "time to back under cable" is then cleared. The angle beta is
either 90 degrees or 270 degrees at this point (depending on which face the movement occurs).
If the face has a positive sx' coordinate, the movement is along the edge defined by sx' = half the
length of the part and the beta angle is 90 degrees. If the face has a negative sx' coordinate,
the movement is along the edge defined by sx' = negative half the length of the part and the
beta angle is 270 degrees.
*****
Cells(current_row, 1) = "Last contact with cable"
If syb_final > syb_initial Then Cells(current_row, 4) = sycb + (beam + dia) / 2 Else _
Cells(current_row, 4) = sycb - (beam + dia) / 2

Cells(current_row, 3) = sxb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxc_b
Cells(current_row, 9) = sycb
Cells(current_row, 10) = 0
Cells(current_row, 11) = 0
Cells(current_row, 12) = Selection.ClearContents
If sxb > 0 Then Cells(current_row, 5) = 90 Else Cells(current_row, 5) = 270
End Sub

Sub delta_sfy()
*****
Activate Sheet2
Worksheets("Sheet2").Activate
*****
Insert a row, label it "Farthest point fwd under cable", calculate the data, and fill in the data
for this row. The sy' coordinate (in column 4) is equal to the sy' coordinate at the center of
the cable "sycb" plus or minus half of the beam and keep out diameter plus or minus the distance
forward under the cable (depending on the direction of travel).
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Farthest point fwd under cable"
Cells(current_row, 13) = 0
If syb_final > syb_initial Then Cells(current_row, 4) = sycb - (beam + dia) / 2 + delta_s_fwd Else _
Cells(current_row, 4) = sycb + (beam + dia) / 2 + delta_s_fwd

Cells(current_row, 3) = sxb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxc_b
Cells(current_row, 9) = sycb
Cells(current_row, 12) = time_shutter_off
*****
Define the parameters and apply them to the quadratic formula for determining the cosine of the
angle alpha under the cable. Write this value for the cosine of alpha into column 19, and then
take the arc cosine and write this value as the angle alpha into column 20. Write the distance
"delta s" under the cable in column 10, and convert alpha to degrees and write it into column 11.
*****
delta_s = Abs(delta_s_fwd)

```

Module1

```

H = Abs(sxcb - sxb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
*****
' Determine the angle beta and write it into column 5. The angle beta is either 90 or 270 degrees
' offset by plus or minus alpha (depending on the edge of the part under the cable, and the
' direction of rotation of the part. Then increment the value of "current_row", to go on to the
' next row.
*****
If sxb > 0 Then Cells(current_row, 5) = 90 - direction * Cells(current_row, 11) Else _
Cells(current_row, 5) = 270 - direction * Cells(current_row, 11)

current_row = current_row + 1
End Sub

Sub delta_sby()
*****
' Activate Sheet2
*****
Worksheets("Sheet2").Activate

*****
' Insert a row, label it "Farthest point bkwd under cable", calculate the data, and fill in the data
' for this row. The sy' coordinate (in column 4) is equal to the sy' coordinate at the center of
' the cable "sycb" plus or minus half of the beam and keep out diameter plus or minus the distance
' backward under the cable (depending on the direction of travel).
*****
Range(Cells(current_row, 1), Cells(current_row, 20)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 1) = "Farthest point bkwd under cable"
Cells(current_row, 13) = 1
If syb_final > syb_initial Then Cells(current_row, 4) = sycb + (beam + dia) / 2 - delta_s_bkwd Else _
Cells(current_row, 4) = sycb - (beam + dia) / 2 - delta_s_bkwd

Cells(current_row, 3) = sxb
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 12) = time_shutter_off
*****
' Define the parameters and apply them to the quadratic formula for determining the cosine of the
' angle alpha under the cable. Write this value for the cosine of alpha into column 19, and then
' take the arc cosine and write this value as the angle alpha into column 20. Write the distance
' "delta_s" under the cable in column 10, and convert alpha to degrees and write it into column 11.
*****
delta_s = Abs(delta_s_bkwd)
H = Abs(sxcb - sxb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
*****
' Determine the angle beta and write it into column 5. The angle beta is either 90 or 270 degrees
' offset by plus or minus alpha (depending on the edge of the part under the cable, and the
' direction of rotation of the part. Then increment the value of "current_row", to go on to the
' next row.
*****
If sxb > 0 Then Cells(current_row, 5) = 90 + direction * Cells(current_row, 11) Else _
Cells(current_row, 5) = 270 + direction * Cells(current_row, 11)

current_row = current_row + 1
End Sub

```


Module2

```

*****
*****
EXCELS.0 MACROS FOR GENERATING SPREADSHEETS FOR LASER SOLDERING
MOTION CONTROL SYSTEM (MODULE2)
SCOTT YERGANIAN 11-11-96
*****
*****

Const first_row = 7
Dim current_row As Integer
Dim lngth As Single
Dim wdth As Single
Dim radius As Single
Dim beam As Single
Dim time_step As Single
Dim dia As Single
Dim ave_speed As Single
Dim sxb_initial As Single
Dim syb_initial As Single
Dim sxb_final As Single
Dim syb_final As Single
Dim sxc_b As Single
Dim syc_b As Single
Dim time_shutter_off As Single
Dim half_beam_and_cable As Single
Dim delta_s_fwd As Single
Dim delta_s_bkwd As Single
Dim syb As Single
Dim sxb As Single
Dim cntclock As Integer
Dim direction As Integer

Sub COPY_AND_CREATE_FULL_DATA()
*****
' This subroutine is run by the button on Sheet2. It runs the macros needed to delete the old
' Sheet3 and recreate Sheet3 (full data) with all of the data generated for a complete move around
' the part.
*****
Recreate_Sheet3
Move
fill_in_beta
fill_in_shutter
Fill_in_motion_data
End Sub

Sub Delete_Sheet3()
*****
' This subroutine is run by the button labeled "Delete Sheet3" on Sheet3. It allows the user to
' easily delete the Sheet3 data to manage the file size of the spreadsheet before saving. Because
' Sheet2 is still intact, Sheet3 may be easily regenerated by activating the button on Sheet2.
' This macro first looks for the sheet called Sheet3 (full data) and deletes it if it exists.
*****
If Sheets(3).Name = "Sheet3" Then Sheets(3).Delete
Sheets(2).Activate
End Sub

Sub Recreate_Sheet3()
*****
' This subroutine looks for the sheet called Sheet3 (full data) and deletes it if it exists, then
' creates a
' copy of Sheet2 (expanded user input data) and names it Sheet3. It then reads in some data needed
' for the rest of the macros, and runs the macros to create the rest of the buttons at the top of
' Sheet3
*****
If Sheets(3).Name = "Sheet3" Then Sheets(3).Delete
Sheets(2).Copy After:=Sheets(2)
Sheets(3).Name = "Sheet3"
Range("A1").Select
*****
Delete the button from Sheet3
*****
ActiveSheet.DrawingObjects("Button 11").Select
Selection.Delete
*****
' Read in the values of some of the parameters used in the rest of the macros and run the macro to
' create the rest of the buttons at the top of Sheet3

```

Module2

```

*****
length = Cells(2, 7)
width = Cells(2, 8)
radius = Cells(2, 9)
beam = Cells(2, 5)
time_step = Cells(2, 11)
Make_Sheet3_Buttons
End Sub

```

