IntelliSuite Scripting Guide

Parametric elements and scripting in IntelliSuite

User Reference

SCRIPTING GUIDE – IntelliSuite Version 8
Version 8.2/PC

Part Number 30-090-105
February 2007

Printed in the United States of America

Patent Number 6,116,766: Fabrication Based Computer Aided Design System Using Virtual Fabrication Techniques
Patent Number 6,157,900: Knowledge Based System and Method for Determining Material Properties from Fabrication and Operating Parameters

Table of contents

Learning to Script

Scripting guide to IntelliMask

How to Script

1.1 *Official Scripting Language*

The officially supported scripting language for IntelliMask is VBScript. While other languages can be used, IntelliSense does not provide technical assistance for using other scripting languages.

IntelliMask using a Windows technology called Windows Scripting Host (WSH) to support scripting. While WSH can be used with other languages, we do not provide official support for other languages.

1.2 *Using other scripting languages*

You can use other scripting languages such as Perl or Tcl/Tk or Python with IntelliMask. However, IntelliSense does not officially support other languages. There are excellent tutorials online for using other languages with Windows Scripting Host.

For example if you wish to use Perl take a look at:
< http://pages.infinit.net/che/perlwsh/perlwsh0.html>

A commercial Perl IDE for Windows can be bought from Active State
< http://www.activestate.com/>.

You can also download a free version of ActivePerl from Active State. For more information on using ActivePerl with IntelliMask please see:
<http://aspn.activestate.com/ASPN/docs/ActivePerl/Windows/WindowsScriptHost.html>

Python users can take a look at examples at ASPN
ActiveScript also provides ActivePython which can be used for scripting IntelliMask in Python.
<http://aspn.activestate.com/ASPN/Cookbook/Python/Recipe/65107 or consult the newsgroup news:comp.lang.python>

Tcl/Tk and Rexx users can take a look at
< http://labmice.techtarget.com/scripting/WSH.htm> for more information.

1.3 *What is VBScript?*

Sections 1.3.1 through 1.10 are excerpts from Microsoft Developer Network and are © Microsoft Corp..

More information on scripting can be found at:
<http://msdn.microsoft.com/scripting/>

For a convenient Online Reference Guide see:
< http://msdn.microsoft.com/library/default.asp?url=/library/en-us/script56/html/vtoriVBScript.asp >

Microsoft Visual Basic Scripting Edition, the newest member of the Visual Basic family of programming languages, brings active scripting to a wide variety of environments, including Web client scripting in Microsoft Internet Explorer and Web server scripting in Microsoft Internet Information Server.

1.3.1 Easy to Use and Learn

If you already know Visual Basic or Visual Basic for Applications, VBScript will be very familiar. Even if you don't know Visual Basic, once you learn VBScript, you're on your way to programming with the whole family of Visual Basic languages. Although you can learn about VBScript in just these few Web pages, they don't teach you how to program. To get started programming, take a look at Step by Step books available from Microsoft Press.

1.3.2 ActiveX Scripting

VBScript talks to host applications using ActiveX™ Scripting. With ActiveX Scripting, browsers and other host applications don't require special integration code for each scripting component. ActiveX Scripting enables a host to compile scripts, obtain and call entry points, and manage the namespace available to the developer. With ActiveX Scripting, language vendors can create standard language run times for scripting. Microsoft will provide run-time support for VBScript. Microsoft is working with various Internet groups to define the ActiveX Scripting standard so that scripting engines can be interchangeable. ActiveX Scripting is used in Microsoft® Internet Explorer and in Microsoft® Internet Information Server.

1.4 *VBScript Data Types*

1.4.1 What Are VBScript Data Types?

VBScript has only one data type called a **Variant**. A **Variant** is a special kind of data type that can contain different kinds of information, depending on how it's used. Because **Variant** is the only data type in VBScript, it's also the data type returned by all functions in VBScript.

At its simplest, a **Variant** can contain either numeric or string information. A **Variant** behaves as a number when you use it in a numeric context and as a string when you use it in a string context. That is, if you're working with data that looks like numbers, VBScript assumes that it is numbers and does the thing that is most appropriate for numbers. Similarly, if you're working with data that can only be string data, VBScript treats it as string data. Of course, you can always make numbers behave as strings by enclosing them in quotation marks (" ").

1.4.2 Variant Subtypes

Beyond the simple numeric or string classifications, a **Variant** can make further distinctions about the specific nature of numeric information. For example, you can have numeric information that represents a date or a time. When used with other date or time data, the result is always expressed as a date or a time. Of course, you can also have a rich variety of numeric information ranging in size from Boolean values to huge floating-point numbers. These different categories of information that can be contained in a **Variant** are called subtypes. Most of the time, you can just put the kind of data you want in a **Variant**, and the **Variant** behaves in a way that is most appropriate for the data it contains.

The following table shows the subtypes of data that a **Variant** can contain.

Empty

Variant is uninitialized. Value is 0 for numeric variables or a zero-length string ("") for string variables.

Null

Variant intentionally contains no valid data.

Boolean

Contains either **True** or **False**.

Byte
Contains integer in the range 0 to 255.

Integer
Contains integer in the range -32,768 to 32,767.

Currency
-922,337,203,685,477.5808 to 922,337,203,685,477.5807.

Long
Contains integer in the range -2,147,483,648 to 2,147,483,647.

Single
Contains a single-precision, floating-point number in the range -3.402823E38 to -1.401298E-45 for negative values; 1.401298E-45 to 3.402823E38 for positive values.

Double
Contains a double-precision, floating-point number in the range -1.79769313486232E308 to -4.94065645841247E-324 for negative values; 4.94065645841247E-324 to 1.79769313486232E308 for positive values.

Date (Time)
Contains a number that represents a date between January 1, 100 to December 31, 9999.

String
Contains a variable-length string that can be up to approximately 2 billion characters in length.

Object
Contains an object.

Error
Contains an error number.

You can use conversion functions to convert data from one subtype to another. In addition, the **VarType** function returns information about how your data is stored within a Variant

1.5 *VBScript Variables*

1.5.1 What Is a Variable?

A variable is a convenient placeholder that refers to a computer memory location where you can store program information that may change during the time your script is running. For example, you might create a variable called `ClickCount` to store the number of times a user clicks an object on a particular Web page. Where the variable is stored in computer memory is unimportant. What's important is that you only have to refer to a variable by name to see its value or to change its value. In VBScript, variables are always of one fundamental data type, **Variant**.

1.5.2 Declaring Variables

You declare variables explicitly in your script using the **Dim** statement, the `Public` statement, and the `Private` statement. For example:

```
Dim DegreesFahrenheit
```

You declare multiple variables by separating each variable name with a comma. For example:

```
Dim Top, Bottom, Left, Right
```

You can also declare a variable implicitly by simply using its name in your script. That's not generally a good practice because you could misspell the variable name in one or more places, causing unexpected results when your script is run. For that reason, the **Option Explicit** statement is available to require explicit declaration of all variables. The **Option Explicit** statement should be the first statement in your script.

1.5.3 Naming Restrictions

Variable names follow the standard rules for naming anything in VBScript. A variable name:

- Must begin with an alphabetic character.
- Cannot contain an embedded period.
- Must not exceed 255 characters.
- Must be unique in the scope in which it is declared.

1.5.4 Scope and Lifetime of Variables

A variable's scope is determined by where you declare it. When you declare a variable within a procedure, only code within that procedure can access or change the value of that variable. It has local scope and is called a procedure-level variable. If you declare a variable outside a procedure, you make it recognizable to all the procedures in your script. This is a script-level variable, and it has script-level scope.

How long a variable exists is its lifetime. The lifetime of a script-level variable extends from the time it's declared until the time the script is finished running. At procedure level, a variable exists only as long as you are in the procedure. When the procedure exits, the variable is destroyed. Local variables are ideal as temporary storage space when a procedure is executing. You can have local variables of the same name in several different procedures because each is recognized only by the procedure in which it is declared.

1.5.5 Assigning Values to Variables

Values are assigned to variables creating an expression as follows: the variable is on the left side of the expression and the value you want to assign to the variable is on the right. For example:

```
B = 200
```

1.5.6 Scalar Variables and Array Variables

Much of the time, you just want to assign a single value to a variable you've declared. A variable containing a single value is a scalar variable. Other times, it's convenient to assign more than one related value to a single variable. Then you can create a variable that can contain a series of values. This is called an array variable. Array variables and scalar variables are declared in the same way, except that the declaration of an array variable uses parentheses ( ) following the variable name. In the following example, a single-dimension array containing 11 elements is declared:

```
Dim A(10)
```

Although the number shown in the parentheses is 10, all arrays in VBScript are zero-based, so this array actually contains 11 elements. In a zero-based array, the number of array elements is always the number shown in parentheses plus one. This kind of array is called a fixed-size array.

You assign data to each of the elements of the array using an index into the array. Beginning at zero and ending at 10, data can be assigned to the elements of an array as follows:

```
A(0) = 256
A(1) = 324
A(2) = 100
. . .
A(10) = 55
```

Similarly, the data can be retrieved from any element using an index into the particular array element you want. For example:

```
. . .
SomeVariable = A(8)
. . .
```

Arrays aren't limited to a single dimension. You can have as many as 60 dimensions, although most people can't comprehend more than three or four dimensions. Multiple dimensions are declared by separating an array's size numbers in the parentheses with commas. In the following example, the `MyTable` variable is a two-dimensional array consisting of 6 rows and 11 columns:

```
Dim MyTable(5, 10)
```

In a two-dimensional array, the first number is always the number of rows; the second number is the number of columns.

You can also declare an array whose size changes during the time your script is running. This is called a dynamic array. The array is initially declared within a procedure using either the **Dim** statement or using the **ReDim** statement. However, for a dynamic array, no size or number of dimensions is placed inside the parentheses. For example:

```
 Dim MyArray()
ReDim AnotherArray()
```

To use a dynamic array, you must subsequently use **ReDim** to determine the number of dimensions and the size of each dmension. In the following example, **ReDim** sets the initial size of the dynamic array to 25. A subsequent **ReDim** statement resizes the array to 30, but uses the **Preserve** keyword to preserve the contents of the array as the resizing takes place.

```
 ReDim MyArray(25)
. . .
ReDim Preserve MyArray(30)
```

There is no limit to the number of times you can resize a dynamic array, but you should know that if you make an array smaller than it was, you lose the data in the eliminated elements.

1.6 *VBScript Constants*

1.6.1 What Is a Constant?

A constant is a meaningful name that takes the place of a number or string and never changes. VBScript defines a number of intrinsic constants. You can get information about these intrinsic constants from the VBScript Language Reference.

1.6.2 Creating Constants

You create user-defined constants in VBScript using the **Const** statement. Using the **Const** statement, you can create string or numeric constants with meaningful names and assign them literal values. For example:

```
Const MyString = "This is my string."
Const MyAge = 49
```

Note that the string literal is enclosed in quotation marks (" "). Quotation marks are the most obvious way to differentiate string values from numeric values. Date literals and time literals are represented by enclosing them in number signs (#). For example:

```
Const CutoffDate = #6-1-97#
```

You may want to adopt a naming scheme to differentiate constants from variables. This will prevent you from trying to reassign constant values while your script is running. For example, you might want to use a "vb" or "con" prefix on your constant names, or you might name your constants in all capital letters. Differentiating constants from variables eliminates confusion as you develop more complex scripts.

1.7 *VBScript Operators*

VBScript has a full range of operators, including arithmetic operators, comparison operators, concatenation operators, and logical operators.

1.7.1 Operator Precedence

When several operations occur in an expression, each part is evaluated and resolved in a predetermined order called operator precedence. You can use parentheses to override the order of precedence and force some parts of an expression to be evaluated before others. Operations within parentheses are always performed before those outside. Within parentheses, however, standard operator precedence is maintained.

When expressions contain operators from more than one category, arithmetic operators are evaluated first, comparison operators are evaluated next, and logical operators are evaluated last. Comparison operators all have equal precedence; that is, they are evaluated in the left-to-right order in which they appear. Arithmetic and logical operators are evaluated in the following order of precedence.

Arithmetic		**Comparison**		**Logical**	
Description	**Symbol**	**Description**	**Symbol**	**Description**	**Symbol**
Exponentiation	^	Equality	=	Logical negation	Not
Unary negation	-	Inequality	<>	Logical conjunction	And
Multiplication	*	Less than	<	Logical disjunction	Or
Division	/	Greater than	>	Logical exclusion	Xor
Integer division	\	Less than or equal to	<=	Logical equivalence	Eqv
Modulus arithmetic	Mod	Greater than or equal to	>=	Logical implication	Imp
Addition	+	Object equivalence	Is		
Subtraction	-				
String concatenation	&				

When multiplication and division occur together in an expression, each operation is evaluated as it occurs from left to right. Likewise, when addition and subtraction occur together in an expression, each operation is evaluated in order of appearance from left to right.

The string concatenation (&) operator is not an arithmetic operator, but in precedence it does fall after all arithmetic operators and before all comparison operators. The Is operator is an object reference comparison operator. It does not compare objects or their values; it checks only to determine if two object references refer to the same object.

1.8 *Using Conditional Statements*

1.8.1 Controlling Program Execution

You can control the flow of your script with conditional statements and looping statements. Using conditional statements, you can write VBScript code that makes decisions and repeats actions. The following conditional statements are available in VBScript:

- **If...Then...Else** statement
- **Select Case** statement

1.8.2 Making Decisions Using If...Then...Else

The **If...Then...Else** statement is used to evaluate whether a condition is **True** or **False** and, depending on the result, to specify one or more statements to run. Usually the condition is an expression that uses a comparison operator to compare one value or variable with another. For information about comparison operators, see Comparison Operators. **If...Then...Else** statements can be nested to as many levels as you need.

1.8.3 Running Statements if a Condition is True

To run only one statement when a condition is **True**, use the single-line syntax for the **If...Then...Else** statement. The following example shows the single-line syntax. Notice that this example omits the **Else** keyword.

```
Sub FixDate()
    Dim myDate
    myDate = #2/13/95#
    If myDate < Now Then myDate = Now
End Sub
```

To run more than one line of code, you must use the multiple-line (or block) syntax. This syntax includes the **End If** statement, as shown in the following example:

```
Sub AlertUser(value)
    If value = 0 Then
        AlertLabel.ForeColor = vbRed
        AlertLabel.Font.Bold = True
        AlertLabel.Font.Italic = True
    End If
End Sub
```

1.8.4 Running Certain Statements if a Condition is True and Running Others if a Condition is False

You can use an **If...Then...Else** statement to define two blocks of executable statements: one block to run if the condition is **True**, the other block to run if the condition is **False**.

```
Sub AlertUser(value)
    If value = 0 Then
        AlertLabel.ForeColor = vbRed
        AlertLabel.Font.Bold = True
        AlertLabel.Font.Italic = True
    Else
        AlertLabel.Forecolor = vbBlack
        AlertLabel.Font.Bold = False
        AlertLabel.Font.Italic = False
    End If
End Sub
```

1.8.5 Deciding Between Several Alternatives

A variation on the **If...Then...Else** statement allows you to choose from several alternatives. Adding **ElseIf** clauses expands the functionality of the **If...Then...Else** statement so you can control program flow based on different possibilities. For example:

```
Sub ReportValue(value)
    If value = 0 Then
        MsgBox value
    ElseIf value = 1 Then
        MsgBox value
    ElseIf value = 2 then
        Msgbox value
    Else
        Msgbox "Value out of range!"
    End If
```

You can add as many **ElseIf** clauses as you need to provide alternative choices. Extensive use of the **ElseIf** clauses often becomes cumbersome. A better way to choose between several alternatives is the **Select Case** statement.

1.8.6 Making Decisions with Select Case

The **Select Case** structure provides an alternative to **If...Then...ElseIf** for selectively executing one block of statements from among multiple blocks of statements. A **Select Case** statement provides capability similar to the **If...Then...Else statement**, but it makes code more efficient and readable.

A **Select Case** structure works with a single test expression that is evaluated once, at the top of the structure. The result of the expression is then compared with the values for each **Case** in the structure. If there is a match, the block of statements associated with that **Case** is executed:

```
 Select Case
Document.Form1.CardType.Options(SelectedIndex).Text
    Case "MasterCard"
        DisplayMCLogo
        ValidateMCAccount
    Case "Visa"
        DisplayVisaLogo
        ValidateVisaAccount
    Case "American Express"
        DisplayAMEXCOLogo
        ValidateAMEXCOAccount
    Case Else
        DisplayUnknownImage
        PromptAgain
End Select
```

Notice that the **Select Case** structure evaluates an expression once at the top of the structure. In contrast, the **If...Then...ElseIf** structure can evaluate a different expression for each **ElseIf** statement. You can replace an **If...Then...ElseIf** structure with a **Select Case** structure only if each **ElseIf** statement evaluates the same expression.

1.9 *Looping Through Code*

1.9.1 Using Loops to Repeat Code

Looping allows you to run a group of statements repeatedly. Some loops repeat statements until a condition is **False**; others repeat statements until a condition is **True**. There are also loops that repeat statements a specific number of times.