```

Sub Move()
*****
' This macro scans down each row of data copied from Sheet2 to Sheet3. Based on the values of the
' sx' and sy' coordinates, it chooses which movement macro is required and then runs the macros
' needed to generate the data describing the complete movement around the part.
*****
' Activate Sheet3
*****
Worksheets("Sheet3").Activate

' Read in the values of some of the parameters used in the rest of the macros.
*****
length = Cells(2, 7)
width = Cells(2, 8)
radius = Cells(2, 9)
beam = Cells(2, 5)
time_step = Cells(2, 11)
*****
' Step through each row beginning with the row following "first row", keeping track of current row
' position using the variable called "current_row". Set variables called "move_x", "move_y", or
' "corner" to be true or false by comparing the sx' and sy' coordinates (columns 3 and 4) of the
' current row, to the part geometry, or if the label in column 1 designates the end of a corner.
' In some cases, (at the beginning or ending of a corner move) both "corner" and "move_x" or "move_y"
' may be true. The selection logic used later will determine the correct macros in these cases.
*****
current_row = first_row + 1
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0.00001
If Abs(Abs(Cells(current_row, 4)) - width / 2) < 0.00001 Then move_x = True Else move_x = False
If Abs(Abs(Cells(current_row, 3)) - length / 2) < 0.00001 Then move_y = True Else move_y = False
If Abs(Cells(current_row, 3)) > length / 2 - radius + 0.00001 And _
Abs(Cells(current_row, 4)) > width / 2 - radius + 0.00001 Then corner = True Else corner = False

If Cells(current_row, 1) = "end of corner c1" Or Cells(current_row, 1) = "end of corner c2" Or _
Cells(current_row, 1) = "end of corner c3" Or Cells(current_row, 1) = "end of corner c4" Then _
corner = True
*****
' Run the one macro for the movement needed, based on the values of the variables "move_x", "move_y",
' and "corner". If all of the variables are false, then something is wrong, skip to the end of the
' subroutine called "last line". Run the macro "Move_delta_x", "Move_delta_y" or "Move_corner" and
' then loop back to run though the subroutine again. If the criteria for both "corner" and "move_x"
' or "move_y" are true, then it is actually a corner, and the "Move_corner" subroutine is run.
*****
If move_x = False And move_y = False And corner = False Then GoTo last_line
If move_x = True And corner = False Then Move_delta_x
If move_y = True And corner = False Then Move_delta_y
If corner = True Then Move_corner
Loop
last_line:
Cells(1, 1).Select
End Sub

```

```

Sub Move_delta_x()
*****
' Activate Sheet3
*****
Worksheets("Sheet3").Activate

' Read in the values for the initial sx' coordinate value and the final sx' coordinate value in the
' interval. Calculate the total distance to move. Compare the values for the initial and final sx'
' coordinates to determine if the velocity is in the positive or negative directions. Then set the

```

Module2

```

initial and final velocities equal to either plus or minus the travel speed (column 6) values.
*****
s_initial = Cells(current_row - 1, 3)
s_final = Cells(current_row, 3)
total_s = s_final - s_initial
If s_final > s_initial Then initial_vel = Cells(current_row - 1, 6) Else _
initial_vel = -1 * Cells(current_row - 1, 6)

If s_final > s_initial Then final_vel = Cells(current_row, 6) Else _
final_vel = -1 * Cells(current_row, 6)
*****
Determine if this is the special case for a quick movement around the cable with the shutter
turned off by checking for the labels designating the farthest points forward or backward under the
cable have been reached. If so, the velocity of movement is not governed by the values entered for
the travel speed (column 6). In these cases, the travel speed value is used to determine the final
velocity of the previous movement. Both the initial and final velocities while moving with the
shutter off are set to the value calculated by dividing the distance to travel during this move by
the value of the "Time to back under cable" (column 12).
*****
If Cells(current_row, 1) = "Farthest point bkwd under cable" Then _
initial_vel = (s_final - s_initial) / Cells(current_row, 12)

If Cells(current_row, 1) = "Farthest point bkwd under cable" Then final_vel = initial_vel
If Cells(current_row - 1, 1) = "Farthest point fwd under cable" Then _
initial_vel = (s_final - s_initial) / Cells(current_row - 1, 12)

If Cells(current_row - 1, 1) = "Farthest point fwd under cable" Then final_vel = initial_vel
*****
Because the velocity can change over an interval, the equations from physics for a body moving
under constant acceleration are used (the user may define different travel speeds at the beginning
and end of a movement interval, but the acceleration is assumed constant).
The first physics relationship used is that the total time is equal to the total distance divided
by the average velocity. The second physics relationship used is that the distance traveled is
equal to the initial distance plus the initial velocity multiplied by the time plus one half the
acceleration multiplied by the time squared. Once the total time is calculated for the interval,
it must be rounded off to a discreet number of time steps. After dividing the total time by the
time step interval, the number of steps are rounded up (if the remainder is greater than or equal
to 0.5) or rounded down (if the remainder is less than 0.5).
*****
ave_vel = (initial_vel + final_vel) / 2
delta_vel = final_vel - initial_vel
time_total = total_s / ave_vel
number_steps = time_total / time_step
If number_steps - Int(number_steps) >= 0.5 Then number_steps = Int(number_steps) + 1 Else _
number_steps = Int(number_steps)

accel = delta_vel / time_total
*****
Use a loop to insert one row at a time and fill in data for each time step in the interval.
As each row is inserted, the rest of the rows are shifted down so that the variable called
"current row" refers to the inserted (empty) row, and "current row + 1" is always the final row of
the interval. The total number of rows to be inserted during the loop execution equals one less
than the number of steps, because the last step is the final row of the interval.
The new sx' coordinate for the inserted row is called s_new and is calculated from the physics
equation with time equal to the number of time steps that have occurred. The sy' coordinate is
constant and is equal to the same value used in the previous row. The angle alpha needs to be
calculated for movements under a cable.
*****
For k = 1 To number_steps - 1 Step 1
s_new = s_initial + initial_vel * k * time_step + accel / 2 * (k * time_step) ^ 2
Range(Cells(current_row, 1), Cells(current_row, 36)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 3) = s_new
Cells(current_row, 4) = Cells(current_row - 1, 4)
*****
Determine if the movement is going forward under a cable by looking for the designator called
"Farthest point fwd under cable". If so, do the following. If not, then skip the next steps by
going to the step in the subroutine called "not_fwd_under_cable".
If the movement is under a cable, then the values for alpha need to be calculated. Because the
current row was inserted as an empty row, the cable data must be read from "current row + 1"
(the final row of the interval). The variables a, b, and c are used in the quadratic formula to
solve for the cosine of the angle alpha. The cosine of alpha is then written into column 19, and
the angle alpha (in radians) is evaluated in column 20. The values for the "keep out diameter"
around the cable, the sx' and sy' coordinates to the center of the cable, the distance "delta_s"
under the cable and the angle alpha (converted to degrees) are then filled in for the row.
*****
If Cells(current_row + 1, 1) <> "Farthest point fwd under cable" Then GoTo not_fwd_under_cable
delta_s = Abs(s_new - s_initial)
syb = Cells(current_row, 4)
dia = Cells(current_row + 1, 7)

```

Module2