The following looping statements are available in VBScript:

- **Do...Loop**: Loops while or until a condition is True.
- **While...Wend**: Loops while a condition is True.
- **For...Next**: Uses a counter to run statements a specified number of times.
- **For Each...Next**: Repeats a group of statements for each item in a collection or each element of an array.

1.9.2 Using Do Loops

You can use **Do...Loop** statements to run a block of statements an indefinite number of times. The statements are repeated either while a condition is **True** or until a condition becomes **True**.

1.9.3 Repeating Statements While a Condition is True

Use the **While** keyword to check a condition in a **Do...Loop** statement. You can check the condition before you enter the loop (as shown in the following ChkFirstWhile example), or you can check it after the loop has run at least once (as shown in the ChkLastWhile example). In the ChkFirstWhile procedure, if myNum is set to 9 instead of 20, the statements inside the loop will never run. In the ChkLastWhile procedure, the statements inside the loop run only once because the condition is already **False**.

```
Sub ChkFirstWhile()
    Dim counter, myNum
    counter = 0
    myNum = 20
    Do While myNum > 10
        myNum = myNum - 1
        counter = counter + 1
    Loop
    MsgBox "The loop made " & counter & " repetitions."
End Sub

Sub ChkLastWhile()
    Dim counter, myNum
    counter = 0
    myNum = 9
    Do
```

```
        myNum = myNum - 1
        counter = counter + 1
    Loop While myNum > 10
    MsgBox "The loop made " & counter & " repetitions."
End Sub
```

1.9.4 Repeating a Statement Until a Condition Becomes True

You can use the **Until** keyword in two ways to check a condition in a **Do...Loop** statement. You can check the condition before you enter the loop (as shown in the following ChkFirstUntil example), or you can check it after the loop has run at least once (as shown in the ChkLastUntil example). As long as the condition is **False**, the looping occurs.

```
Sub ChkFirstUntil()
    Dim counter, myNum
    counter = 0
    myNum = 20
    Do Until myNum = 10
        myNum = myNum - 1
        counter = counter + 1
    Loop
    MsgBox "The loop made " & counter & " repetitions."
End Sub

Sub ChkLastUntil()
    Dim counter, myNum
    counter = 0
    myNum = 1
    Do
        myNum = myNum + 1
        counter = counter + 1
    Loop Until myNum = 10
    MsgBox "The loop made " & counter & " repetitions."
End Sub
```

1.9.5 Exiting a Do...Loop Statement from Inside the Loop

You can exit a **Do...Loop** by using the **Exit Do** statement. Because you usually want to exit only in certain situations, such as to avoid an endless loop, you should use the **Exit Do** statement in the **True** statement block of an **If...Then...Else** statement. If the condition is **False**, the loop runs as usual.

In the following example, `myNum` is assigned a value that creates an endless loop. The **If...Then...Else** statement checks for this condition, preventing the endless repetition.

```
Sub ExitExample()
    Dim counter, myNum
```

```
    counter = 0
    myNum = 9
    Do Until myNum = 10
        myNum = myNum - 1
        counter = counter + 1
        If myNum < 10 Then Exit Do
    Loop
    MsgBox "The loop made " & counter & " repetitions."
End Sub
```

1.9.6 Using While...Wend

The **While...Wend** statement is provided in VBScript for those who are familiar with its usage. However, because of the lack of flexibility in **While...Wend**, it is recommended that you use **Do...Loop** instead.

1.9.7 Using For...Next

You can use **For...Next** statements to run a block of statements a specific number of times. For loops, use a counter variable whose value is increased or decreased with each repetition of the loop.

For example, the following procedure causes a procedure called `MyProc` to execute 50 times. The **For** statement specifies the counter variable x and its start and end values. The **Next** statement increments the counter variable by 1.

```
Sub DoMyProc50Times()
    Dim x
    For x = 1 To 50
        MyProc
    Next
End Sub
```

Using the **Step** keyword, you can increase or decrease the counter variable by the value you specify. In the following example, the counter variable j is incremented by 2 each time the loop repeats. When the loop is finished, total is the sum of 2, 4, 6, 8, and 10.

```
Sub TwosTotal()
    Dim j, total
    For j = 2 To 10 Step 2
        total = total + j
    Next
    MsgBox "The total is " & total
End Sub
```

To decrease the counter variable, you use a negative **Step** value. You must specify an end value that is less than the start value. In the following example, the counter variable `myNum` is decreased by 2 each time the loop repeats. When the loop is finished, total is the sum of 16, 14, 12, 10, 8, 6, 4, and 2.

```
Sub NewTotal()
    Dim myNum, total
    For myNum = 16 To 2 Step -2
        total = total + myNum
    Next
    MsgBox "The total is " & total
End Sub
```

You can exit any **For...Next** statement before the counter reaches its end value by using the **Exit For** statement. Because you usually want to exit only in certain situations, such as when an error occurs, you should use the **Exit For** statement in the **True** statement block of an **If...Then...Else** statement. If the condition is **False**, the loop runs as usual.

1.9.8 Using For Each...Next

A **For Each...Next** loop is similar to a **For...Next** loop. Instead of repeating the statements a specified number of times, a **For Each...Next** loop repeats a group of statements for each item in a collection of objects or for each element of an array. This is especially helpful if you don't know how many elements are in a collection.

1.10 *VBScript Procedures*

1.10.1 Kinds of Procedures

In VBScript there are two kinds of procedures; the **Sub** procedure and the Function procedure.

1.10.2 Sub Procedures

A **Sub** procedure is a series of VBScript statements, enclosed by **Sub** and **End Sub** statements, that perform actions but don't return a value. A **Sub** procedure can take arguments (constants, variables, or expressions that are passed by a calling procedure). If a **Sub** procedure has no arguments, its **Sub** statement must include an empty set of parentheses ().

The following **Sub** procedure uses two intrinsic, or built-in, VBScript functions, **MsgBox** and InputBox, to prompt a user for some information. It then displays the results of a calculation based on that information. The calculation is performed in a Function procedure created using VBScript. The **Function** procedure is shown after the following discussion.

```
 Sub ConvertTemp()
    temp = InputBox("Please enter the temperature in
degrees F.", 1)
    MsgBox "The temperature is " & Celsius(temp) & "
degrees C."
 End Sub
```

1.10.3 Function Procedures

A **Function** procedure is a series of VBScript statements enclosed by the **Function** and **End Function** statements. A **Function** procedure is similar to a **Sub** procedure, but can also return a value. A **Function** procedure can take arguments (constants, variables, or expressions that are passed to it by a calling procedure). If a **Function** procedure has no arguments, its **Function** statement must include an empty set of parentheses. A **Function** returns a value by assigning a value to its name in one or more statements of the procedure. The return type of a **Function** is always a **Variant**.

In the following example, the Celsius function calculates degrees Celsius from degrees Fahrenheit. When the function is called from the ConvertTemp **Sub** procedure, a variable containing the argument value is passed to the function. The result of the calculation is returned to the calling procedure and displayed in a message box.

```
 Sub ConvertTemp()
     temp = InputBox("Please enter the temperature in
degrees F.", 1)
     MsgBox "The temperature is " & Celsius(temp) & "
```

```
degrees C."
 End Sub

 Function Celsius(fDegrees)
     Celsius = (fDegrees - 32) * 5 / 9
 End Function
```

1.10.4 Getting Data into and out of Procedures

Each piece of data is passed into your procedures using an argument. Arguments serve as placeholders for the data you want to pass into your procedure. You can name your arguments anything that is valid as a variable name. When you create a procedure using either the **Sub** statement or the **Function** statement, parentheses must be included after the name of the procedure. Any arguments are placed inside these parentheses, separated by commas. For example, in the following example, `fDegrees` is a placeholder for the value being passed into the Celsius function for conversion:

```
 Function Celsius(fDegrees)
    Celsius = (fDegrees - 32) * 5 / 9
 End Function
```

To get data out of a procedure, you must use a **Function**. Remember, a **Function** procedure can return a value; a **Sub** procedure can't.

1.10.5 Using Sub and Function Procedures in Code

A **Function** in your code must always be used on the right side of a variable assignment or in an expression. For example:

```
 Temp = Celsius(fDegrees)
```

or

```
 MsgBox "The Celsius temperature is " & Celsius(fDegrees)
& " degrees."
```

To call a **Sub** procedure from another procedure, you can just type the name of the procedure along with values for any required arguments, each separated by a comma. The **Call** statement is not required, but if you do use it, you must enclose any arguments in parentheses.

The following example shows two calls to the MyProc procedure. One uses the **Call** statement in the code; the other doesn't. Both do exactly the same thing.

```
Call MyProc(firstarg, secondarg)
MyProc firstarg, secondarg
```

Notice that the parentheses are omitted in the call when the **Call** statement isn't used.

1.11 *Your first script*

1.11.1 Step-Wise Description of the Bi-Morph Script

This portion of the document explains how a VB-Script is written in IntelliMask, taking the example of the Bi-Morph Element:

1.11.2 Comment Statements

The Script begins with the line

'VB_Script Bi-Morph.

This line is a **comment**, which can be used as descriptive statements. The comment line should be preceded by a **single quote** (**'**).

Alternatively comment statements can also take the form as below:

```
REM+++++++++++++++
REM. ……Comments………………
REM-----------------------
```

For example in this script we use

```
REM+++++++++++++++
REM Layer Information
REM-----------------------
```

to enter the Layer details of the mask layout.

1.11.3 Declaration of Variables

The next step involves the declaration of variables.
A variable is a "container" for information you want to store. A variable's value can change during the script.
You can declare variables with the **Dim**, **Public** or the **Private** statements.
The declaration of variables using **Dim statement** in this script is shown below.

```
Dim L , f_l, f_w, spacing, w_ca, w_ha, w_a, d_a, cross ,
d_s, d_r, N
Dim L_s, L_a, L_d
```

1.11.4 Assign Values to Variables

In this part of the script a brief description of each of the variables is given and values are assigned to them.
The variable name is on the left side of the expression and the value you want to assign to the variable is on the right.
The description of variables and assignment of values to the bi-morph structure are given below.

```
'L_s      :    Layer number to draw bi-morph
'L_a      :    Layer number to draw anchor
'L_d      :    Layer number to draw dimples

L_s  =    5
L_a  =    6
L_d  =    7

'L        :    Length from the terminals to the end of
actuator, µm
'f_l      :    Length of flange which connects the wide
part of cold-arm to the terminal, µm
'f_w      :    width of flange, µm
'spacing :    space between hot-arm and cold-arm, µm
'w_ca     :    width of wide part of cold-arm, µm
'w_ha     :    width of hot-arm, µm
'w_a      :    width of anchor, µm
'd_a      :    distance of anchor from edge of frame, µm
'cross    :    width of the part connecting the hot-arm and
cold-arm, µm
'd_s      :    spacing between dimples, µm
'd_r      :    radius of dimple, µm
'd_l      :    length of rectangular dimple, µm
'd_w      :    width of rectangular dimple, µm
'dimple_type :     type of dimple required (round or
rectangle)
'N        :    Number of dimples


L    =    200
f_l  =    40
f_w  =    2
spacing  =    3
w_ca =    16
w_ha =    2
```

```
w_a  =    15
d_a  =    10
cross     =    8
d_s  =    20
d_r  =    2
d_l  =    5
d_w  =    3
N    =    6
dimple_type =      1    'For round dimple enter
dimple_type = 0, for rectangular dimple enter dimple_type
= 1
```

The user has the freedom to change these values to parameterize the structure.

1.11.5 Body of the Script

- The body of the script starts with the line

```
SetLayer(L_s)
```

In this script using the **keyword** *SetLayer* draws the mask layout on layer number 5, as a value of 5 was assigned to the L_s variable.

Thus for a muti-layered mask the user can use this keyword followed by a declared variable to draw layouts on different layers.

- Define the **coordinates** of the **starting point**, which in this case is the origin i.e.

```
X=0
Y=0
```

- Since this structure consists only of orthogonal polygons, the layout can be drawn using series of rectangles or polygons. The **command**

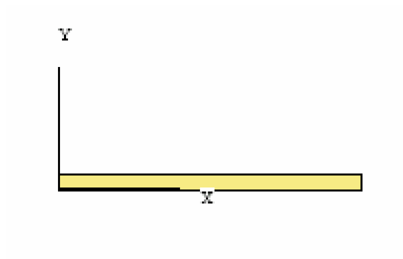
  z=DrawRectangle(x,y,x1,y1)

  can be used to draw rectangles where *x,y,x1,y1* represent the coordinates of the lower left and upper right corners of the rectangle.

For ex. The first rectangle drawn in the layout is that of the flange and the script to draw this is given below.

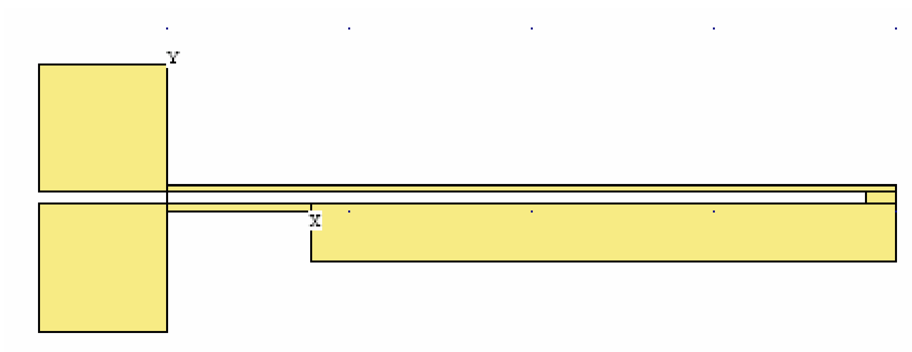
```
x=0
y=0
x1=x+f_l
y1=y+f_w
```

```
z=DrawRectangle(x,y,x1,y1)
```



The flange generated for the block of script shown above

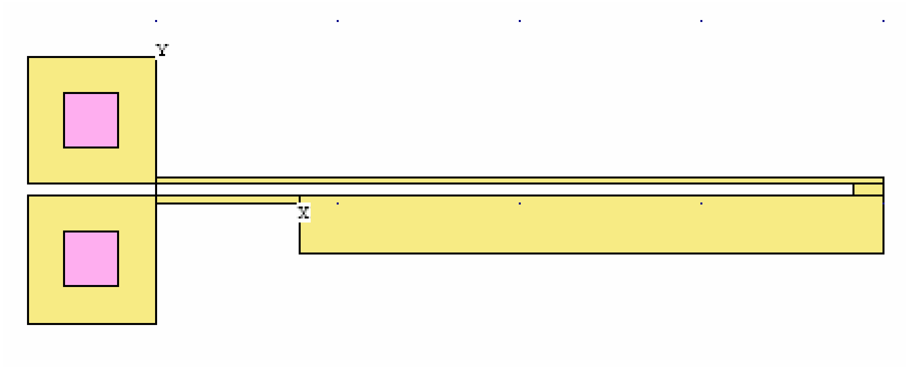
In this way a series of rectangles or alternately polygons can be used to draw the bi-morph layout.



The bi-morph layout generated on layer 5

Next we **define** the **anchors**, which again consists of two rectangles, however the layer to draw anchors is changed using

SetLayer(L_a).



The layout after writing script for anchors

- Next we draw an **array of dimples** on the arm on a new layer L_d.

Here to provide the user with a choice of using different geometries for the dimples a **Conditional statement** is used. The user can either draw **rectangular dimples** or **round dimples**.

- The conditional statement used here is the **If...Then...Else** statement
  This statement is used if you want to
  * execute some code if a condition is true
  * select one of two blocks of code to execute.

  The block of script in this example executing this loop is:

```
 If dimple_type = 0 Then

x=x1+d_a+f_l+d_s+d_r
y=y-d_a-spacing-w_ca/2
z=Circle(x,y,d_r)
for i = 1 to N-1
x=x+2*d_r+d_s
z=Circle(x,y,d_r)
next

Else

x=x1+d_a+f_l+d_s
y=y-d_a-spacing-(w_ca/2)+(d_w/2)
x1=x+d_l
y1=y-d_w
z=DrawRectangle(x,y,x1,y1)
```

```
for i = 1 to N-1
x=x+d_l+d_s
x1=x+d_l
z=DrawRectangle(x,y,x1,y1)
next

End If
```

It can be seen from the script that when the condition dimple_type=0 is **true** then round dimples are drawn and if this condition is **false** rectangular dimples are drawn.
Since in this script during assigning values to the variables, we enter

```
dimple_type =      1
```

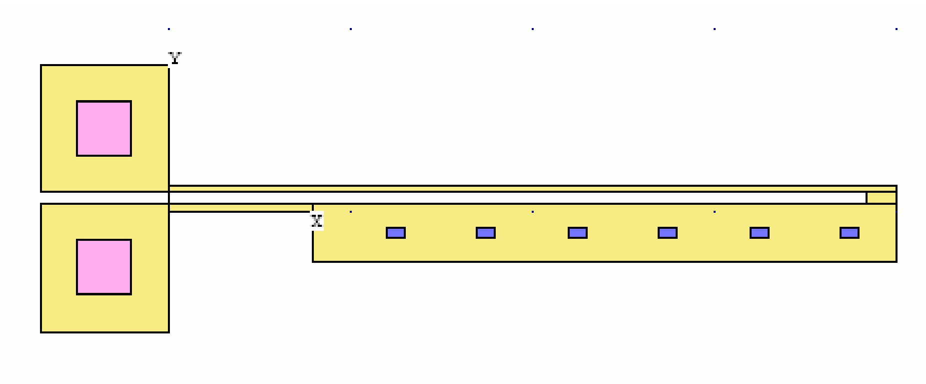
when the script is executed, the layout is generated with rectangular dimples.

The If...Then...Else statement ends with the keyword **end if**.

- Also, the above block of script uses a **looping statement**.

Here we employ the **For……Next** loop in order to generate an array of *N* dimples separated in the x-direction by a fixed distance.

```
x=x1+d_a+f_l+d_s+d_r
y=y-d_a-spacing-w_ca/2
z=Circle(x,y,d_r)
for i = 1 to N-1
x=x+2*d_r+d_s
z=Circle(x,y,d_r)
next
```



The Multi-Layered bi-morph after executing the complete script

- The script is ended with a comment statement

```
REM+++++++++
REM End of Script
REM--------------------
```

Now you are ready to start scripting. We've provided you with a ton of scripts to explore. You can use these as a starting point for writing your own scripts.

Parametric element library

MEMS Parametric Elements

2 Active MEMS Elements

2.1 *Linear Comb Drive Element*

Description:
This script generates a Linear Comb Drive Element. It consists of a stator and a rotor, with the stator fixed to the surface. The stator and rotor have a number of closely spaced interdigited fingers which provide the electrostatic force of attraction. The Linear Comb Drive element is used for sensing and actuation purposes.

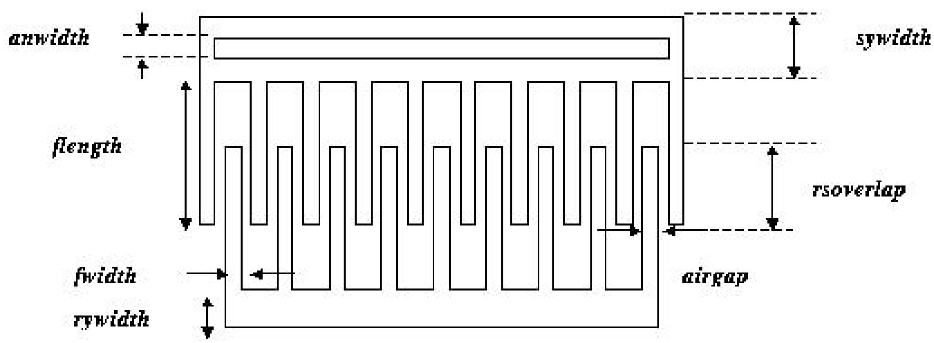


Figure 1 Linear Comb Drive with parameters illustrated

Function Name: comb

```
call  comb(numComb, anwidth, rywidth, sywidth, flength,
fwidth,   airgap,  rsoverlap)
```

Table 1 describes the various components of the Linear Comb Drive Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of stator	4
2	Lr	Layer number of rotor	5
3	La	Layer number of anchor	6

Table 1 Layer details

Table 2 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	numComb	Number of combs of stator	20
2	anwidth	Width of anchors	16μm
3	rywidth	Rotor yoke width	30μm
4	sywidth	Stator yoke width	50μm
5	flength	Length of comb fingers	110μm
6	fwidth	Width of comb fingers	10μm
7	airgap	Air gap between fingers	5μm
8	rsoverlap	Stator-rotor finger overlap	60μm

Table 2 List of parameters

Figure 2 depicts the linear comb drive element with the sample dimensions as displayed in Table 2.

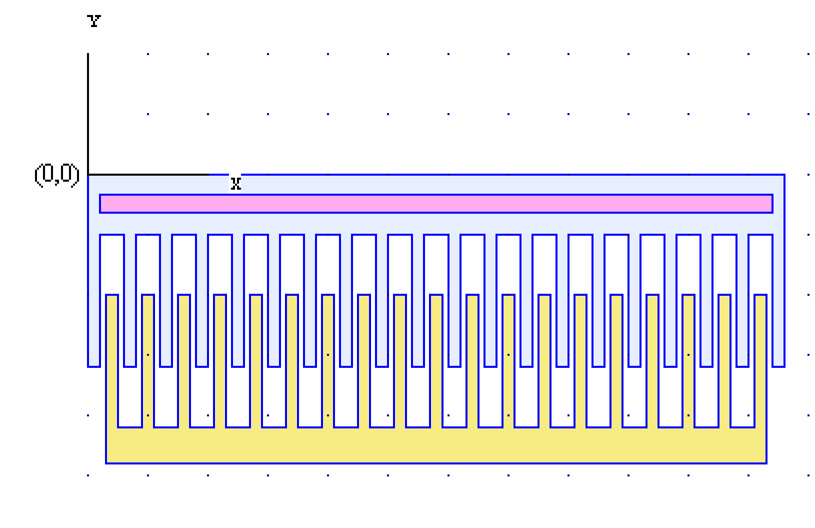


Figure 2 Linear Comb Drive

Figure 2 shows a multilayered mask layout wherein each layer is represented by a different color. The origin is located at the upper left corner of the comb drive structure.

2.2 *Linear Side Drive Elements*

Description:
This script generates a linear side drive element. It consists of a rotor with a number of tooth and stator with a number of electrodes. The electrostatic force of attraction is generated between the stator and the rotor.

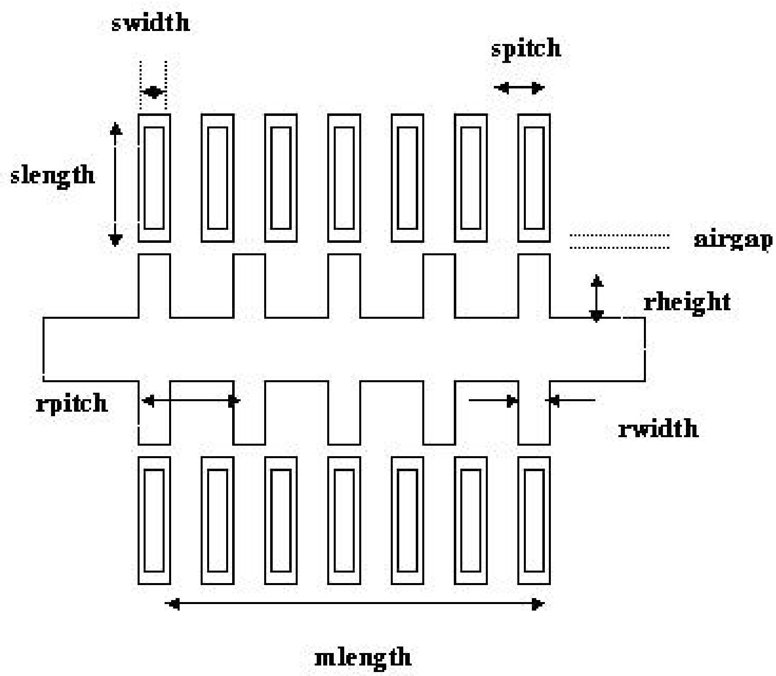


Figure 3 Linear Side Drive Element with parameters

Function Name: LSDE

```
call LSDE (mlength, swidth, spitch, slength, rwidth,
rpitch, rheight, yokewidth, airgap, roffset)
```

The table below describes the various components of the Linear Side Drive Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Lr	Layer number rotor	4
2	Ls	Layer number of stator	5
3	La	Layer number of anchor	6

Table 3 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	mlength	Active length of motor	64 μm
2	swidth	Stator electrode width	5 μm
3	spitch	Stator electrode pitch	10 μm
4	slength	Stator electrode length	20 μm
5	rwidth	Rotor tooth width	5 μm
6	rpitch	Rotor tooth pitch	15 μm
7	rheight	Rotor tooth height	10 μm
8	yokewidth	Rotor yoke width	10 μm
9	airgap	Air gap between stator and rotor pole faces	2 μm
10	roffset	Rotor offset with respect to the stator	0 μm
*11	nr	Number of tooth on the rotor	
*12	ns	Number of electrodes on stator	

Table 4 List of Parameters

*Note: nr and ns are calculated using active length of motor, rotor tooth pitch and stator electrode pitch.

The next figure shows Linear Side Drive Elements with the sample dimensions as mentioned in Table 4.

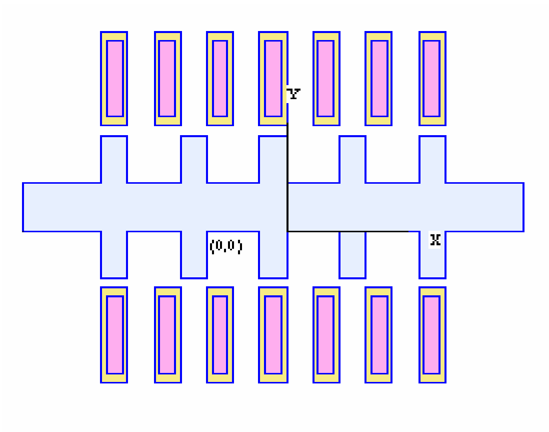


Figure 4 Linear Side Drive Elements

Figure 4 shows the elements in various layers represented by different colors. The origin of the mask is located at the center of the rotor.

2.3 *Unidirectional Rotary Comb Drive Elements-1*

Description:
This script generates a unidirectional rotary comb drive element, which is a planar electrostatic actuator providing angular motion along one direction. It has a static set of curved comb fingers on the stator spoke and a set of curved comb fingers on its rotor spoke that is capable of moving along a angular direction up to a certain range of degree. The stator and the rotor spoke have straight edges. A typical application is in actuation of optical switches.

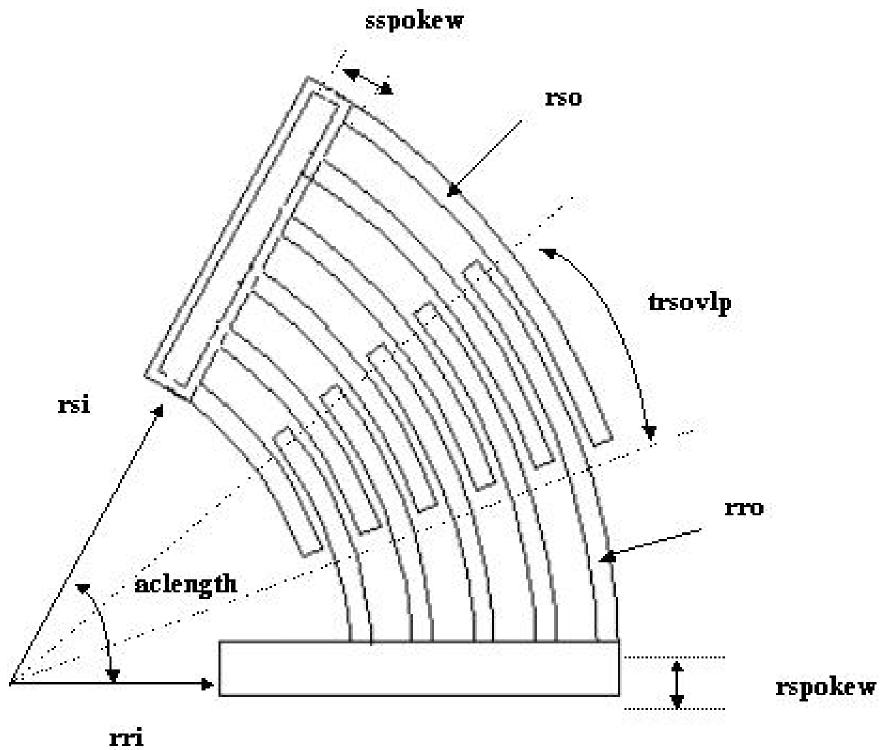


Figure 5 Unidirectional Rotary Comb Drive Elements with parameters

Function Name: urcomb1

```
call urcomb1 (aclength, rri, rsi, rro, rso fwidth ,
rspokew, sspokew,  airgap, trsovlp, n, sfingerength)
```

The table below describes the various components of the Unidirectional Rotary Comb Drive Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_comb	Layer number of comb	4
2	Layer_anchor	Layer number of anchor	5

Table 5 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	aclength	Active angular comb length,	60 degrees
2	rri	Inner radius of rotor	100 μm
3	rsi	Inner radius of stator comb	20 μm
*4	rro	Outer radius of rotor comb	
*5	rso	Outer radius of stator comb	
6	fwidth	Width of comb fingers	10 μm
7	rspokew	Rotor spoke width	25 μm
8	sspokew	Stator spoke width	25 μm
9	airgap	Airgap between adjacent comb fingers	5 μm
10	trsovlp	Angular stator-rotor finger overlap	20 degrees
11	n	Number of fingers on stator	6

Table 6 List of Parameters

*Note: 1.rso is calculated using rsi, n, fwidth, airgap.
2.rro is calculated using rso, fwidth, airgap.

The next figure depicts a Unidirectional Rotary Comb Drive Element with 6 fingers on its stator, as viewed in Intellimask with the dimensions mentioned in Table 6.

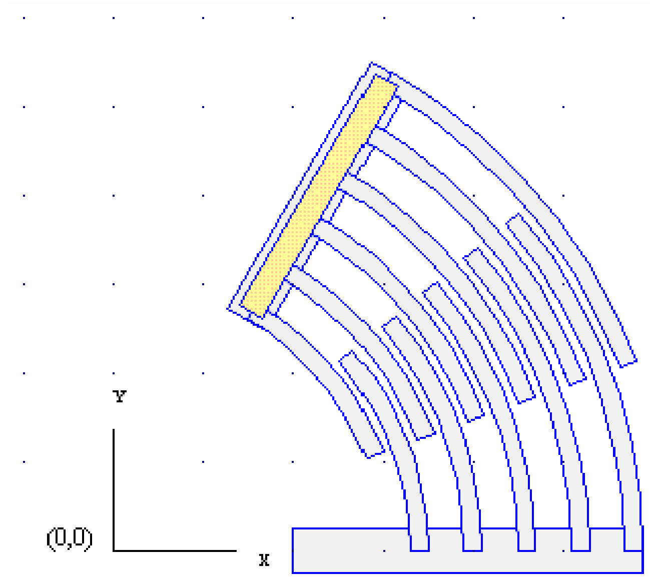


Figure 6 Unidirectional Rotary Comb Drive Elements

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The comb is generated with its origin located at the center of the circular comb fingers and the rotor spoke aligned with the x-axis.

2.4 *Unidirectional Rotary Comb Drive-2*

Description:
This script generates a unidirectional rotary comb drive element, which is a planar electrostatic actuator providing angular motion along one direction. It has a static set of curved comb fingers on the stator spoke and a set of curved comb fingers on its rotor spoke that is capable of moving along a angular direction up to a certain range of degree. The stator and the rotor spoke have tapered edges. They can be used to actuate optical switches.

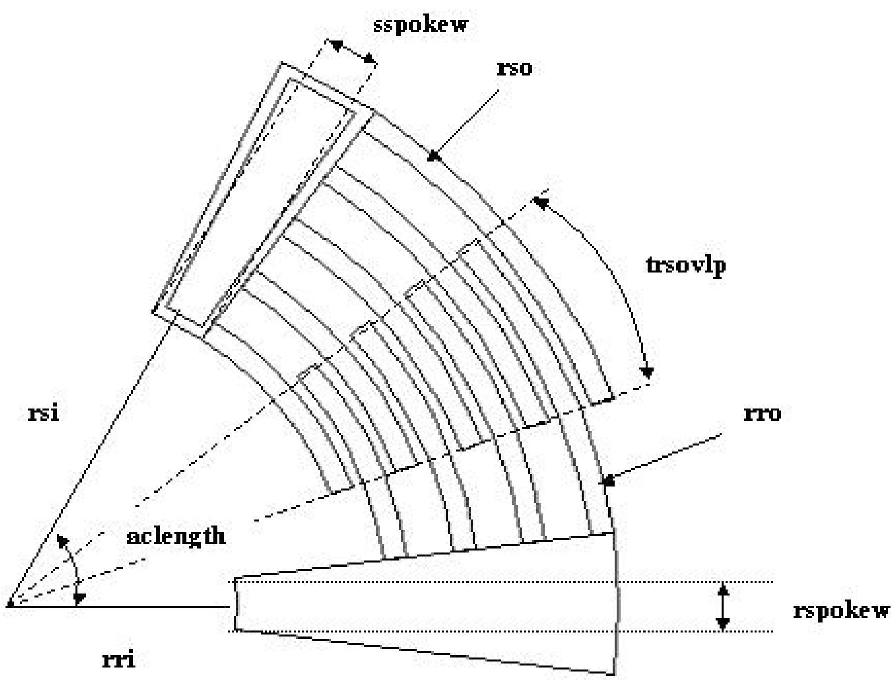


Figure 7 Unidirectional Rotary Comb Drive Elements with parameters

Function Name: urcomb2

```
call  urcomb2 (aclength, rri, fwidth, airgap, rro,
rspokew, trsovlp, n,   sfingerlength, gap,rsi,rso,sspokew)
```

Table 7 below describes the various layer components of the Unidirectional Rotary Comb Drive drawn on the 2 layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_comb	Layer number of comb	1
2	Layer_anchor	Layer number of anchor	6

Table 7 Layer details

Table 8 below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	aclength	Active angular comb length	60 degrees
2	rri	Inner radius of rotor	100 µm
3	rsi	Inner radius of stator comb	150 µm
*4	rro	Outer radius of rotor comb	
*5	rso	Outer radius of stator comb	
6	fwidth	Width of comb fingers	10 µm
7	rspokew	Rotor spoke width	25 µm
8	sspokew	Stator spoke width	25 µm
9	airgap	Airgap between adjacent comb fingers	5 µm
10	trsovlp	Angular stator-rotor finger overlap	30 degrees
11	n	Number of fingers	6

Table 8 List of Parameters

*Note: 1.rso is calculated using rsi, n, fwidth, airgap.
2.rro is calculated using rso, fwidth, airgap.