```

sxcb = Cells(current_row + 1, 8)
sycb = Cells(current_row + 1, 9)
H = Abs(syxb - syb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos_alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos_alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
not_fwd_under_cable:
'*****
' Determine if the movement is going backward under a cable by looking for the designator called
' "Farthest point bkwd under cable". If so, do the following. If not, then skip the next steps by
' going to the step in the subroutine called "not_bkwd_under_cable".
' If the movement is under a cable, then the values for alpha need to be calculated. Because the
' current row was inserted as an empty row, the cable data must be read from "current_row + 1"
' (the final row of the interval). The variables a, b, and c are used in the quadratic formula to
' solve for the cosine of the angle alpha. The cosine of alpha is then written into column 19, and
' the angle alpha (in radians) is evaluated in column 20. The values for the "keep out diameter"
' around the cable, the sx' and sy' coordinates to the center of the cable, the distance "delta_s"
' under the cable and the angle alpha (converted to degrees) are then filled in for the row.
'*****
If Cells(current_row - k, 1) <> "Farthest point bkwd under cable" Then GoTo not_bkwd_under_cable
delta_s = Abs(s_new - s_final)
syb = Cells(current_row, 4)
dia = Cells(current_row + 1, 7)
sxcb = Cells(current_row + 1, 8)
sycb = Cells(current_row + 1, 9)
H = Abs(syxb - syb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos_alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos_alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
not_bkwd_under_cable:
'*****
' Increment the row number and run through the loop again
'*****
current_row = current_row + 1
Next k
'*****
' Increment the row number and return to the main subroutine called "Move"
'*****
current_row = current_row + 1
End Sub

Sub Move_delta_y()
'*****
' Activate Sheet3
'*****
Worksheets("Sheet3").Activate

'*****
' Read in the values for the initial sy' coordinate value and the final sy' coordinate value in the
' interval. Calculate the total distance to move. Compare the values for the initial and final sy'
' coordinates to determine if the velocity is in the positive or negative directions. Then set the
' initial and final velocities equal to either plus or minus the travel speed (column 6) values.
'*****
s_initial = Cells(current_row - 1, 4)
s_final = Cells(current_row, 4)
total_s = s_final - s_initial
If s_final > s_initial Then initial_vel = Cells(current_row - 1, 6) Else _
initial_vel = -1 * Cells(current_row - 1, 6)

If s_final > s_initial Then final_vel = Cells(current_row, 6) Else final_vel = -1 * Cells(current_row
, 6)
'*****
' Determine if this is the special case for a quick movement around the cable with the shutter

```

Module2

```

turned off by checking for the labels designating the farthest points forward or backward under the
cable have been reached. If so, the velocity of movement is not governed by the values entered for
the travel speed (column 6). In these cases, the travel speed value is used to determine the final
velocity of the previous movement. Both the initial and final velocities while moving with the
shutter off are set to the value calculated by dividing the distance to travel during this move by
the value of the "Time to back under cable" (column 12).
*****
If Cells(current_row, 1) = "Farthest point bkwd under cable" Then _
initial_vel = (s_final - s_initial) / Cells(current_row, 12)

If Cells(current_row, 1) = "Farthest point bkwd under cable" Then final_vel = initial_vel
If Cells(current_row - 1, 1) = "Farthest point fwd under cable" Then _
initial_vel = (s_final - s_initial) / Cells(current_row - 1, 12)

If Cells(current_row - 1, 1) = "Farthest point fwd under cable" Then final_vel = initial_vel
*****
Because the velocity can change over an interval, the equations from physics for a body moving
under constant acceleration are used (the user may define different travel speeds at the beginning
and end of a movement interval, but the acceleration is assumed constant).
The first physics relationship used is that the total time is equal to the total distance divided
by the average velocity. The second physics relationship used is that the distance traveled is
equal to the initial distance plus the initial velocity multiplied by the time plus one half the
acceleration multiplied by the time squared.
Once the total time is calculated for the interval, it must be rounded off to a discreet number
of time steps. After dividing the total time by the time step interval, the number of steps are
rounded up (if the remainder is greater than or equal to 0.5) or rounded down (if the remainder is
less than 0.5).
*****
ave_vel = (initial_vel + final_vel) / 2
delta_vel = final_vel - initial_vel
time_total = total_s / ave_vel
number_steps = time_total / time_step
If number_steps - Int(number_steps) >= 0.5 Then number_steps = Int(number_steps) + 1
accel = delta_vel / time_total
*****
Use a loop to insert one row at a time and fill in data for each time step in the interval.
As each row is inserted, the rest of the rows are shifted down so that the variable called
"current_row" refers to the inserted (empty) row, and "current_row + 1" is always the final row of
the interval. The total number of rows to be inserted during the loop execution equals one less
than the number of steps, because the last step is the final row of the interval.
The new sy' coordinate for the inserted row is called s_new and is calculated from the physics
equation with time equal to the number of time steps that have occurred. The sx' coordinate is
constant and is equal to the same value used in the previous row. The angle alpha needs to be
calculated for movements under a cable.
*****
For k = 1 To number_steps - 1 Step 1
s_new = s_initial + initial_vel * k * time_step + accel / 2 * (k * time_step) ^ 2
Range(Cells(current_row, 1), Cells(current_row, 36)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 4) = s_new
Cells(current_row, 3) = Cells(current_row - 1, 3)
*****
Determine if the movement is going forward under a cable by looking for the designator called
"Farthest point fwd under cable". If so, do the following. If not, then skip the next steps by
going to the step in the subroutine called "not_fwd_under_cable".
If the movement is under a cable, then the values for alpha need to be calculated. Because the
current row was inserted as an empty row, the cable data must be read from "current_row + 1"
(the final row of the interval). The variables a, b, and c are used in the quadratic formula to
solve for the cosine of the angle alpha. The cosine of alpha is then written into column 19, and
the angle alpha (in radians) is evaluated in column 20. The values for the "keep out diameter"
around the cable, the sx' and sy' coordinates to the center of the cable, the distance "delta_s"
under the cable and the angle alpha (converted to degrees) are then filled in for the row.
*****
If Cells(current_row + 1, 1) <> "Farthest point fwd under cable" Then GoTo not_fwd_under_cable
delta_s = Abs(s_new - s_initial)
sxb = Cells(current_row, 3)
dia = Cells(current_row + 1, 7)
sxcb = Cells(current_row + 1, 8)
sycb = Cells(current_row + 1, 9)
H = Abs(sxcb - sxb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos_alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos_alpha
Cells(current_row, 20) = "=ACOS(RC[-1])"
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 10) = delta_s

```

Module2