The next figure depicts the Unidirectional Rotary Comb Drive Elements as viewed in Intellimask with the sample dimensions mentioned in Table 8.

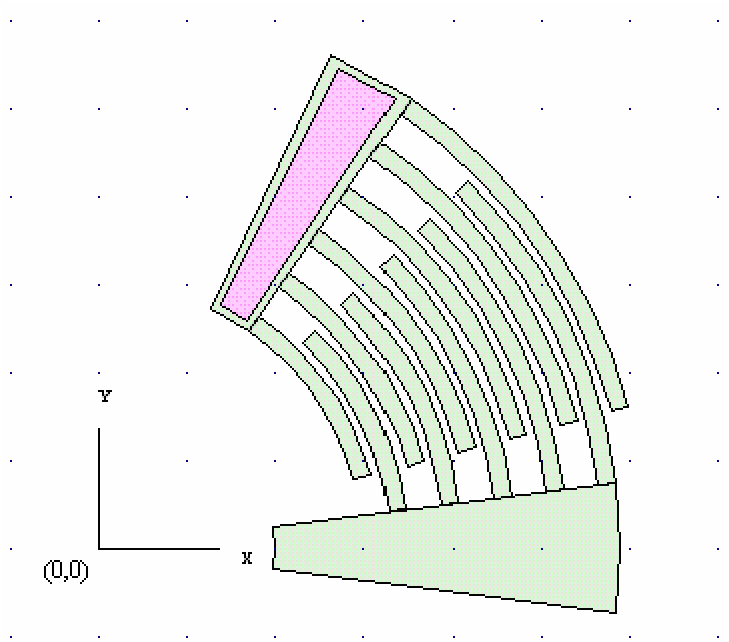


Figure 8 Unidirectional Rotary Comb Drive Elements

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The comb is generated with its origin located at the center of the circular comb fingers and the rotor spoke aligned with the x-axis.

2.5 *Bi-directional Rotary Comb Drive Elements*

Description:
This script generates a Bidirectional rotary comb drive element, which is a planar electrostatic actuator providing angular motion of the rotor in two directions. It has two static set of curved comb fingers on its stator spokes which are located on either side of the rotor spoke. The rotor is capable of moving in the two directions to a certain degree. The stator and the rotor spoke have straight edges. They can be used for multi-channel switching purposes.

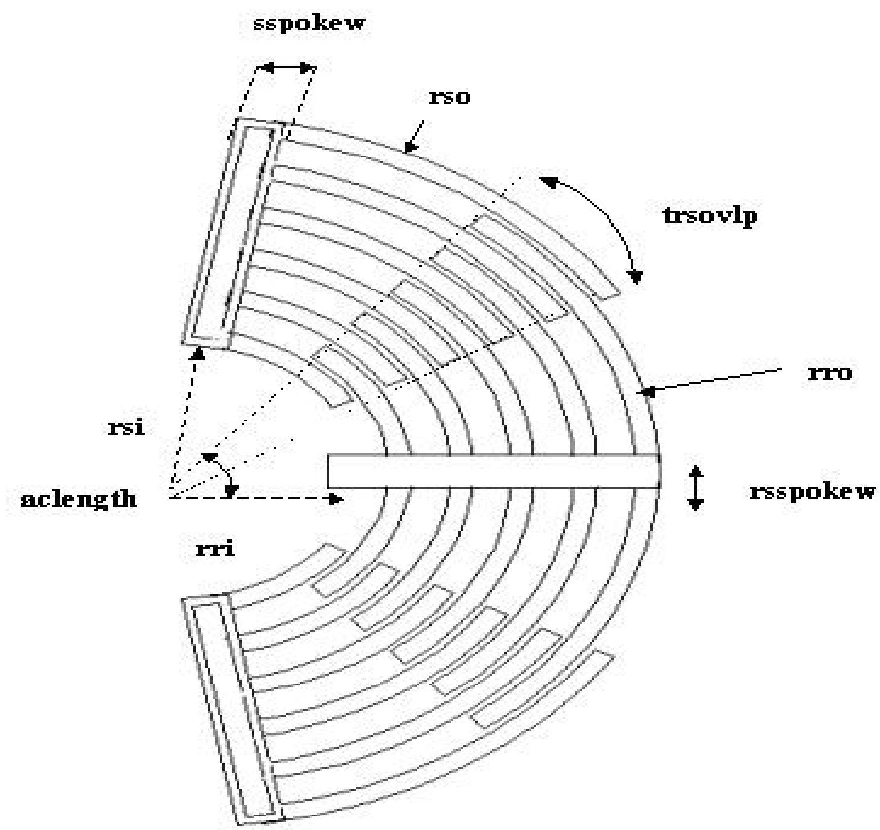


Figure 9 Bidirectional Rotary Comb Drive Elements with parameters

Function Name: brcomb

```
call  brcomb (aclength, rri, fwidth, airgap, rro, rspokew,
trsovlp, n, sfingerlength)
```

The table below describes the various components of the Bidirectional Rotary Comb Drive Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of stator	1
2	Lr	Layer number of rotor	2
3	La	Layer number of anchor	3

Table 9 Layer details

The table below gives the parameter list for this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	aclength	Active angular comb length	80 degrees
2	rri	Inner radius of rotor	100 µm
3	rsi	Inner radius of stator comb	120 µm
*4	rro	Outer radius of rotor comb	
*5	rso	Outer radius of stator comb	
6	fwidth	Width of comb fingers	15 µm
7	rspokew	Rotor spoke width	30 µm
8	sspokew	Stator spoke width	30 µm
9	airgap	Airgap between adjacent comb fingers	5 µm
10	trsovlp	Angular stator-rotor finger overlap	20 degrees
11	n	Number of fingers on each stator	6

Table 10 List of Parameters

*Note: 1.rso is calculated using rsi, n, fwidth, airgap.
2.rro is calculated using rso, fwidth, airgap.

The next figure depicts a Bidirectional Rotary Comb Drive Element with 6 fingers on each of its stator, as generated in Intellimask with the dimensions mentioned in Table 10.

Error! Objects cannot be created from editing field codes.

Figure 10 Bidirectional Rotary Comb Drive Elements

The figure shows the multilayered mask layout wherein each layer is represented by a different color. The comb is generated with its origin located at the center of the circular comb fingers and the rotor spoke aligned with the x-axis.

2.6 *Harmonic Side Drive Elements*

Description:
A central bearing when added to the harmonic side drives completes the formation of a harmonic or wobble motor. Harmonic motors are electrostatic actuators, wherein the rotor rolls on the inside of the stator without slipping and rotates slightly in the process. This slight rotation of the rotor produces the output motion of the motor.
A voltage applied between the rotor and the electrodes in the stator hole drives the rotor. These elements produce superior gear reductions.

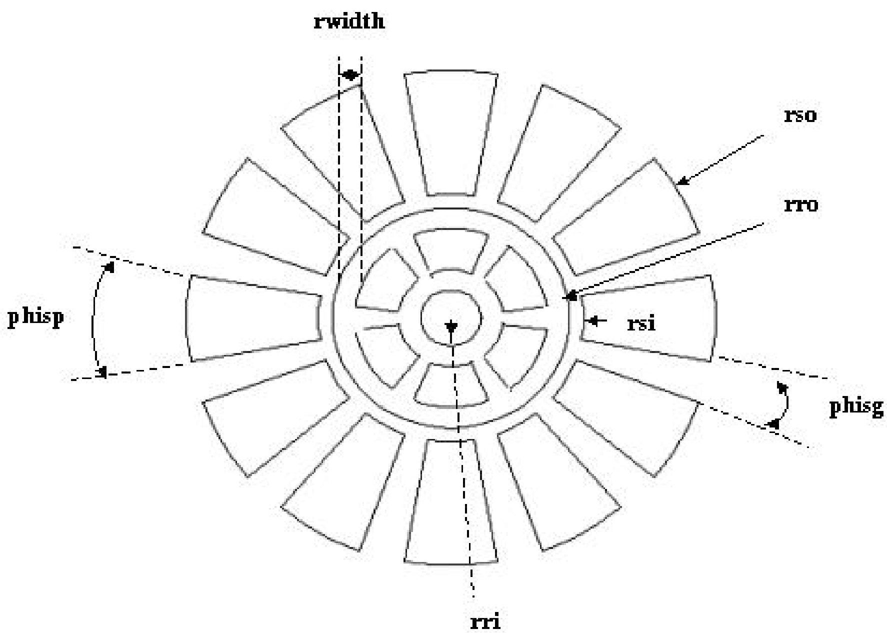


Figure 11 Harmonic Side Drive Elements with parameters

Function Name: HSDE

```
call HSDE (rri, rro, rwidth, rsi, rso, phisp, phisg)
```

The table below describes the various components of the Harmonic Side Drive Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of stator	1
2	Lr	Layer number of rotor	2

Table 11 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	rri	Inner rotor radius	20 μm
2	rro	Outer rotor radius	80 μm
3	rwidth	Rotor ring width	15 μm
4	rsi	Stator inner radius	90 μm
5	rso	Stator outer radius	180 μm
6	phisp	Stator pole angle	20 degrees
*7	phisg	Angular gap between stator poles degrees	
8	nr	Number of electrodes on rotor	6
9	ns	Number of electrodes on stator	12

Table 12 List of Parameters

*Note: 1. Phisg is calculated from phisp.

The figure below depicts the Harmonic Side Drive Element as viewed in IntelliMask with the sample dimensions mentioned in Table 12.

Error! Objects cannot be created from editing field codes.

Figure 12 Harmonic Side Drive Elements

The figure shows a two-layered mask layout wherein each layer is represented by a different color. The origin is located at the center of the stator.

2.7 *Rotary Side Drive Elements*

Description:
Rotary side drive elements have a set of rotor tooth rotating inside the set of stator electrodes. They generate an electrostatic force when an offset exists between stator and the rotor. With a zero offset, the first rotor tooth will be aligned with the first stator electrodes, i.e., the x-axis as shown in the figure below.

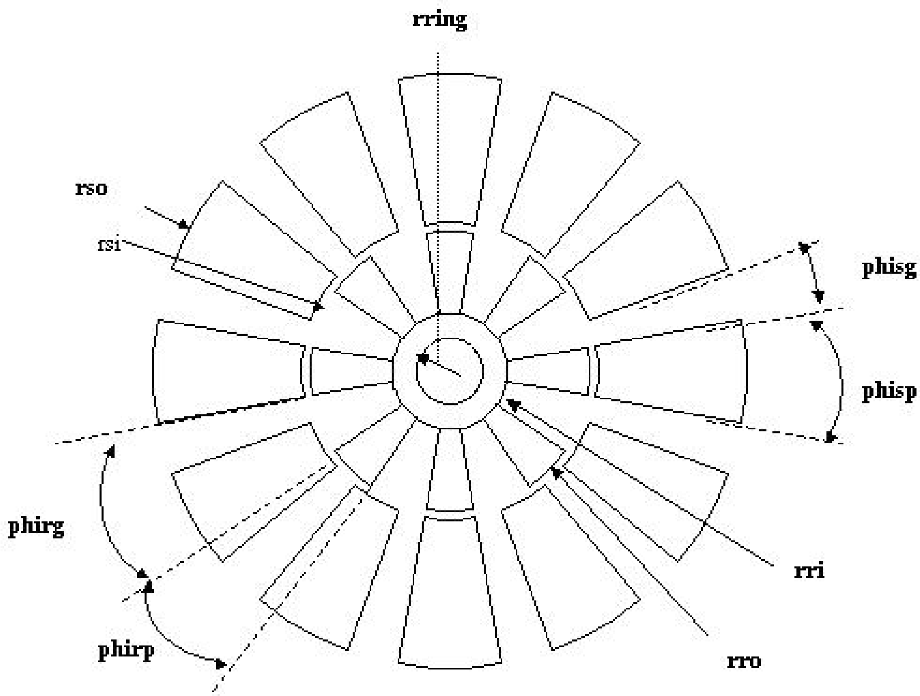


Figure 13 Rotary Side Drive Elements with parameters

Function Name: RSDE

```
    call RSDE (rring, rri, rro, rsi,  rso, phirp,
phirg,phisp, phisg, roffset)
```

The table below describes the various components of the Rotary Side Drive Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of stator	0
2	Lr	Layer number of rotor	1

Table 13 Layer details

The parameters required to generate this element are tabulated below:

Serial Number	Parameter	Description	Dimensions used as sample
1	rring	Inner radius of rotor ring	20 µm
2	rri	Inner rotor radius	35 µm
3	rro	Outer rotor radius	85 µm
4	rsi	Stator inner radius	90 µm
5	rso	Stator outer radius	180 µm
6	phirp	Angular width of rotor pole (tooth)	20 degrees
7	phirg	Angular gap between adjacent rotor teeth	25 degrees
8	phisp	Angular width of stator pole	20 degrees
9	phisg	Angular gap between adjacent stator poles	10 degrees
10	roffset	Angular offset of rotor with respect to stator	5 degrees
*11	nr	Number of tooth on rotor	
*12	ns	Number of electrodes on stator	

Table 14 List of Parameters

*Note: nr is calculated using phirp and phirg, while ns is calculated using phisp and phisg.

The next figure depicts a Rotary Side Drive Element having 8 teeth in its rotor and 12 electrodes in its stator, as viewed in IntelliMask with the sample dimensions mentioned in Table 14.

Error! Objects cannot be created from editing field codes.

Figure 14 Rotary Side Drive Elements

The figure shows a two layered mask layout wherein each layer is represented by a different color. The origin is located at the center of the rotor ring.

2.8 *Folded Spring*

Description:
The script generates a folded spring element. One end of the spring can optionally be anchored to the wafer. The spring is implemented as a number of bars connected on alternating ends at right angles.

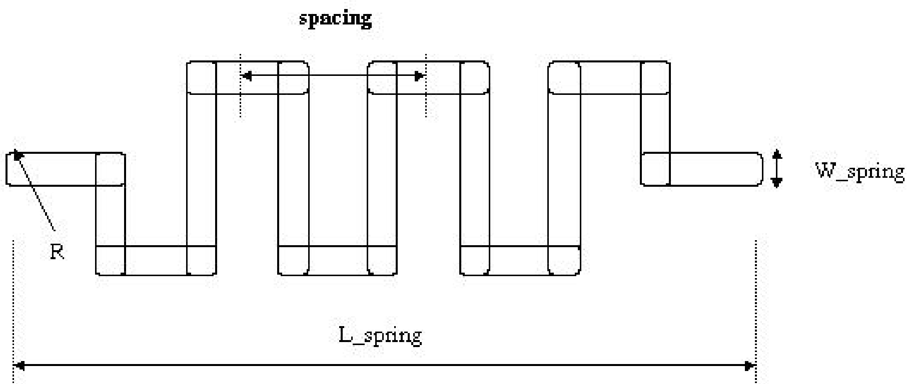


Figure 15 Folded Spring with parameters

Function Name: Folded_spring

```
    call Folded_Spring(L_spring, n_folds, spacing,
w_spring, R)
```

The table below gives the layer number variable of the folded spring drawn:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_spring	Layer number to draw spring	6

Table 15 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
*1	L_spring	Overall length of the spring	320 µm
2	n_folds	Number of folds of the spring	6 µm
3	spacing	Inter tether spacing	80 µm
4	w_spring	Width of the spring	15 µm
5	R	Curvature of the spring corners	3 µm

Table 16 List of Parameters

*Note: L_spring is calculated using number of folds of the spring, width of spring and the spacing.

The next figure shows the folded spring element generated in IntelliMask with the dimensions as shown in Table 16.

Error! Objects cannot be created from editing field codes.

Figure 16 Folded Spring

The mask is drawn considering the origin at the lower left corner as the starting point.

3 Passive MEMS Elements

3.1 *Journal Bearing Element*

Description:
The script generates a Journal Bearing element. A journal bearing is a cylinder, which surrounds the shaft and is filled with some form of fluid lubricant. Industrial machinery with high horsepower and high loads, such as steam turbines, centrifugal compressors, pumps and motors, utilize journal bearings as rotor supports to provide a frictionless environment to support and guide a rotating shaft.

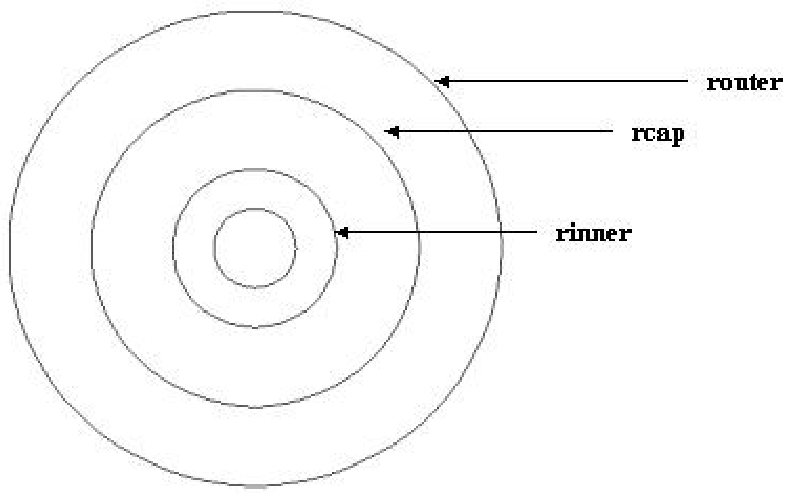


Figure 17 Journal bearing with parameters

Function Name: bearing

```
call bearing(rcap, rinner, router)
```

The table below describes the various components of the Journal Bearing drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	La1	Layer number of rcap	1
2	La2	Layer number of rinner	2
3	La3	Layer number of router	3
*4	La4	Layer number of rinner1	4

Table 17 Layer details

*Note: La4 is the innermost layer whose radius is dependent on the other parameters. The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	rcap	Radius of cap on central shaft	200 μm
2	rinner	Inner radius of journal rotor	100 μm
3	router	Outer radius of journal rotor	300 μm
4	rinner1	Inner most radius	

Table 18 List of Parameters

The next figure shows the Journal Bearing element with the sample dimensions as mentioned in Table 18, generated in IntelliMask.

Error! Objects cannot be created from editing field codes.

Figure 18 Journal Bearing

The journal bearing element with each layer represented by a different color is shown in the figure above. The origin for the mask is the center of the shaft and cap.

3.2 *Linear Crab Leg Suspension Elements-1*

Description:
This script generates a Linear Crab Leg Suspension or Lobster Suspension Element. A suspension is a spring like element, which is designed to be compliant along its length. However, it is stiff in the perpendicular direction. Linear actuation elements can be connected to the shuttle yokes to create a linear resonator.

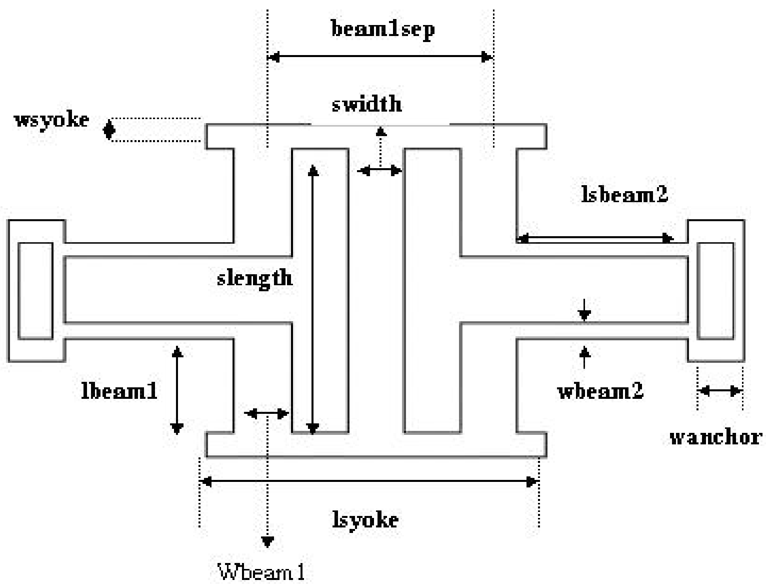


Figure 19 Linear Crab Leg Suspension Elements with parameters

Function Name: LCLS

```
call LCLS(lbeam1, wbeam1, wbeam1, lbeam2, beam1sep,
swidth, slength, wanchor, wsyoke, lsyoke, offset, sheight,
wheight, sbreadth)
```

The table below describes the various components of the Linear Crab Leg Suspension Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of Linear Crab Leg Suspension Element	4
2	La	Layer number of anchor	3

Table 19 Layer details

The table below gives the design parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	lbeam1	Length of beam 1	40 μm
2	wbeam1	Width of beam 1	20 μm
3	lbeam2	Length of beam 2	60 μm
4	wbeam2	Width of beam 2	6 μm
5	beam1sep	Separation between type 1 beams	80 μm
6	swidth	Width of shuttle width	20 μm
7	slength	Length of shuttle	120 μm
8	wanchor	Width of anchor support	20 μm
9	wsyoke	Width of shuttle yoke	10 μm
10	lsyoke	Length of shuttle yoke	120 μm

Table 20 List of Parameters

The next figure depicts the Linear Crab Leg Suspension Elements as viewed in IntelliMask with the sample dimensions shown in Table 20.

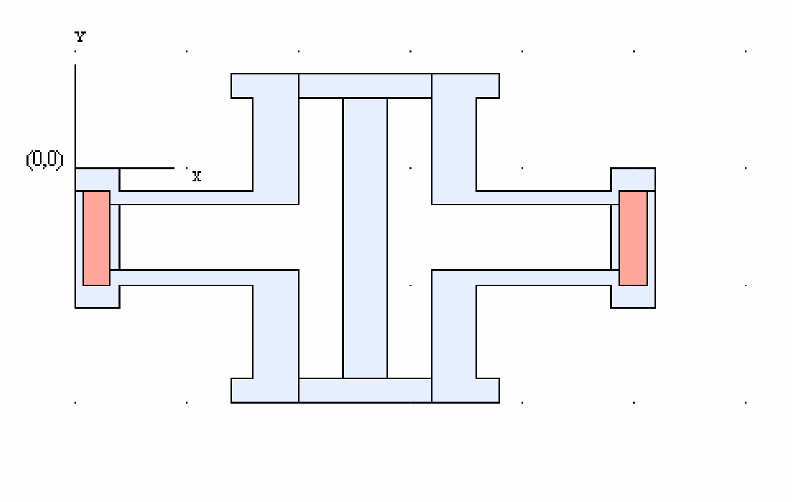


Figure 20 Linear Crab Leg Suspension Elements

Figure 20 shows a two layered mask layout wherein each layer is represented by a different color. The origin is located at the upper left corner of the element.

3.3 *Linear Crab Leg Suspension Elements-2*

Description:
This script generates a Linear Crab Leg Suspension Element. A suspension is a spring like element, which is designed to be compliant along its length. However, it is stiff along its the perpendicular direction.
Actuators or other mechanical elements like comb-drives can be connected to the yokes at the ends of the shuttle mass.

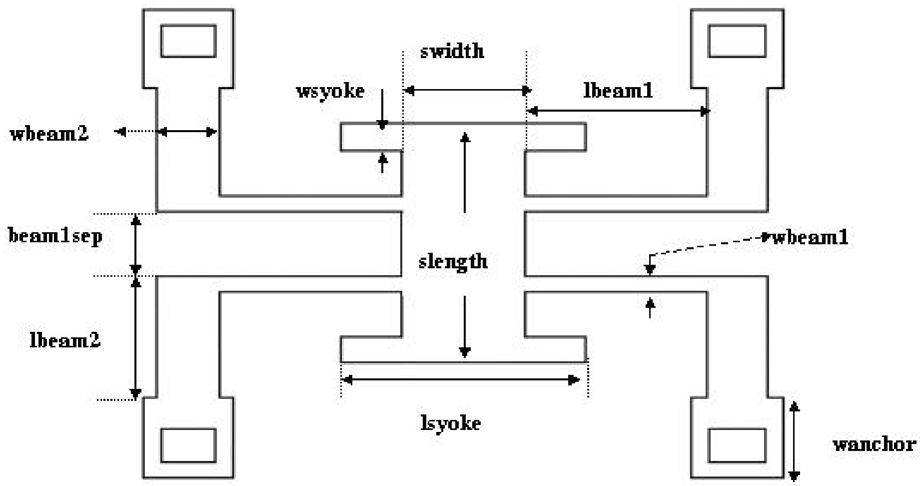


Figure 21 Linear Crab Leg Suspension Elements with parameters

Function Name: LCLSb

```
call LCLSb (lbeam1, wbeam1, wbeam2, lbeam2, beam1sep,
swidth,   slength, wanchor, wsyoke, lsyoke, aprojection,
sprojection, sheight, sheight1)
```

The table below gives the layer details of the Linear Crab Leg Suspension Elements:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of crab	1

Table 21 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	lbeam1	Length of beam 1	60 µm
2	wbeam1	Width of beam 1	6 µm
3	lbeam2	Length of beam 2	40 µm
4	wbeam2	Width of beam 2	20 µm
5	beam1sep	Separation between type 1 beams	30 µm
6	swidth	Width of shuttle width	40 µm
7	slength	Length of shuttle	70 µm
8	wanchor	Width of anchor support	30 µm
9	wsyoke	Width of shuttle yoke	10 µm
10	lsyoke	Length of shuttle yoke	80 µm

Table 22 List of Parameters

The next figure depicts the Linear Crab Leg Suspension Elements generated in IntelliMask with the sample dimensions shown in Table 22.

Error! Objects cannot be created from editing field codes.

Figure 22 Linear Crab Leg Suspension Elements

The figure shows the mask layout of the linear crab leg suspension element. The element is drawn considering the starting point as the origin, which is located at the upper left corner.

3.4 *Linear Folded Beam Suspension Elements*

Description:
This script generates a Linear Folded Beam Suspension Element. A folded beam suspension is a spring like element, which is designed to be compliant along its length. However, it is stiff in the perpendicular direction. Actuators or other mechanical elements like comb-drives can be connected to the yokes at the ends of the shuttle mass.

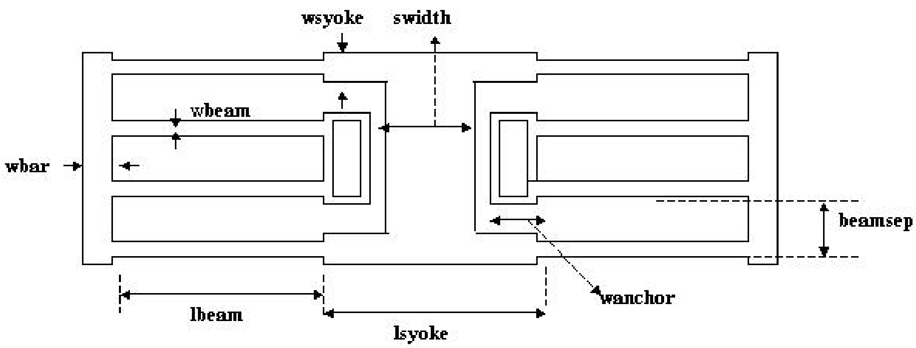


Figure 23 Linear Folded Beam Suspension Elements with parameters

Function Name: LFBS

```
call LFBS(lbeam, wbeam, beamsep, wbar, swidth ,wanchor,
wsyoke,    lsyoke)
```

The table below describes the various components of the Linear Folded Beam Suspension Elements drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of structure	6
2	La	Layer number of anchor	5

Table 23 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	lbeam	Length of beam	70 μm
2	wbeam	Width of beam	5 μm
3	beamsep	Separation between beams	20 μm
4	wbar	Width of connecting bar	10 μm
5	swidth	Width of shuttle width	30 μm
6	wanchor	Width of anchor support	15 μm
7	wsyoke	Width of shuttle yoke	10 μm
8	lsyoke	Length of shuttle yoke	70 μm

Table 24 List of Parameters

The next figure depicts the Linear Folded Beam Suspension Elements generated in Intellimask with the dimensions shown in Table 24.

Error! Objects cannot be created from editing field codes.

Figure 24 Linear Folded Beam Suspension Elements

The figure shows the two layered mask layout wherein each layer is represented by a different color. The origin is located at the upper left corner of the element.

4 MEMS Packaging Elements

4.1 *Dual Inline Pin Package*

Description:
The pins hang vertically from the two long edges of the rectangular package, spaced at certain intervals. The pins fit through holes in the circuit board to which they are soldered or into a socket. The most common type of package for small and medium scale integrated circuits, have up to about 48 pins.

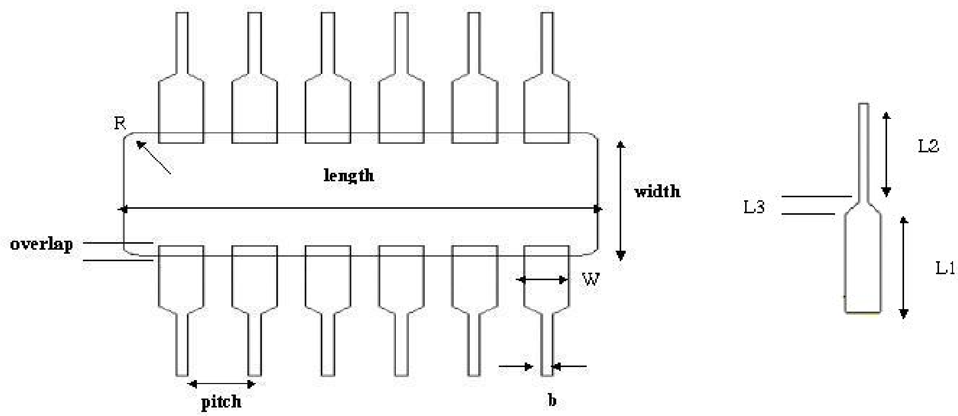


Figure 25 Dual Inline Pin Package with parameters, also showning pin detail

Function Name: DIPP

```
     call
DIPP(n,pitch,length,width,R,b,W,L1,L2,L3,overlap)
```

The table below describes the various components of the Dual Inline Pin Package drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample Value
1	Layer_base	Layer for drawing the base package (rectangle)	2
2	Layer_pins	Layer for drawing the pins	3

Table 25 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	n	Number of pins in length	6
2	pitch	Spacing between pins (center to center distance)	2.29 mm
*3	Length	Length of package	
4	Width	Width of package	6.10 mm
5	R	Radius of curvature	0.5 mm
6	b	Width of bottom of pin	0.38 mm
7	W	Width of top of pin	1.4 mm
8	L1	Length of top part of pin	3.04 mm
9	L2	Length of bottom part of pin	3.04 mm
10	L3	Length of pin taper	0.38 mm
11	Overlap	Overlap between pin and package	0.5 mm

Table 26 List of Parameters

*Note: Length is calculated based on the number of pins in length and pitch.
Please note the dimensions are entered in millimeters(mm).

Figure 26 shows the Dual Inline Pin Package generated in IntelliMask with the sample dimensions shown in Table 26.

Error! Objects cannot be created from editing field codes.

Figure 26 Dual Inline Pin Package

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The origin of the mask is located at the lower left corner of the base layer.

4.2 *Small Outline IC Package*

Description:
The script generates a Small Outline IC Package element.
SOIC's are Popular, cost effective, high density and widely available IC packages.
Their applications include memory chips and linear ICs.

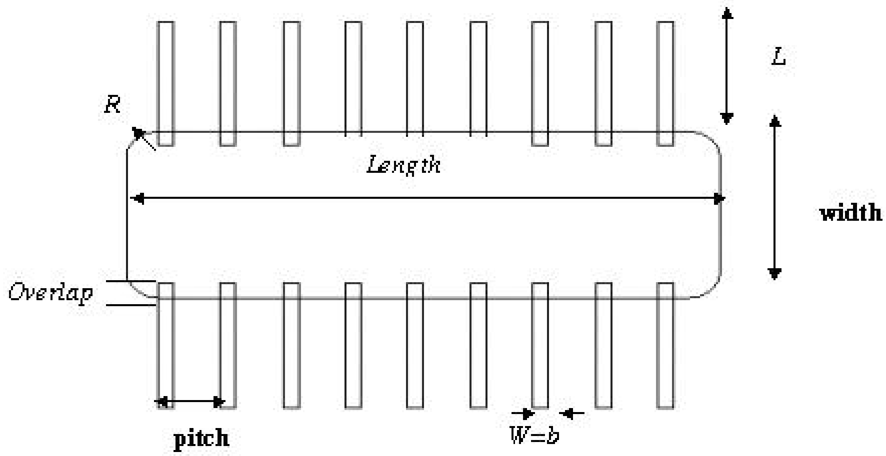


Figure 27 Small outline IC package with parameters

Function Name: SOIC

```
    call SOIC(n, pitch ,length, width, R, b, W, L
,overlap)
```

The table below describes the various components of the Small Outline IC Package drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer base	Layer for drawing the base package (rectangle)	3
2	Layer pins	Layer for drawing the pins	4

Table 27 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
*1	length	Length of package	
2	width	Width of package	3.81 mm
3	pitch	Spacing between pins	1.27 mm
4	n	Number of pins	8
5	R	Radius of curvature	0.5 mm
*6	b	Width of bottom of pin	0.3 mm
*7	W	Width of top of pin	0.33 mm
8	L	Length of both top and bottom part of pin	1.015 mm
9	Overlap	Overlap between pin and package	0.1 mm

Table 28 List of Parameters

*Note: width of bottom of pin is equal to the top of the pin in this case, i-e b=W when compared to DIPP.
Length is calculated using number of pins (n) and pitch.