```

Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
not fwd under cable:
*****
' Determine if the movement is going backward under a cable by looking for the designator called
' "Farthest point bkwd under cable". If so, do the following. If not, then skip the next steps by
' going to the step in the subroutine called "not_bkwd_under_cable".
' If the movement is under a cable, then the values for alpha need to be calculated. Because the
' current row was inserted as an empty row, the cable data must be read from "current_row + 1"
' (the final row of the interval). The variables a, b, and c are used in the quadratic formula to
' solve for the cosine of the angle alpha. The cosine of alpha is then written into column 19, and
' the angle alpha (in radians) is evaluated in column 20. The values for the "keep out diameter"
' around the cable, the sx' and sy' coordinates to the center of the cable, the distance "delta_s"
' under the cable and the angle alpha (converted to degrees) are then filled in for the row.
*****
If Cells(current_row - k, 1) <> "Farthest point bkwd under cable" Then GoTo not_bkwd_under_cable
delta_s = Abs(s_new - s_final)
sxb = Cells(current_row, 3)
dia = Cells(current_row + 1, 7)
sxcb = Cells(current_row + 1, 8)
sycb = Cells(current_row + 1, 9)
H = Abs(sxcb - sxb)
a = (delta_s - (dia + beam) / 2) ^ 2 + H ^ 2
b = 2 * (dia + beam) / 2 * (delta_s - (dia + beam) / 2)
c = ((dia + beam) / 2) ^ 2 - H ^ 2
cos_alpha = (-b + Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
Cells(current_row, 19) = cos_alpha
Cells(current_row, 20) = "ACOS(RC[-1])"
Cells(current_row, 7) = dia
Cells(current_row, 8) = sxcb
Cells(current_row, 9) = sycb
Cells(current_row, 10) = delta_s
Cells(current_row, 11) = Cells(current_row, 20) * 180 / 3.14159265358979
not_bkwd_under_cable:
*****
' Increment the row number and run through the loop again
*****
current_row = current_row + 1
Next k
*****
' Increment the row number and return to the main subroutine called "Move"
*****
current_row = current_row + 1
End Sub

Sub Move_corner()
*****
' Activate Sheet3
*****
Worksheets("Sheet3").Activate
*****
' Read in the values for the initial sx' and sy' coordinates and the final sx' and sy' coordinates
' in the interval. The x distance and y distance to the center of the radiused corners are half the
' length minus the radius and half the width minus the radius respectively. The sx' and sy'
' coordinates to the center of the radiused corners are calculated and labeled "xcb" and "ycb" and
' are either positive or negative depending on the initial sx' and sy' coordinates.
*****
sxb_initial = Cells(current_row - 1, 3)
syb_initial = Cells(current_row - 1, 4)
sxb_final = Cells(current_row, 3)
syb_final = Cells(current_row, 4)
If sxb_initial > 0 Then xcb = lngth / 2 - radius Else xcb = -(lngth / 2 - radius)
If syb_initial > 0 Then ycb = wdth / 2 - radius Else ycb = -(wdth / 2 - radius)
*****
' In the corners, the sx' and sy' coordinates are related by the angle though the corner called
' "theta". The value for "theta_initial" and "theta_final" are calculated (using absolute values),
' and are always either 0 or pi/2 radians (if "theta_initial" = 0 then "theta_final" = pi/2 radians
' and vice versa). The arc tangent method was used to calculate the theta values because this
' version of Visual Basic doesn't support arc cosines or arc sines. Because of this, a small number
' was added to the denominator to prevent division by zero. The "total_theta" value (difference
' between the initial and final theta values) will always be either plus or minus pi/2 and the
' angular velocities "theta_dot_initial" and "theta_dot_final" will have the same positive or negative
' sign as the value for "total_theta". The initial and final velocities are still based on the user
' input value for travel speed (column 6), but these travel speed values are used to determine the
' corresponding angular velocities "theta_dot" based on the relationship that the tangential velocity
' (travel speed) is equal to the angular velocity multiplied by the radius. Using this relationship,

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' the initial and final angular velocities "theta_dot_initial" and "theta_dot_final" are calculated
' as either plus or minus the travel speed divided by the radius.
'*****
theta_initial = Atn(Abs(syb_initial - ycb) / (Abs(sxb_initial - xcb) + 0.000000000000001))
theta_final = Atn(Abs(syb_final - ycb) / (Abs(sxb_final - xcb) + 0.000000000000001))
total_theta = theta_final - theta_initial
If total_theta > 0 Then theta_dot_initial = Cells(current_row - 1, 6) / radius Else _
theta_dot_initial = -1 * Cells(current_row - 1, 6) / radius

If total_theta > 0 Then theta_dot_final = Cells(current_row, 6) / radius Else _
theta_dot_final = -1 * Cells(current_row, 6) / radius
'*****
' Because the velocity can change over an interval, the equations from physics for a body moving
' under constant acceleration due to a constant angular acceleration are used (the user may define
' different travel speeds at the beginning and end of a movement interval, but the acceleration is
' assumed constant). The first physics relationship used is that the total time is equal to the
' total theta distance "total_theta" divided by the average angular velocity "ave_theta_dot". The
' second physics relationship used is that the angle traveled is equal to the initial angle plus the
' initial angular velocity multiplied by the time plus one half the angular acceleration multiplied
' by the time squared.
' Once the total time is calculated for the interval, it must be rounded off to a discreet number of
' time steps. After dividing the total time by the time step interval, the number of steps are
' rounded up (if the remainder is greater than or equal to 0.5) or rounded down (if the remainder is
' less than 0.5).
'*****
ave_theta_dot = (theta_dot_initial + theta_dot_final) / 2
delta_theta_dot = theta_dot_final - theta_dot_initial
time_total = total_theta / ave_theta_dot
number_steps = time_total / time_step
If number_steps - Int(number_steps) >= 0.5 Then number_steps = Int(number_steps) + 1 Else _
number_steps = Int(number_steps)

theta_double_dot = delta_theta_dot / time_total
'*****
' Use a loop to insert one row at a time and fill in data for each time step in the interval.
' As each row is inserted, the rest of the rows are shifted down so that the variable called
' "current_row" refers to the inserted (empty) row, and "current_row + 1" is always the final row of
' the interval. The total number of rows to be inserted during the loop execution equals one less
' than the number of steps, because the last step is the final row of the interval.
' The new theta value used to calculate the sx' and sy' coordinates for the inserted row is called
' "theta_new" and is calculated from the physics equation for theta with time equal to the number of
' time steps that have occurred. Once the new value for theta is calculated, the new sx' and sy'
' coordinates for the inserted row (called "sxb_new" and "syb_new" respectively) are calculated
' using the coordinates of the radius center, the radius, and the angle theta. The value called
' "sign_x" or "sign_y" are used to correct the equation for use on all corners of the part.
'*****
For k = 1 To number_steps - 1 Step 1
theta_new = theta_initial + theta_dot_initial * k * time_step + _
theta_double_dot / 2 * (k * time_step) ^ 2

If xcb > 0 Then sign_x = 1 Else sign_x = -1
If ycb > 0 Then sign_y = 1 Else sign_y = -1
sxb_new = xcb + sign_x * radius * Cos(theta_new)
syb_new = ycb + sign_y * radius * Sin(theta_new)
'*****
' Insert a row and fill in the calculated values for the sx' and sy' coordinates
'*****
Range(Cells(current_row, 1), Cells(current_row, 36)).Activate
Selection.Insert Shift:=xlDown
Cells(current_row, 3) = sxb_new
Cells(current_row, 4) = syb_new
'*****
' Increment the row number and run through the loop again
'*****
current_row = current_row + 1
Next k
'*****
' Increment the row number and return to the main subroutine called "Move"
'*****
current_row = current_row + 1
End Sub

```

```

Sub fill_in_beta()
'*****
' Activate Sheet2
'*****

```


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Worksheets("Sheet2").Activate

```

*****
Find the direction of movement around the part by starting at the beginning and searching for
each corner by looking for the "end of corner c1" type of label. Give a weighting factor
called "w" to each each corner (as it is found) and compare the size of the weighting factors
to determine the direction of rotation. The variable called "direction" = 1 for
counterclockwise rotation and -1 for clockwise rotation.
*****
current_row = first_row
w = 0
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) + Abs(Cells(current_row, 8)) +
Abs(Cells(current_row, 9)) > 0

If Cells(current_row, 1) = "end of corner c1" Or Cells(current_row, 1) = "end of corner c2" Or
Cells(current_row, 1) = "end of corner c3" Or Cells(current_row, 1) = "end of corner c4" Then
w = w + 1

If Cells(current_row, 1) = "end of corner c1" Then c1 = w
If Cells(current_row, 1) = "end of corner c2" Then c2 = w
current_row = current_row + 1
Loop
If c1 > c2 Then direction = 1
If c1 < c2 And c1 = 1 And c2 = 4 Then direction = 1
If c1 > c2 And c2 = 1 And c1 = 4 Then direction = -1
If direction <> 1 Then direction = -1
*****
Activate Sheet3
*****
Worksheets("Sheet3").Activate

*****
Start at the second row and run the major loop used to fill in the beta values until the end of the
data is found. Reset the variable "interval" to zero each time through the loop
*****
current_row = first_row + 1
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0
interval = 0
*****
Look for a cell with out a value for beta. When such an empty cell is found, increment the
variable called "interval" and then check for a beta value in the next row. Do this until a beta
value is found (the number of empty beta cells is the final value of "interval").
*****
Do While IsEmpty(Cells(current_row, 5)) = True
interval = interval + 1
current_row = current_row + 1
Loop
*****
Name the row just before the empty interval "starting_row" and the current row (just after the
empty interval) as "ending_row".
Calculate the incremental step for beta "delta_beta" as the change in beta values over the interval
divided by the size of the interval (number of empty rows plus one). Make the current row the
first row in the empty beta interval.
*****
starting_row = current_row - interval - 1
ending_row = current_row
delta_beta = (Cells(ending_row, 5) - Cells(starting_row, 5)) / (interval + 1)
current_row = starting_row + 1
*****
Run a loop to fill in the beta values incrementing each beta by adding the "delta_beta" value
*****
For k = 1 To interval Step 1
Cells(current_row, 5) = Cells(starting_row, 5) + k * delta_beta
*****
Check whether the interval includes forward movement under a cable. If so, set the variable
called "fwd" to be true. If "fwd" is true, then determine over which edge of the part, the
movement under the cable occurs.
The situation called "case_1" occurs when the cable is over the edge defined by sy' = width/2
(verified by a positive sy' value and the absolute value of the sx' value less than the length/2).
The situation called "case_2" occurs when the cable is over the edge defined by sx' = length/2
(verified by a positive sx' value and the absolute value of the sy' value less than the width/2).
The situation called "case_3" occurs when the cable is over the edge defined by sy' = -width/2
(verified by a negative sy' value and the absolute value of the sx' value less than the length/2).
The situation called "case_4" occurs when the cable is over the edge defined by sx' = -length/2
(verified by a negative sx' value and the absolute value of the sy' value less than the width/2).
For each case, the direction of rotation of the part determines the value of beta which will
violate the "keep out dia" of the cable. This value is called "beta_max". If the beta value
previously calculated violates the "beta_max" restriction then the beta value will be changed
to the "beta_max" value.
*****

```


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```

If Cells(ending_row, 1) = "Farthest point fwd under cable" Then fwd = True Else fwd = False

If fwd = True And Cells(current_row, 4) > 0 And Abs(Cells(current_row, 3)) < lngth / 2 Then _
case_1 = True Else case_1 = False

If case_1 = True Then beta_max = 0 - direction * Cells(current_row, 11)
If case_1 = True And direction = 1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_1 = True And direction = -1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If fwd = True And Cells(current_row, 3) > 0 And Abs(Cells(current_row, 4)) < wdth / 2 Then _
case_2 = True Else case_2 = False

If case_2 = True Then beta_max = 90 - direction * Cells(current_row, 11)
If case_2 = True And direction = 1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_2 = True And direction = -1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If fwd = True And Cells(current_row, 4) < 0 And Abs(Cells(current_row, 3)) < lngth / 2 Then _
case_3 = True Else case_3 = False

If case_3 = True Then beta_max = 180 - direction * Cells(current_row, 11)
If case_3 = True And direction = 1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max
If case_3 = True And direction = -1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If fwd = True And Cells(current_row, 3) < 0 And Abs(Cells(current_row, 4)) < wdth / 2 Then _
case_4 = True Else case_4 = False

If case_4 = True Then beta_max = 270 - direction * Cells(current_row, 11)
If case_4 = True And direction = 1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_4 = True And direction = -1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

*****
Check whether the interval includes backward movement under a cable. If so, set the variable
called "bkwd" to be true. If "bkwd" is true, then determine over which edge of the part, the
movement under the cable occurs.
The situation called "case_1" occurs when the cable is over the edge defined by sy' = width/2
(verfified by a positive sy' value and the absolute value of the sx' value less than the length/2).
The situation called "case_2" occurs when the cable is over the edge defined by sx' = length/2
(verfified by a positive sx' value and the absolute value of the sy' value less than the width/2).
The situation called "case_3" occurs when the cable is over the edge defined by sy' = -width/2
(verfified by a negative sy' value and the absolute value of the sx' value less than the length/2).
The situation called "case_4" occurs when the cable is over the edge defined by sx' = -length/2
(verfified by a negative sx' value and the absolute value of the sy' value less than the width/2).
For each case, the direction of rotation of the part determines the value of beta which will
violate the "keep out dia" of the cable. This value is called "beta_max". If the beta value
previously calculated violates the "beta_max" restriction then the beta value will be changed to
the "beta_max" value.
*****
If Cells(starting_row, 1) = "Farthest point bkwd under cable" Then bkwd = True Else bkwd = False

If bkwd = True And Cells(current_row, 4) > 0 And Abs(Cells(current_row, 3)) < lngth / 2 Then _
case_1 = True Else case_1 = False

If case_1 = True Then beta_max = 0 + direction * Cells(current_row, 11)
If case_1 = True And direction = 1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_1 = True And direction = -1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If bkwd = True And Cells(current_row, 3) > 0 And Abs(Cells(current_row, 4)) < wdth / 2 Then _
case_2 = True Else case_2 = False

If case_2 = True Then beta_max = 90 + direction * Cells(current_row, 11)
If case_2 = True And direction = 1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_2 = True And direction = -1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

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```

If bkwd = True And Cells(current_row, 4) < 0 And Abs(Cells(current_row, 3)) < lngth / 2 Then _
case_3 = True Else case_3 = False

If case_3 = True Then beta_max = 180 + direction * Cells(current_row, 11)
If case_3 = True And direction = 1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_3 = True And direction = -1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If bkwd = True And Cells(current_row, 3) < 0 And Abs(Cells(current_row, 4)) < width / 2 Then _
case_4 = True Else case_4 = False

If case_4 = True Then beta_max = 270 + direction * Cells(current_row, 11)
If case_4 = True And direction = 1 And beta_max > Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max