Figure 28 shows the Small Outline IC Package generated in IntelliMask with the sample dimensions shown in Table 28

Error! Objects cannot be created from editing field codes.

Figure 28 Small Outline IC Package

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the left extreme as the starting point.

4.3 *Quad Flatpack Package_Gull-Winged Pins*

Description:
This is a rectangular or square structure with gull-wing shaped leads on all four sides. It is used for standard Surface Mount Technology package.

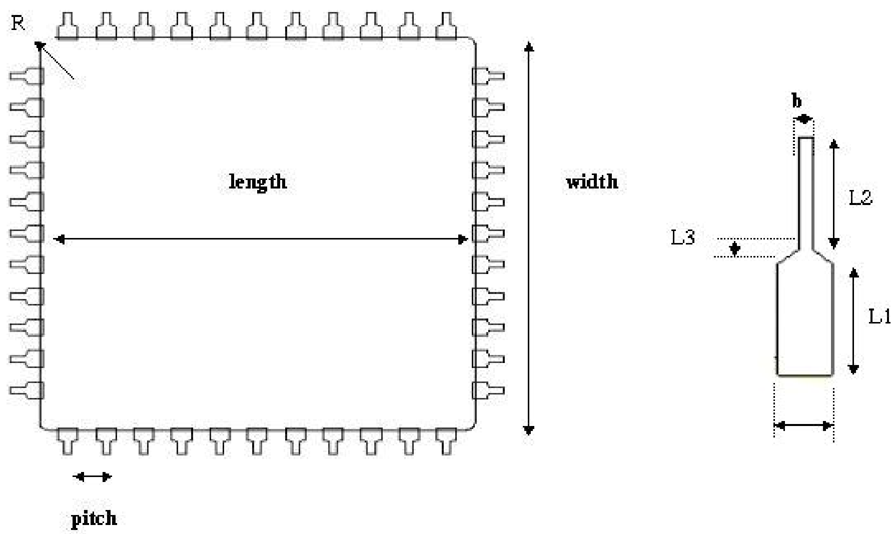


Figure 29 Quad Flatpack Package with gull wing shaped pins, with pin detail

Function Name: QFPGWP

```
     call
QFPGWP(nl,nw,pitch,length,width,R,b,W,L1,L2,L3,overlap)
```

The table below describes the various components of the Quad Flatpack Package drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample Values
1	Layer base	Layer for drawing the base package (rectangle)	2
2	Layer pins	Layer for drawing the pins	3

Table 29 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	nl	Number of pins in length	11
2	nw	Number of pins in width	11
3	pitch	Spacing between pins (center to center distance)	1.27 mm
*4	Length	Length of package	
*5	Width	Width of package	
6	R	Radius of curvature	0.3 mm
7	b	Width of bottom of pin	0.254 mm
8	W	Width of top of pin	0.6604 mm
9	L1	Length of top part of pin	0.5 mm
9	L2	Length of bottom part of pin	0.5 mm
10	L3	Length of pin taper	0.09 mm
11	Overlap	Overlap between pin and package	0.1 mm

Table 30 List of Parameters

*Note: The length and width are calculated based on the number of pins in length and width respectively and pitch.

Figure 30 shows the QFP package with 44 pins for the sample dimensions shown in Table 30, as viewed in IntelliMask.

Error! Objects cannot be created from editing field codes.

Figure 30 Quad Flatpack Package

The above figure shows QFP package with its each layer represented by a different color. The origin of the mask is located at the lower left corner of the base layer.

4.4 *Quad Flatpack Package*

Description:
The script generates a Quad Flatpack Package element with rectangular pins.
These are high-density peripheral surface mount packages with leads protruding on all four sides of the package.
Major areas of application include microcontrollers.

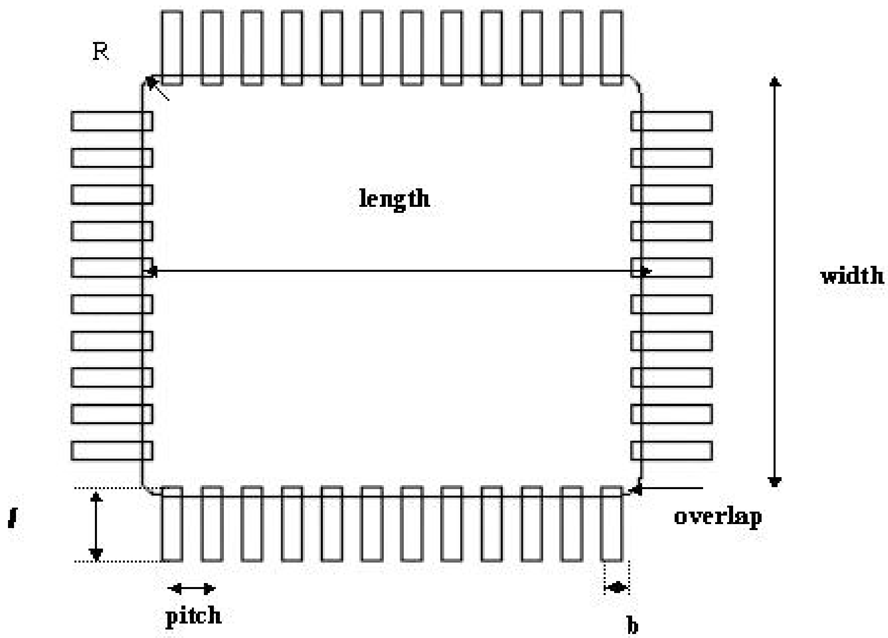


Figure 31 Quad Flatpack Package with parameters

Function Name: QFP

```
call QFP (nl, nw, pitch, length, width, R, b, W, L, overlap)
```

The table below describes the various components of the Quad Flatpack Package drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_base	Layer for drawing the base package (rectangle)	3
2	Layer_pins	Layer for drawing the pins	4

Table 31 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	nl	Number of pins in length	24
2	nw	Number of pins in width	16
3	pitch	Spacing between pins	0.8 mm
*4	length	Length of package	
*5	width	Width of package	
6	R	Radius of curvature	0.2 mm
7	b	Width of pin	0.3 mm
8	L	Length of pin	1.75 mm
9	Overlap	Overlap between pin and package	0.25 mm

Table 32 List of Parameters

*Note:
The Length and width are calculated using number of pins in length (nl) and number of pins in width (nw) respectively.

Figure 32 shows an 80 pin QFP for the dimensions shown in Table 32, as viewed in IntelliMask.

Error! Objects cannot be created from editing field codes.

Figure 32 Quad Flatpack Package

The above figure shows QFP with its each layer represented by a different color. The origin of the mask is located at the lower left corner of the base layer.

4.5 *To Can*

Description:
This element generates a CAN element, which is used in IC Packaging industry for connecting multiple leads. The number of pins generally varies between 5 and 12.

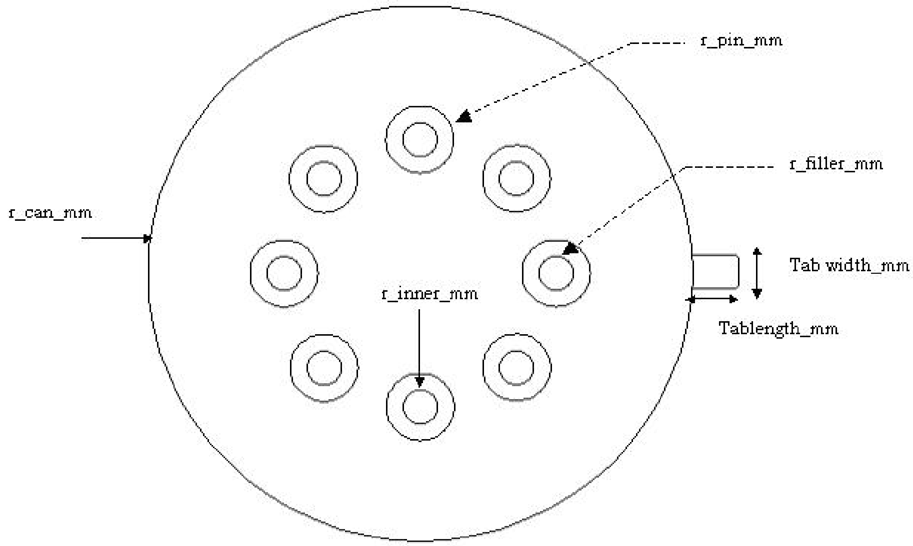


Figure 33 To Can

Function Name: Can

```
     call Can
(x1,y1,n,r_can,r_inner,r_pin,r_filler,tab_length,tab_width
)
```

The table below describes the various components of the To Can drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_Can	Layer number for drawing can	3
2	Layer_Pin	Layer number for drawing pins	4
3	Layer_Filler	Layer number for drawing fillers	5

Table 33 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	n	Number of pins	8
2	r_can_mm	Outer radius of can	3.875 mm
3	r_inner_mm	Inner radius around which the pins are placed	2.235 mm
4	r_pin_mm	Pin radius	0.205 mm
5	r_filler_mm	Radius of filler hole	0.305 mm
6	tab_length_mm	Length of tab	0.690 mm
7	tab_width_mm	Width of tab	0.690 mm

Table 34 List of Parameters

The next figure depicts the CAN with 8 pins, generated in Intellimask with the sample dimensions shown in Table 34.

Error! Objects cannot be created from editing field codes.

Figure 34 To Can

The figure shows a multilayered mask layout wherein each layer is represented by a different color. The origin is at the center of the CAN element.

4.6 *Perforated Rectangular Plate*

Description:
The script generates a Perforated Rectangular Plate element.

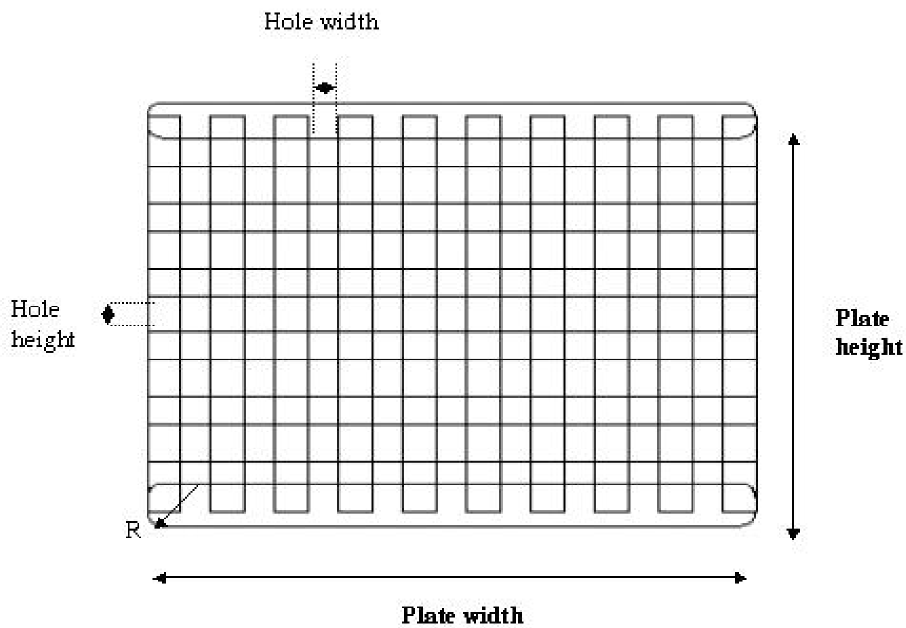


Figure 35 Perforated Rectangular Plate with parameters

Function Name: PRP
```
    Call PRP (Plate_width ,Plate height, Corner radius
,n_rows,
     n_columns, hole_width, hole_height)
```

The table below gives the layer details of the perforated plate:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_plate	Layer number to draw plate	3

Table 35 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	Plate_width	Width of the plate	200 μm
2	Plate_height	Height of the plate	150 μm
3	Corner_radius	Radius of curvature of plate	5 μm
4	n_rows	Number of perforations in a row	9
5	n_columns	Number of perforations in a column	6
6	hole_width	Width of the perforation	10 μm
7	hole_height	Height of the perforation	10 μm

Table 36 List of parameters

Figure 36 shows the Perforated Rectangular Plate as seen in IntelliMask with the sample dimensions specified in Table 36.

Error! Objects cannot be created from editing field codes.

Figure 36 Perforated Rectangular Plate

The mask is drawn considering the origin located at the lower left corner as the starting point.

5 Electrical and mechanical test elements

5.1 *Area-Perimeter Dielectric Isolation Test Structure (APTEST)*

Description:
The APTEST element generates an area-perimeter test structure that can be used to test the dielectric properties of the isolation layer between the first electrical connect layer and the substrate.
It can also be used to characterize electrical resistance. Electrical pads are connected to both the ends of the serpentine structure.

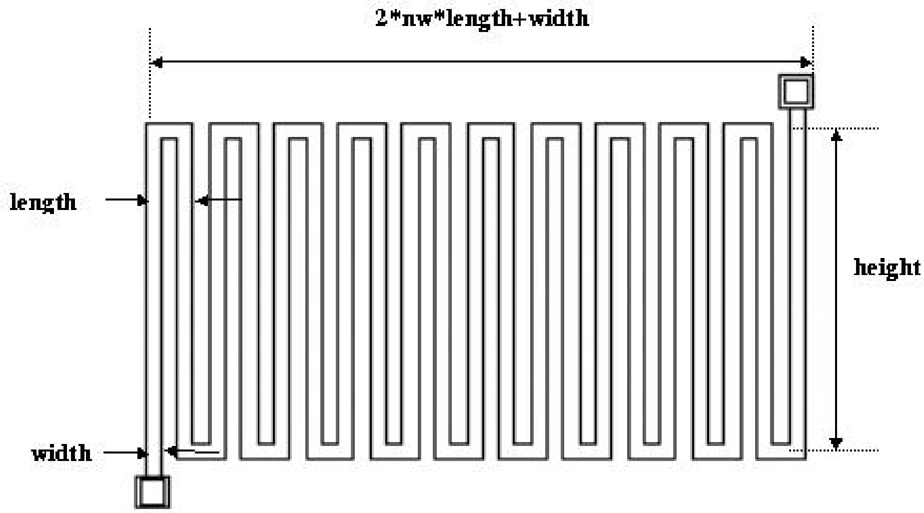


Figure 37 Area-Perimeter Dielectric Isolation Test Structure with parameters

Function Name: Aptest

```
call Aptest(width, height, length, nw)
```

The table below describes the various components of the Area-Perimeter Dielectric Isolation Test Structure drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number of serpentine	3
2	La	Layer number of anchor	4

Table 37 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	width	Width of electrical connect wire	5 μm
2	height	Serpentine height	100 μm
3	length	Serpentine half wavelength	10 μm
4	nw	Number of wavelengths	10 μm

Table 38 List of Parameters

The next figure shows the Area-Perimeter Dielectric Isolation Test Structure generated in IntelliMask with the values from Table 38.

Error! Objects cannot be created from editing field codes.

Figure 38 Area-Perimeter Dielectric Isolation Test Structure

Figure 38 shows the Area-Perimeter Dielectric Isolation Test Structure with two of its layers represented by different colors. The origin of the mask is located at the lower left corner of the serpentine structure.

5.2 *Crossover Test Structure Element*

Description: The script generates a crossover test structure that can be used to test electrical interconnection of standard conducting lines using bridges on structural layers 2 to cross over lines on structural layer 1. The wire on structural layer 2 is anchored to the substrate everywhere except at the bridges. Pads are added to the wires to allow electrical probing of the test structures. The structure below shows two horizontal bridge (crossover) wires on structural layer 2 that cross the anchored underpass which is the vertical wire on structural layer 1.