If case_4 = True And direction = -1 And beta_max < Cells(current_row, 5) Then _
Cells(current_row, 5) = beta_max
'*****
' Increment the row number and run through the internal loop again to fill in all beta values in the
' interval
'*****
current_row = current_row + 1
Next k
'*****
' Increment the row number and run through the large loop again to find another interval without
' beta values
'*****
current_row = current_row + 1
Loop
End Sub

Sub fill_in_shutter()
'*****
' Activate Sheet3
'*****
Worksheets("Sheet3").Activate
'*****
' Start at the second row and run the major loop used to fill in the shutter values until the end
' of the data is found. Run the next loop when ever the shutter cell (column 13) is empty
'*****
current_row = first_row + 1
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0
'*****
' For each shutter value that is empty, fill in the shutter with the previous shutter value.
'*****
Do While IsEmpty(Cells(current_row, 13)) = True
Cells(current_row, 13) = Cells(current_row - 1, 13)
current_row = current_row + 1
Loop
'*****
' Increment the row number and run through the large loop again to find another interval without
' shutter values
'*****
current_row = current_row + 1
Loop
Cells(1, 1).Select
End Sub

Sub Fill_in_motion_data()
'*****
' Activate Sheet3
'*****
Worksheets("Sheet3").Activate
'*****
' Set up area for calculating the incremental move data for driving the motion control system
' The first cells defined by the "first_row - 1" row designation are the labels for the data
' columns. The next cells defined by the "first_row" row designation are the initial values
' and are set to zero in some cases (such as the Delta_x or Delta_y values). The final cells
' defined by the "first_row + 1" designation are the formulas to be used for calculating all
' of the subsequent values.
'*****
'*****
' Elapsed Time (column 21): first value = 0 subsequent values = previous value plus time step

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*****
Cells(first_row - 1, 21) = "Elapsed Time (sec)"
Cells(first_row, 21) = "0"
Cells(first_row + 1, 21) = "=R[-1]C+R2C11"
*****
Beta (radians) (column 22): first and second value = beta in degrees converted to radians
*****
Cells(first_row - 1, 22) = "Beta (rad)"
Cells(first_row, 22) = "=RC[-17]*PI()/180"
Cells(first_row + 1, 22) = "=RC[-17]*PI()/180"
*****
Beta (steps) (column 23): first and second value = beta in radians converted to steps and rounded
off to the nearest whole integer
*****
Cells(first_row - 1, 23) = "Beta (steps)"
Cells(first_row, 23) = "=ROUND(RC[-1]*507904/(2*PI()),0)"
Cells(first_row + 1, 23) = "=ROUND(RC[-1]*507904/(2*PI()),0)"
*****
Sx global coordinate (column 24): first and second value = global Sx vector from transforming the
body fixed s vector to global coordinates
*****
Cells(first_row - 1, 24) = "Sx (in)"
Cells(first_row, 24) = "=RC3*COS(RC22)-RC4*SIN(RC22)"
Cells(first_row + 1, 24) = "=RC3*COS(RC22)-RC4*SIN(RC22)"
*****
Sy global coordinate (column 25): first and second value = global Sy vector from transforming the
body fixed s vector to global coordinates
*****
Cells(first_row - 1, 25) = "Sy (in)"
Cells(first_row, 25) = "=RC3*SIN(RC22)+RC4*COS(RC22)"
Cells(first_row + 1, 25) = "=RC3*SIN(RC22)+RC4*COS(RC22)"
*****
Global X coordinate to the center of the part (column 26): first and second value = global Rpx
vector minus the global Sx vector
*****
Cells(first_row - 1, 26) = "RAX (in)"
Cells(first_row, 26) = "=R2C3-RC24"
Cells(first_row + 1, 26) = "=R2C3-RC24"
*****
Global Y coordinate to the center of the part (column 27): first and second value = global Rpy
vector minus the global Sy vector
*****
Cells(first_row - 1, 27) = "RAY (in)"
Cells(first_row, 27) = "=R2C4-RC25"
Cells(first_row + 1, 27) = "=R2C4-RC25"
*****
Incremental change in the global x coordinate to the center of the part (column 28):
first value = 0 second value = current row global Rpx vector minus the previous row Rpx vector
(rounded off to the nearest 0.0001 inch)
*****
Cells(first_row - 1, 28) = "Delta X (in)"
Cells(first_row, 28) = "0"
Cells(first_row + 1, 28) = "=ROUND(RC26-R[-1]C26,4)"
*****
Incremental change in the global y coordinate to the center of the part (column 29):
first value = 0 second value = current row global Rpy vector minus the previous row Rpy vector
(rounded off to the nearest 0.0001 inch)
*****
Cells(first_row - 1, 29) = "Delta Y (in)"
Cells(first_row, 29) = "0"
Cells(first_row + 1, 29) = "=ROUND(RC27-R[-1]C27,4)"
*****
Incremental change in the beta angle in steps (column 30): first value = 0
second value = current row beta value minus the previous row beta value
*****
Cells(first_row - 1, 30) = "Delta Beta (steps)"
Cells(first_row, 30) = "0"
Cells(first_row + 1, 30) = "=RC23-R[-1]C23"
*****
Actual global X coordinate to the center of the part as the part is moved into position including
round off error (column 31): first value = theoretical value from column 26
second value = previous value plus the incremental change in the global x coordinate to the center
of the part from column 28
*****
Cells(first_row - 1, 31) = "RAX actual (in)"
Cells(first_row, 31) = "=RC26"
Cells(first_row + 1, 31) = "=R[-1]C31+RC28"
*****
Error between theoretical X coordinate to the center of the part from column 26 minus the actual
global X coordinate to the center of the part as the part is moved into position from column 31

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' (column 32) first and second values = column 26 - column 31
' *****
Cells(first_row - 1, 32) = "Error X (in)"
Cells(first_row, 32) = "=RC26-RC31"
Cells(first_row + 1, 32) = "=RC26-RC31"
' *****
' Actual global Y coordinate to the center of the part as the part is moved into position including
' round off error (column 33): first value = theoretical value from column 27
' second value = previous value plus the incremental change in the global y coordinate to the center
' of the part from column 29
' *****
Cells(first_row - 1, 33) = "RAY actual (in)"
Cells(first_row, 33) = "=RC27"
Cells(first_row + 1, 33) = "=R[-1]C33+RC29"
' *****
' Error between theoretical Y coordinate to the center of the part from column 27 minus the actual
' global Y coordinate to the center of the part as the part is moved into position from column 33
' (column 34) first and second values = column 27 - column 33
' *****
Cells(first_row - 1, 34) = "Error Y (in)"
Cells(first_row, 34) = "=RC27-RC33"
Cells(first_row + 1, 34) = "=RC27-RC33"
' *****
' Actual beta value of the part as the part is rotated into position including round off
' error (column 35): first value = theoretical value from column 23 second value = previous value
' plus the incremental change in beta from column 30
' *****
Cells(first_row - 1, 35) = "Beta actual (steps)"
Cells(first_row, 35) = "=RC23"
Cells(first_row + 1, 35) = "=R[-1]C35+RC30"
' *****
' Error between theoretical beta from column 23 minus the actual beta as the part is rotated into
' position from column 35 (column 36) first and second values = column 23 - column 35
' *****
Cells(first_row - 1, 36) = "Error Beta (steps)"
Cells(first_row, 36) = "=RC23-RC35"
Cells(first_row + 1, 36) = "=RC23-RC35"
' *****
' Find the end of the full data and label the last row "last_row"
' *****
' Find the end of the full data
current_row = first_row + 1
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0
current_row = current_row + 1
last_row = current_row - 1
Loop
' *****
' Autofill the motion control data by expanding the formulas contained in the first row plus one to
' a range ending with the last row. End by going to, and selecting the top corner of the sheet.
' *****
Range(Cells(first_row + 1, 21), Cells(first_row + 1, 36)).Select
Selection.AutoFill Destination:=Range(Cells(first_row + 1, 21), Cells(last_row, 36)), _
Type:=xlFillDefault

Cells(1, 1).Select
End Sub

```

```

Sub Make_Sheet3_Buttons()
' *****
' Activate Sheet3
' *****
Worksheets("Sheet3").Activate

' *****
' Create a button for deleting sheet three. The first commands define the button size and position,
' define the macro assigned to it, and the label. The rest of the commands define the way the
' button should look
' *****
ActiveSheet.Buttons.Add(3, 10, 120, 36).Select
Selection.OnAction = "Delete Sheet3"
Selection.Characters.Text = "Delete This Data Sheet"
With Selection.Characters(Start:=1, Length:=22).Font
.Name = "Times New Roman"
.FontStyle = "Bold"
.Size = 10
.Strikethrough = False
.Superscript = False
.Subscript = False

```

Module2

```

        .OutlineFont = False
        .Shadow = False
        .Underline = xlNone
        .ColorIndex = xlAutomatic
    End With
    With Selection
        .Placement = xlFreeFloating
        .PrintObject = False
    End With

'*****
' Create a button for making the CADSI DADS curve files. The first commands define the button size
' and position, define the macro assigned to it, and the label. The rest of the commands define the
' way the button should look.
'*****
ActiveSheet.Buttons.Add(3, 50, 120, 36).Select
Selection.OnAction = "create_rax_ray_beta_shutter_data_files"
Selection.Characters.Text = "Create CADSI DADS Curve Data Files for Simulation"
With Selection.Characters(Start:=1, Length:=22).Font
    .Name = "Times New Roman"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = xlAutomatic
End With
With Selection
    .Placement = xlFreeFloating
    .PrintObject = False
End With

'*****
' Create a button for creating the input file for driving the motion control system. The first
' commands define the button size and position, define the macro assigned to it, and the label.
' The rest of the commands define the way the button should look.
'*****
ActiveSheet.Buttons.Add(3, 90, 120, 36).Select
Selection.OnAction = "create_motion_control_system_data_files"
Selection.Characters.Text = "Create Input File for Driving Motion Control System"
With Selection.Characters(Start:=1, Length:=22).Font
    .Name = "Times New Roman"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = xlAutomatic
End With
With Selection
    .Placement = xlFreeFloating
    .PrintObject = False
End With
Cells(1, 1).Select
End Sub

```

Module3

```

*****
*****
' EXCELS.0 MACROS FOR GENERATING SPREADSHEETS FOR LASER SOLDERING
' MOTION CONTROL SYSTEM (MODULE3)
' SCOTT YERGANIAN 11-11-96
*****
*****

Const first_row = 7
Dim current_row As Integer
Dim lngth As Single
Dim wdth As Single
Dim radius As Single
Dim beam As Single
Dim time_step As Single
Dim dia As Single
Dim ave_speed As Single
Dim sxb_initial As Single
Dim syb_initial As Single
Dim sxb_final As Single
Dim syb_final As Single
Dim sxc_b As Single
Dim syc_b As Single
Dim time_shutter_off As Single
Dim half_beam_and_cable As Single
Dim delta_s_fwd As Single
Dim delta_s_bkwd As Single
Dim syb As Single
Dim sxb As Single
Dim cntclock As Integer
Dim direction As Integer

Sub create_rax_ray_beta_shutter_data_files()
'*****
' Name a variable called "currentbook" to be the name of the current workbook so that you can return
' to this workbook after activating others
'*****
Set currentbook = Application.ActiveWorkbook

'*****
' Activate the workbook called "DADS_DAT.XLS"
'*****
Workbooks.Open Filename:="DADS_DAT.XLS"

'*****
' Delete the old data sheets from the "DADS_DAT.XLS" workbook if they exist
'*****
If Sheets(1).Name = "rax" Then Sheets(1).Delete
If Sheets(1).Name = "ray" Then Sheets(1).Delete
If Sheets(1).Name = "beta" Then Sheets(1).Delete
If Sheets(1).Name = "shutter" Then Sheets(1).Delete
'*****
' Create Sheet "shutter"
'*****
Sheets(1).Select
Sheets.Add
Sheets(1).Name = "shutter"

'*****
' Create Sheet "beta"
'*****
Sheets(1).Select
Sheets.Add
Sheets(1).Name = "beta"

'*****
' Create Sheet "ray"
'*****
Sheets(1).Select
Sheets.Add
Sheets(1).Name = "ray"

'*****
' Create Sheet "rax"
'*****
Sheets(1).Select
Sheets.Add
Sheets(1).Name = "rax"
'*****
' Activate the workbook and activate Sheet3 (full data)

```


Module3

```

*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
*****
' Find end of input data
*****
current_row = first_row
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0
current_row = current_row + 1
Loop
last_row = current_row
*****
' Copy elapsed time data
*****
Range(Cells(first_row, 21), Cells(last_row, 21)).Select
Selection.Copy
Cells(1, 1).Select
*****
' Activate the "DADS_DAT.XLS" workbook and the sheets "rax", "ray", "beta", and "shutter" and paste
elapsed time values.
*****
Workbooks("DADS_DAT.XLS").Activate
Worksheets("rax").Activate
Cells(1, 1).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
Worksheets("ray").Activate
Cells(1, 1).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
Worksheets("beta").Activate
Cells(1, 1).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
Worksheets("shutter").Activate
Cells(1, 1).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
*****
' Activate the workbook and Sheet3 and copy rax data.
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Range(Cells(first_row, 26), Cells(last_row, 26)).Select
Selection.Copy
Cells(1, 1).Select
*****
' Activate the "DADS_DAT.XLS" workbook and the sheet "rax" and paste the values (paste special,
values)
*****
Workbooks("DADS_DAT.XLS").Activate
Worksheets("rax").Activate
Cells(1, 2).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
Cells(1, 1).Select
*****
' Activate the workbook and sheet3 and copy ray data
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Range(Cells(first_row, 27), Cells(last_row, 27)).Select
Selection.Copy
Cells(1, 1).Select
*****
' Activate the "DADS_DAT.XLS" workbook and the sheet "ray" and paste values (paste special, values)
*****
Workbooks("DADS_DAT.XLS").Activate
Worksheets("ray").Activate
Cells(1, 2).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
Cells(1, 1).Select
*****
' Activate the workbook and sheet3 and copy beta data
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Range(Cells(first_row, 22), Cells(last_row, 22)).Select
Selection.Copy