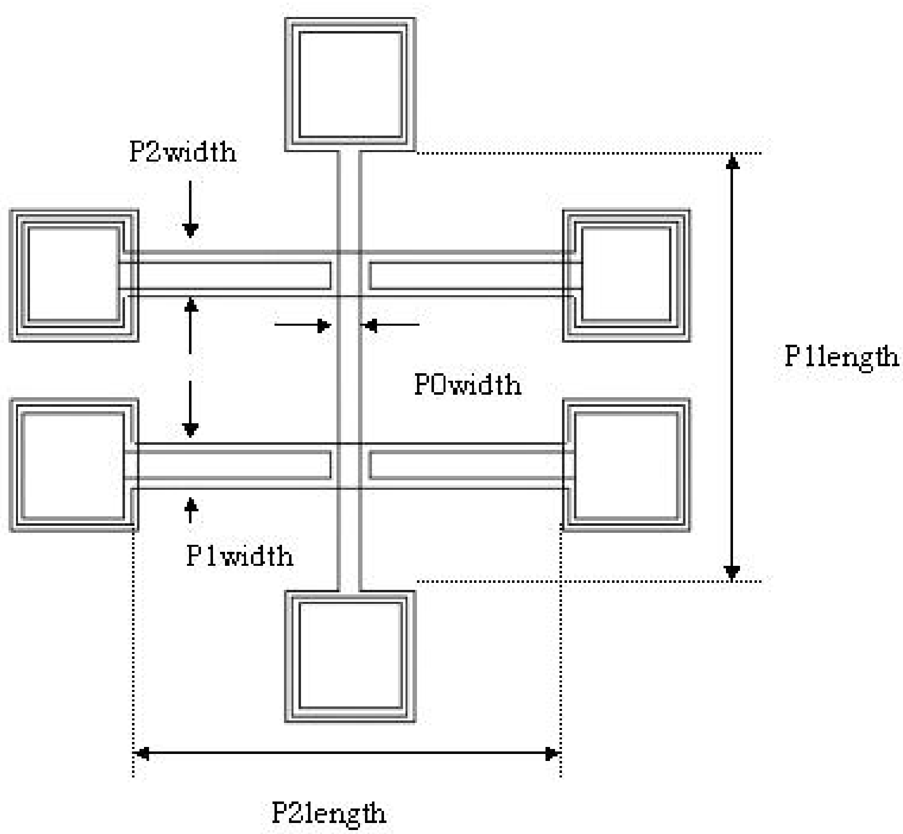


Figure 39 Crossover Test Structure-2 Element with parameters

Function Name: coatst

```
    call coatst (p0width, p1width, p2width, p2length,
p1length)
```

The table below describes the various components of the Crossover Test Structure Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	L1	Electrical connect Layer	1
2	L2	First Structural Layer	2
3	L3	Second Structural Layer	3
4	L4	Third Layer	4

Table 39 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	p0width	Width of wire on first electrical connect layer	5μm
2	p1width	Width of wire on first structural layer	10 μm
3	p2width	Width of wire on second structural layer, μm	10 μm
4	p2length	Length of crossover structures	100 μm
5	p1length	Length of underpass structure	100 μm

Table 40 List of Parameters

The next figure shows the Crossover Test Structure Element in Intellimask with the sample dimensions shown in Table 40.

Error! Objects cannot be created from editing field codes.

Figure 40 Crossover Test Structure-2 Element

The figure shows a multilayered mask layout with each layer is represented by a different color. The origin for the structure is located between left side pads of the crossover structures as evident from the figure.

5.3 Crossover Test Structure Element

Description: The script generates a crossover test structure that can be used to test electrical interconnection of standard conducting lines using bridges on structural layers 2 to cross over lines on structural layer 1. The wire on structural layer 2 is anchored to the substrate everywhere except at the bridges. Pads are added to the wires to allow electrical probing of the test structures. The structure below shows a horizontal bridge (crossover) wire on structural layer 2 that crosses the anchored underpass, vertical wire on structural layer 1.

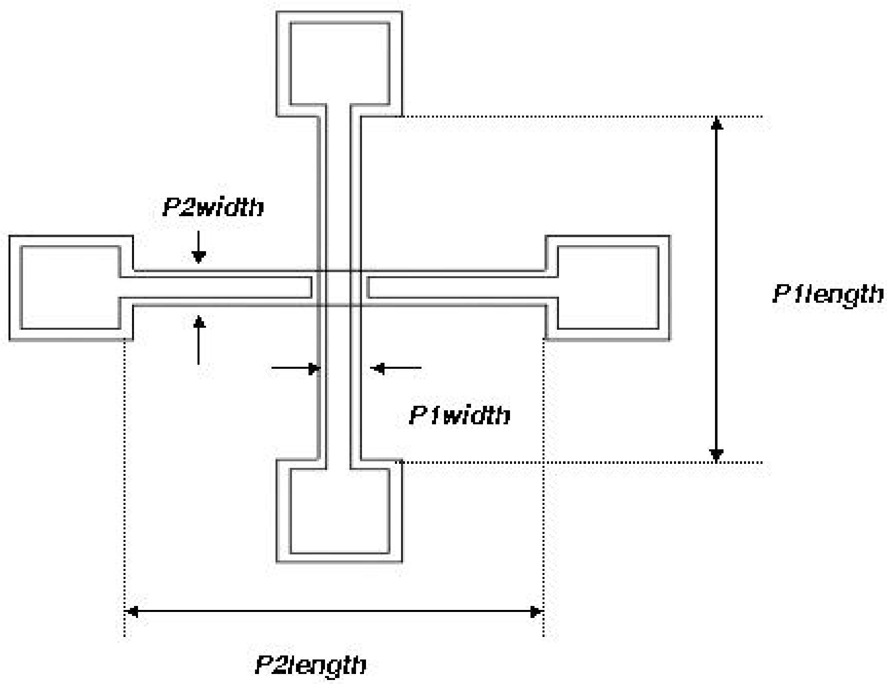


Figure 41 Crossover Test Structure Element with parameters

Function Name: cotest

```
call  cotest (p1width,p2width,p2length, p1length)
```

The table below describes the various components of the Crossover Test Structure-1 Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Lup1	Layer number of underpass	3
2	Lup2	Layer number of underpass	4
3	Lco1	Layer number of crossover	5
4	Lco2	Layer number of cross over	6

Table 41 Layer details

The table below gives the parameter list used to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	p1width	Width of wire on first structural layer	10 µm
2	p2width	Width of wire on second structural layer	10 µm
3	p2length	Length of crossover structure	100 µm
4	p1length	Length of underpass structure	100 µm

Table 42 List of Parameters

The next figure depicts the Crossover Test Structure-1 Element as viewed in Intellimask with the sample dimensions mentioned in Table 42.

Error! Objects cannot be created from editing field codes.

Figure 42 Crossover Test Structure-1 Element

The figure shows a multilayered mask layout with each layer is represented by a different color. The origin for the structure is located at the lower left corner of the pad of the crossover structure.

5.4 *Euler Column (Doubly supported Beam)*

Description: The script generates an Euler Column.
A Euler column is also known as a doubly supported beam. It consists of beams and anchors.
Euler columns are often used to test for compressive stress in layers.

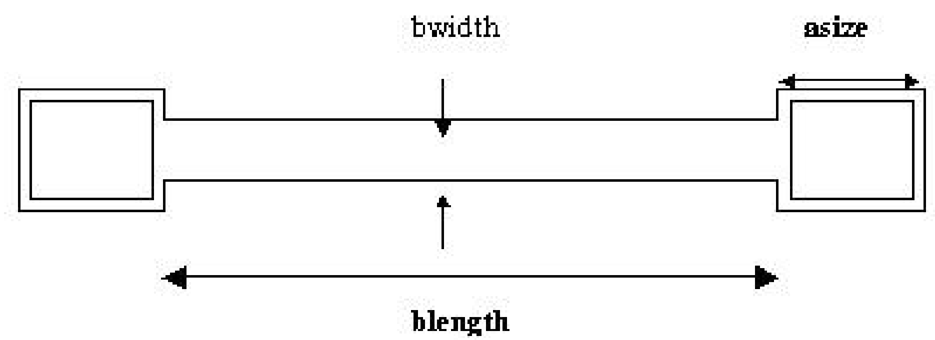


Figure 43 Euler Column with parameters

Function Name: eulercolumn

```
call eulercolumn (blength, bwidth, asize)
```

The table below describes the various components of the Euler Column drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Lb	Layer number of beam	2
2	La	Layer number of anchor	6

Table 43 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	blength	Length of doubly supported beam, µm	100µm
2	bwidth	Width of doubly supported beam, µm	10µm
3	asize	Size of anchor supports, µm	20µm
*4	bsize		

Table 44 List of Parameters

* Note: bsize is the allowance with respect to the anchor width.

The next figure depicts the Euler column as viewed in Intellimask with the sample dimensions shown in Table 44.

Error! Objects cannot be created from editing field codes.

Figure 44 Euler Column (Doubly Supported Beam)

The figure shows a multilayered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin as the starting point.

5.5 Array of Euler Column - Doubly Supported Beam

Description: This program implements an array of Euler columns. The lengths of the Euler columns are varied along the array.
This element can be used to estimate the residual strain in a film with a compressive residual strain.

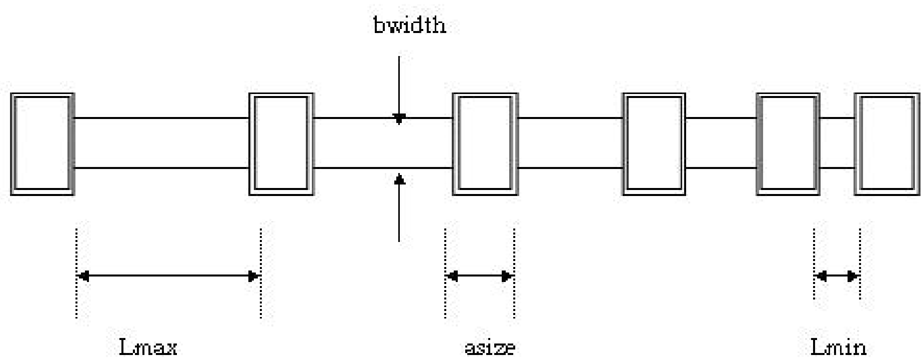


Figure 45 Array of Euler Column with parameters

Function Name: eulerarray

```
call  eulerarray (Lmin, Lmax, Lstep, bwidth, height, asize, bsize)
```

The table below describes the various components of the Array of Euler Column drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	La	Layer number anchor	3
2	Lb	Layer number of beam	2

Table 45 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	Lmin	The length of the shortest Euler column	20 µm
2	Lmax	The length of the longest Euler column	100 µm
3	Lstep	Change in length between Euler columns as the length is varied,	10 µm
4	bwidth	Width of doubly supported beam	30 µm
5	height	Thickness of structural layer of the beam	2 µm
6	asize	Size of anchor supports	30 µm
*7	bsize		

Table 46 List of Parameters

*Note: bsize is the allowance with respect to the anchor width.

The next figure shows an array of 9 Euler Columns generated in IntelliMask with the length of the column decreasing gradually from the longest to the shortest length. The difference in lengths between two consecutive columns is the step length. The dimensions are specified in Table 46.

Error! Objects cannot be created from editing field codes.

Figure 46 Array of Euler Coulmn

Figure 46 shows the element with the two layers represented by different colors. The origin of the element is located at the left end of the set of columns.

5.6 *Guckel Ring Test Structure Element*

Description:

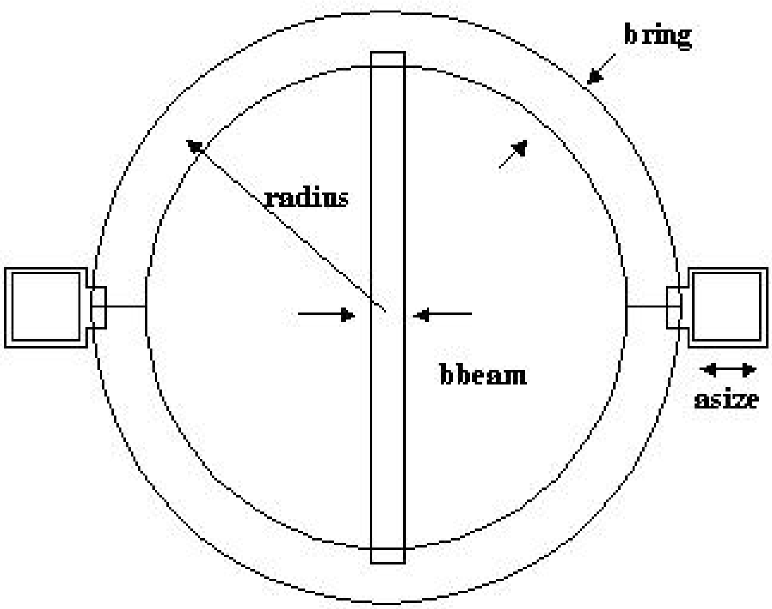


Figure 47 Guckel Ring Test Structure Element with parameters

Function Name: guckelring

```
call  guckelring(radius, bring, bbeam, asize)
```

The table below describes the various components of the Guckel Ring Test Structure Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Lg	Layer number of RingLa	1
2	La	Layer number of anchor	3

Table 47 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	radius	mean radius of ring, µm	200 µm
2	bring	width of ring, µm	40 µm
3	bbeam	width of cross beam, µm	25 µm
4	asize	size of anchor supports, µm	50 µm
*5	r_inner	inner radius of ring, µm	
*6	r_outer	outer radius of ring, µm	
*7	a2	start angle of arc segment, degrees	
*8	a1	end angle of arc segment, degrees	

Table 48 List of parameters

*Note:
r_inner and r_outer is calculated using mean radius and width of ring.
a2 and a1 are start angle and end angle of arc segments respectively.

The next figure shows the Guckel Ring Test Structure Element with dimensions as specified in Table 48.

Error! Objects cannot be created from editing field codes.

Figure 48 Guckel Ring Test Structure Element

Figure 48 shows the element with two of its layers represented by different colors. The mask is drawn considering the origin as the starting point.

5.7 Array of Guckel Ring

Description: This script generates an array of guckel rings. The radii of the rings vary along the array. These ring structures can be used to estimate the residual strain in a film with tensile residual strain

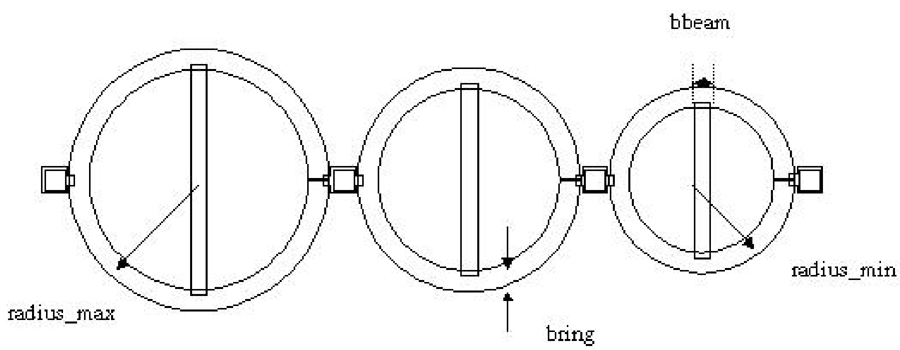


Figure 49 Array of Guckel Ring with parameters

Function Name: guckelarray

```
        call guckelarray (radius_min, radius_max,
radius_step, bring, bbeam, asize)
```

The table below describes the various components of the Array of Guckel Ring drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Lg	Layer number of ring	1
2	La	Layer number of anchor	6

Table 49 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	radius_min	Mean radius of the smallest guckel ring	200 µm
2	radius_max	Mean radius of the largest guckel ring	300 µm
3	radius_step	Difference in mean radius between adjacent rings	20 µm
4	bring	Width of ring	40 µm
5	bbeam	Width of cross beam	30 µm
6	asize	Size of anchor supports	50 µm
*7	r_inner	Inner radius of ring	
*8	r_outer	Outer radius of ring	

Table 50 List of Parameters

*Note: r_inner and r_outer are calculated using mean radii of the smallest and largest rings and width of ring.

The next figure shows the IntelliMask generated Guckel Array, containing 6 Rings with the radius of the rings gradually decreasing from the maximum to minimum radius. The figure shown the sample dimensions specified in Table 50.

Error! Objects cannot be created from editing field codes.

Figure 50 Array of Guckel Ring

Figure 50 shows the element with its two layers represented by different colors. The origin of the element is located at the center of the ring with the maximum radius.

5.8 Multilayer Pad Element (MPE)

Description: The script generates a Multilayer Pad Element.
The MPE implements the standard bonding pad. It has a stack of layers electrically connected layers.
Bonding pads are the regions where the electrical bonding wires are interconnected for wafer probe or wire bond purposes.

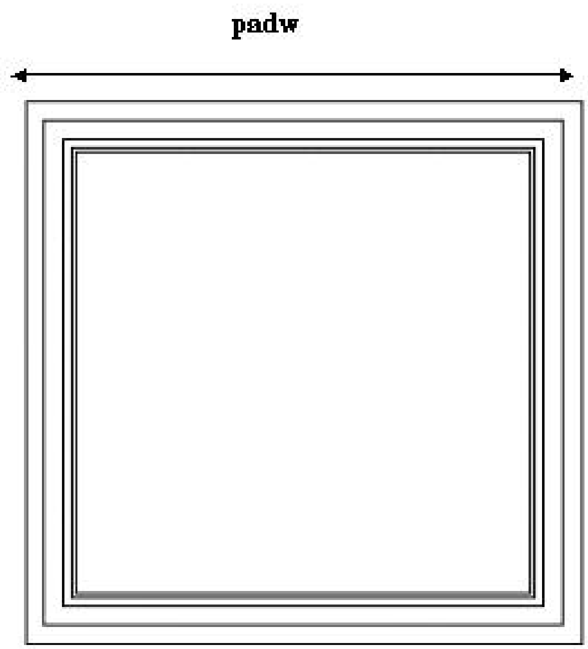


Figure 51 Multilayer Pad Element with parameters

Function Name: MPE

```
call MPE (padw)
```

The table below describes the various components of the MultiLayer Pad Element drawn on multiple layers:

Serial Number	Layer number Variable	Sample value
1	Lp1	1
2	Lp2	2
3	Lp3	3
4	Lp4	4
5	Lp5	5
6	Lp6	6

Table 51 Layer details

Lp1 to Lp6 are the layer numbers of the 6 layers of the element.