```

Module3

```

Cells(1, 1).Select
'*****
' Activate the "DADS_DAT.XLS" workbook and the sheet "beta" and paste values (paste special, values)
'*****
Workbooks("DADS_DAT.XLS").Activate
Worksheets("beta").Activate
Cells(1, 2).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Cells(1, 1).Select
'*****
' Activate the workbook and sheet3 and make a column of DADS shutter data
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Cells(first_row - 1, 17) = "DADS Shutter Data"
Cells(first_row, 17) = "=IF(RC[-4]>0,0,1000)"
Cells(first_row, 17).Select
Selection.AutoFill Destination:=Range(Cells(first_row, 17), Cells(last_row - 1, 17)), _
    Type:=xlFillDefault

Range(Cells(first_row, 17), Cells(last_row, 17)).Select
Selection.Copy
Cells(1, 1).Select
'*****
' Activate the "DADS_DAT.XLS" workbook and the sheet "shutter" and paste values (paste special,
values)
'*****
Workbooks("DADS_DAT.XLS").Activate
Worksheets("shutter").Activate
Cells(1, 2).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Cells(1, 1).Select
'*****
' Save DADS_dat.xls file
'*****
ActiveWorkbook.Save

'*****
' Activate the workbook and Sheet3 and go to the top of the sheet by selecting cells(1,1)
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Cells(1, 1).Select
'*****
' Save "rax", "ray", and "beta" sheets as txt files
'*****
Workbooks("DADS_DAT.XLS").Activate
Sheets("rax").Select
Range("A1").Select
ActiveWorkbook.SaveAs Filename:="RAX.TXT", FileFormat:=xlTextMSDOS, _
    CreateBackup:=False
Sheets("ray").Select
Range("A1").Select
ActiveWorkbook.SaveAs Filename:="RAY.TXT", FileFormat:=xlTextMSDOS, _
    CreateBackup:=False
Sheets("beta").Select
Range("A1").Select
ActiveWorkbook.SaveAs Filename:="BETA.TXT", FileFormat:=xlTextMSDOS, _
    CreateBackup:=False
Sheets("shutter").Select
Range("A1").Select
ActiveWorkbook.SaveAs Filename:="shutter.TXT", FileFormat:=xlTextMSDOS, _
    CreateBackup:=False
ActiveWorkbook.Close
End Sub

```

```

Sub create_motion_control_system_data_files()
'*****
' Name a variable called "currentbook" to be the name of the current workbook so that you can return
' to this workbook after activating others
'*****
Set currentbook = Application.ActiveWorkbook

'*****
' Activate the workbook called "MTN_DAT.CSV"
'*****

```


Module3

Workbooks.Open Filename:="MTN_DAT.CSV"

```

*****
Delete the old columns of data from the "MTN_DAT.CSV" workbook
*****
Range(Columns(1), Columns(8)).Delete

*****
Activate the workbook and activate Sheet3 (full data)
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
*****
Find end of input data
*****
current_row = first_row
Do While Abs(Cells(current_row, 3)) + Abs(Cells(current_row, 4)) > 0
current_row = current_row + 1
Loop
last_row = current_row - 1
*****
Copy some data from the current worksheet to fill in the header row (first row) of the
"MTN_DAT.CSV" file
*****
X_val = Cells(2, 3)           'x distance from the first fiducial to the starting point
Y_val = Cells(2, 4)           'y distance from the first fiducial to the starting point
Z_val = 0                     'z distance from the first fiducial to the starting point
T_val = Cells(first_row, 23)  'rotation beta at the start (usually zero)
S_val = Cells(first_row, 13)   'shutter value at the start (on = 1 and off = 0)
SxpOld = Cells(first_row, 3)   'x distance from the center of the part to the starting point
                                   '(in body fixed coordinates)
SypOld = Cells(first_row, 4)   'y distance from the center of the part to the starting point
                                   '(in body fixed coordinates)
tmr_v = Int(Cells(2, 11) * 1000) 'time step value in milliseconds
*****
Activate the "MTN_DAT.CSV" workbook and fill in the header row
*****
Workbooks("MTN_DAT.CSV").Activate
Cells(1, 1) = X_val
Cells(1, 2) = Y_val
Cells(1, 3) = Z_val
Cells(1, 4) = T_val
Cells(1, 5) = S_val
Cells(1, 6) = SxpOld
Cells(1, 7) = SypOld
Cells(1, 8) = tmr_v
*****
Activate the workbook and activate Sheet3 (full data) and get the first column of data
(delta x values)
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
*****
Copy delta x values
*****
Range(Cells(first_row + 1, 28), Cells(last_row, 28)).Select
Selection.Copy
Cells(1, 1).Select
*****
Activate the "MTN_DAT.CSV" workbook and paste delta x values (paste special, values)
*****
Workbooks("MTN_DAT.CSV").Activate
Cells(2, 1).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
SkipBlanks:=False, Transpose:=False
*****
Activate the workbook and activate Sheet3 (full data) and get the second column of data
(delta y values)
*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
*****
Copy delta y values
*****
Range(Cells(first_row + 1, 29), Cells(last_row, 29)).Select
Selection.Copy
Cells(1, 1).Select
*****
Activate the "MTN_DAT.CSV" workbook and paste delta y values (paste special, values)
*****

```

Module3

```

Workbooks("MTN_DAT.CSV").Activate
Cells(2, 2).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
'*****
' Fill in third column (delta z) of the "MTN_DAT.CSV" worksheet with zeros
'*****
current_row = 2
For k = 1 To last_row - first_row Step 1
    Cells(current_row, 3) = 0
    current_row = current_row + 1
Next k
'*****
' Activate the workbook and activate Sheet3 (full data) and get the fourth column of data
' (delta beta values)
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
'*****
' Copy delta beta values (delta beta measured in steps)
'*****
Range(Cells(first_row + 1, 30), Cells(last_row, 30)).Select
Selection.Copy
Cells(1, 1).Select
'*****
' Activate the "MTN_DAT.CSV" workbook and paste delta beta values (paste special, values)
'*****
Workbooks("MTN_DAT.CSV").Activate
Cells(2, 4).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
'*****
' Activate the workbook and activate Sheet3 (full data) and get the fifth column of data
' (shutter values)
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
'*****
' Copy shutter values (one is on and zero is off)
'*****
Range(Cells(first_row + 1, 13), Cells(last_row, 13)).Select
Selection.Copy
Cells(1, 1).Select
'*****
' Activate the "MTN DAT.CSV" workbook and paste shutter values (paste special, values)
'*****
Workbooks("MTN_DAT.CSV").Activate
Cells(2, 5).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
'*****
' Activate the workbook and activate Sheet3 (full data) and get the sixth column of data
' (sx' values)
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
'*****
' Copy sx' values
'*****
Range(Cells(first_row + 1, 3), Cells(last_row, 3)).Select
Selection.Copy
Cells(1, 1).Select
'*****
' Activate the "MTN_DAT.CSV" workbook and paste sx' values (paste special, values)
'*****
Workbooks("MTN_DAT.CSV").Activate
Cells(2, 6).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
'*****
' Activate the workbook and activate Sheet3 (full data) and get the seventh column of data
' (sy' values)
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
'*****
' Copy sy' values
'*****
Range(Cells(first_row + 1, 4), Cells(last_row, 4)).Select
Selection.Copy

```

Module3

```

Cells(1, 1).Select
'*****
'  Activate the "MTN_DAT.CSV" workbook and paste sy' values (paste special, values)
'*****
Workbooks("MTN_DAT.CSV").Activate
Cells(2, 7).Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Cells(1, 1).Select
'*****
'  Save the "MTN_DAT.CSV" workbook as a comma delimited file and then close it
'*****
ActiveWorkbook.SaveAs Filename:="MTN_DAT.CSV", FileFormat:=xlCSV, _
    CreateBackup:=False
ActiveWorkbook.Close
'*****
'  Activate the workbook ,activate Sheet3 (full data) and go to the top of the worksheet
'*****
Workbooks(currentbook.Name).Activate
Worksheets("Sheet3").Activate
Cells(1, 1).Select
End Sub

```