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	padw	Width of the exterior most pad	118 µm
*2	Width of 2 to 6 layers		

Table 52 List of parameters

*The width of the subsequent 5 inner layers is calculated as per MUMPS standard.

The next figure shows the MPE with the sample dimensions as shown in Table 52, generated in IntelliMask.

Error! Objects cannot be created from editing field codes.

Figure 52 Multilayer Pad Element

The above figure shows a multilayered mask layout wherein each of the 6 layers is represented by a different color. The layers 2 and 4, being overlapped by layers 3 and 5 respectively are not visible. The origin for the element is located at the lower left corner of the exterior most pad.

5.9 Rectangular Coil

Description: The script generates a rectangular coil element. This element can be used for generating electrical and magnetic elements for applications such as inductors and resistors.

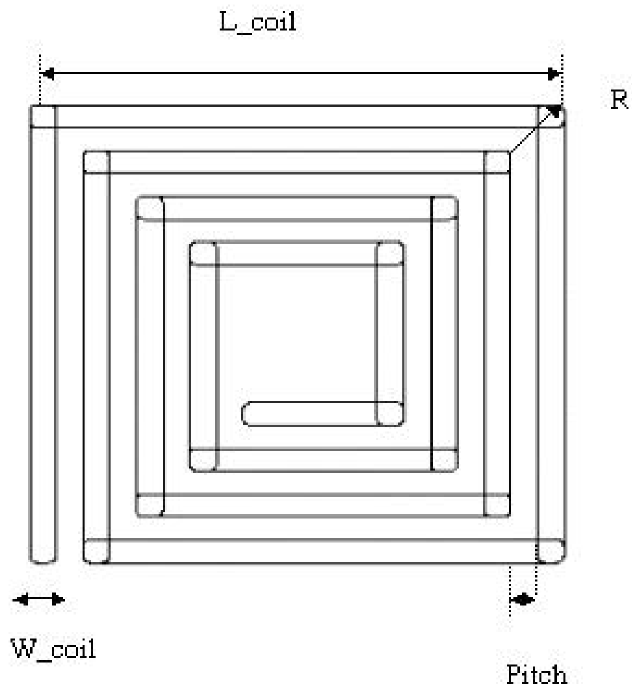


Figure 53 Coil with parameters

Function Name: coil

```
call coil (L_coil, w_coil ,n, pitch, R)
```

The table below gives the layer number variable of the coil drawn:

Serial Number	Layer number Variable	Description	Sample Values
1	Layer_coil	layer to draw the coil	7

Table 53 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_coil	Outer length of the coil	200 µm
2	w_coil	Width of the coil strand	10 µm
3	n	Number of turns of the coil	4
4	pitch	pitch of the coil	10 µm
5	R	curvature of the coil corners	3 µm

Table 54 List of Parameters

Figure 54 shows the coil structure with the sample dimensions as shown in Table 54, generated in IntelliMask.

Error! Objects cannot be created from editing field codes.

Figure 54 Coil

The mask is drawn considering the origin at the lower left corner as the starting point.

6 MEMS Stress Elements

6.1 *Bent Beam*

Description: The script generates the Bent Beam Element.

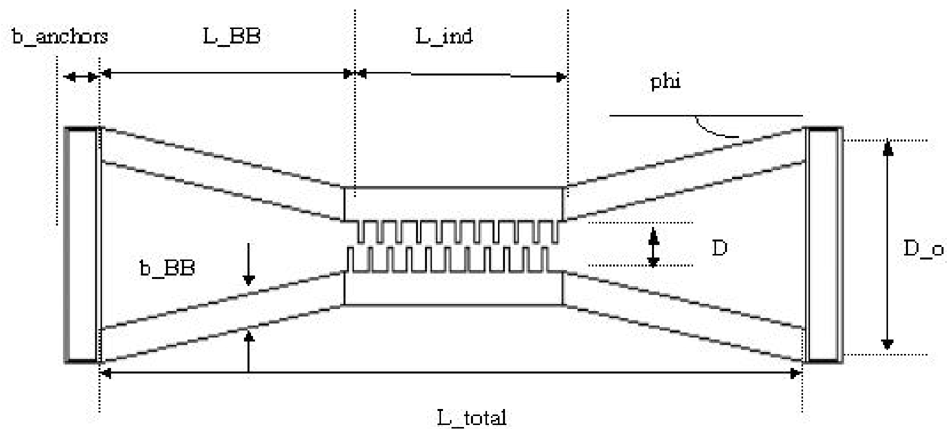


Figure 55 Bent Beam with parameters

Function Name: Bent_Beam

```
   Call Bent_Beam (L_total, L_BB, b_BB, phi, D_o, D,
L_ind, t1, l1, b_anchors)
```

The table below describes the various components of the Bent Beam Element drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample Value
1	La	Layer number of anchor	6
2	Lb	Layer number of Beam	4

Table 55 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Sample Values
*1	L_total	Total length of beams	
2	L_BB	Length of bent beam	100μm
3	b_BB	Width of bent beam	10μm
*4	phi	Bent angle	10 degrees
*5	D_o	Distance between beams	
6	D	Distance between verniers	15 μm
*7	L_ind	Length of verniers	
8	t1	Width of vernier fingers	2 μm
9	l1	Length of vernier fingers	7 μm
10	b_anchors	Width of anchors	15 μm
11	nfingers	Number of fingers	11
12	airgap	Gap between fingers	2 μm
*13	overlap	Overlap in vernier fingers	

Table 56 List of Parameters

*Note
1. L_total is calculated using length of bent beam (L_BB) and length of verniers (L_ind).
2. D_o is calculated using length of bent beam (L_BB) and phi.
3. L_ind is calculated using width of vernier fingers (t1), number of fingers (nfingers) and airgap.
4. overlap is calculated using distance between verniers and length of vernier fingers.

The bent beam is shown in the figure below as generated in IntelliMask using the dimensions as specified in Table 56.

Error! Objects cannot be created from editing field codes.

Figure 56 Bent Beam

The figure shows the mask layout wherein each of the two layers is represented by a different color. The mask is drawn considering the origin as the starting point.

6.2 *Vernier Frame*

Description: This script generates a Vernier Frame element.
It is a measuring instrument consisting of L-shaped frames with a vernier scale at its one end and a horizontal pointer arm supported by two vertical arms.

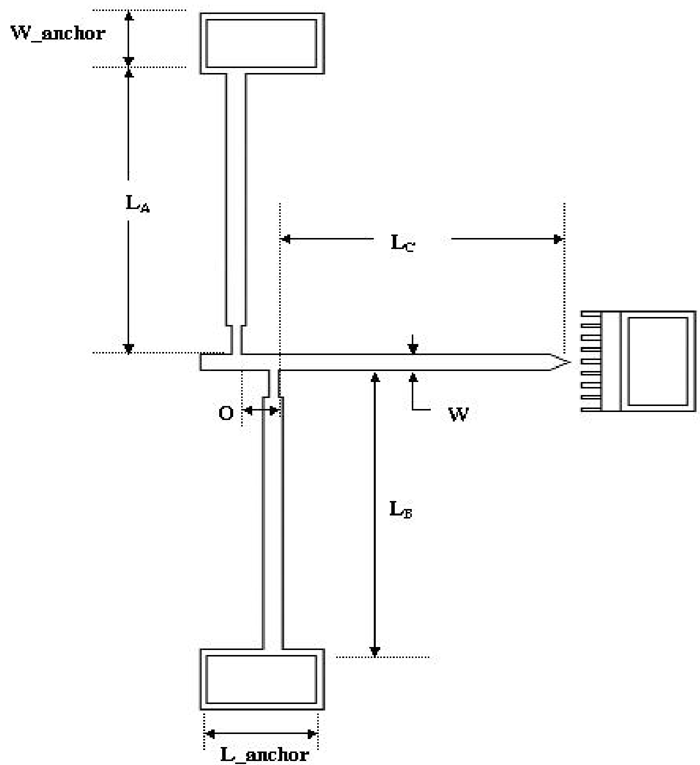


Figure 57 Vernier Frame with parameters

Function Name: Vernier_Frame

```
call Vernier_Frame (W_anchor, L_anchor, Frame_thickness,
w_vernier, l_vernier, La, Lb, Lc, W, O, n)
```

The table below describes the various layered components of the Vernier Frame drawn on multiple layers:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_structure	Layer on which structures are drawn	5
2	Layer_anchors	Layer on which anchors are drawn	6

Table 57 Layer details

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	W_anchor	Width of anchor regions	30 μm
2	L_anchor	Length of anchor regions	50 μm
3	Frame_thickness	Thickness of the frame around the anchors	2 μm
4	w_vernier	Width of vernier fingers	2 μm
5	l_vernier	Length of vernier fingers	8 μm
6	La	Length of beam	140 μm
7	Lb	Length of beam	140 μm
8	Lc	Length of beam	120 μm
9	W	Width of beams	5 μm
10	O	Gap between vertical beams	15 μm
11	n	Number of vernier fingers	9
12	G_pv	Gap between pointer and vernier frame	5 μm

Table 58 List of Parameters

The next figure below depicts the Vernier Frame as viewed in Intellimask with the sample dimensions shown in Table 58.

Error! Objects cannot be created from editing field codes.

Figure 58 Vernier Frame

The figure shows a multilayered mask layout wherein each layer is represented by a different color. The origin is located at lower-left end of the horizontal beam.

7 Miscellaneous MEMS Elements

7.1 *Meter*

Description:
This script generates a meter stick. It consists of a structural layer with a rectangle, which is notched at one side at regular intervals. It can be mounted directly on the device surface to find for example the distance moved by an actuator. Thus is basically a measurement element.

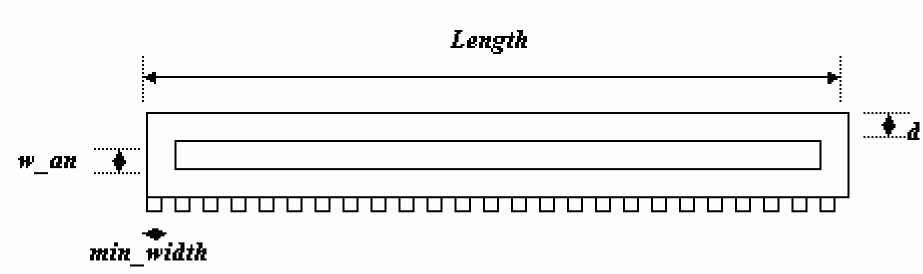


Figure 59 Meter with parameters illustrated

Table 59 describes the Layer Information of the Meter Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_M	Layer number to draw Meter	0
2	L_a	Layer number to draw Anchor	1

Table 59 Layer details

Table 60 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	Length	Length of Meter	100µm
2	min_width	The Distance between consecutive markings	2µm
3	w_an	The width of anchor	4µm
4	d	The distance of anchor	4µm

		from each edge	
5	N	Number of markings	110µm

Table 60 List of parameters

Note: N is calculated using the formula, N=Length/(2*min_width)

The figure below shows the Meter Element generated in IntelliMask with the sample dimensions as mentioned in Table 60.

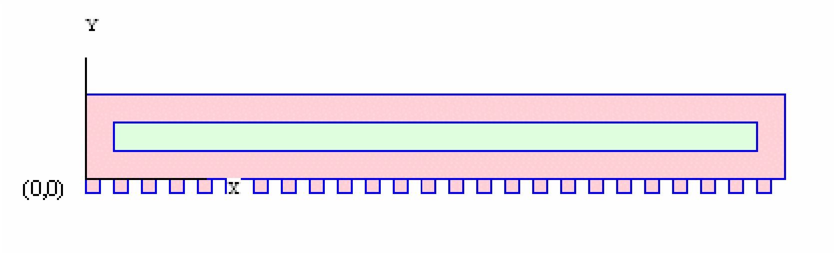


Figure 60 Meter Element

Figure 60 shows a multilayered mask layout wherein each layer is represented by a different color. The origin is located at the Lower Left corner of the rectangle on the notched side.

7.2 *Staple*

Description:
This script generates a staple element. It consists of a single section of structural layer that is anchored at both the ends. Due to the conformal topology of the deposition process, rods underneath the staple can move back forth along their axis. However, they may not necessarily be able to move sideways along the wafer surface.

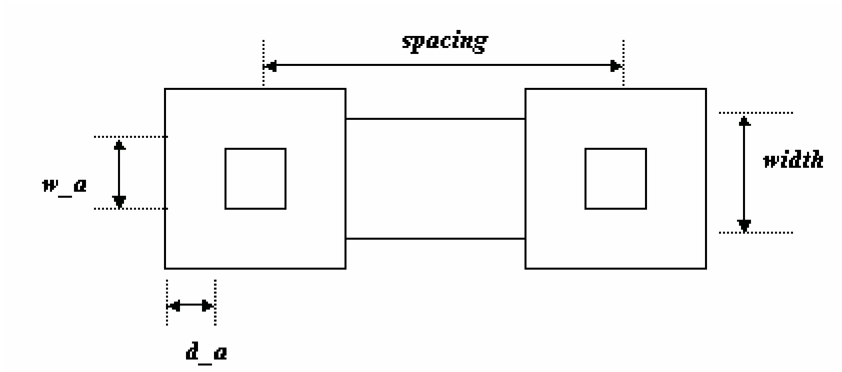


Figure 61 Staple Element Parametric Illustration

Table 61 describes the Layer Information of the Meter Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw staple	4
2	L_a	Layer number to draw Anchor	6

Table 61 Layer details

Table 62 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	width	The width of the bridge connecting the two anchors	10µm
2	space	The distance between the two anchors	30µm
3	w_a	The width of anchor	5µm
4	d_a	The distance of the anchor from edge	5µm

Table 62 List of parameters

The figure below shows the Staple Element generated in IntelliMask with the sample dimensions as mentioned in Table 62

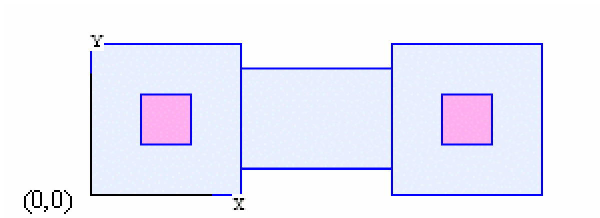


Figure 62 Staple Element

Figure 62 shows a multilayered mask layout wherein each layer is represented by a different color. The origin is located at the Lower Left corner of the structural layer.

7.3 *Bearing*

Description:
This script generates a journal bearing element. It consists of Poly1 and Poly2 layers with the dimples being on another layer (see Fig. 63)
A bearing allows parts to rotate in plane about an axle. This bearing can be used in gears for Power Transmission mechanisms.

Table 63 describes the Layer Information of the Bearing Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_p1	Layer number to draw POLY1	2
2	L_p2	Layer number to draw POLY2	3
3	L_d	Layer number to draw dimples	7

Table 63 Layer details

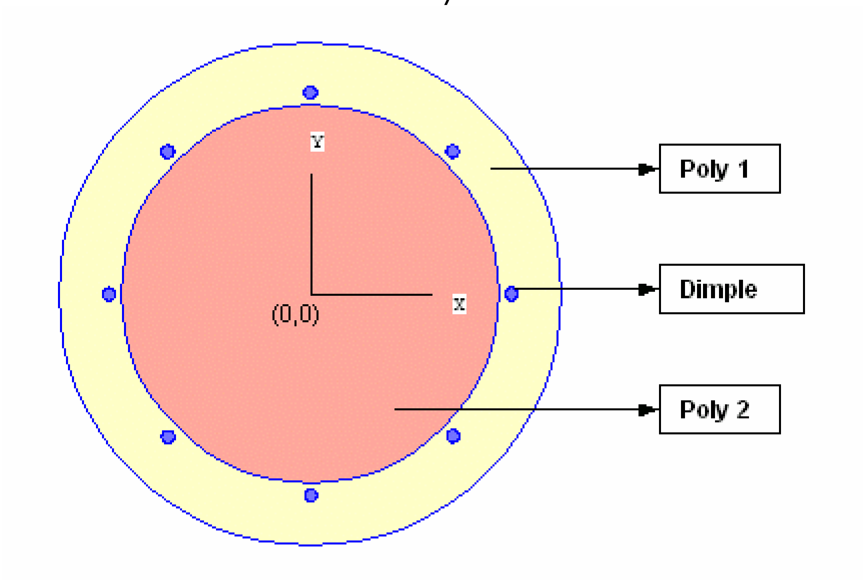


Figure 63 Illustrates the Part and Layer details

Figure 63 shows an IntelliMask generated multilayered mask with the Layer details and for the sample values given in table 64.

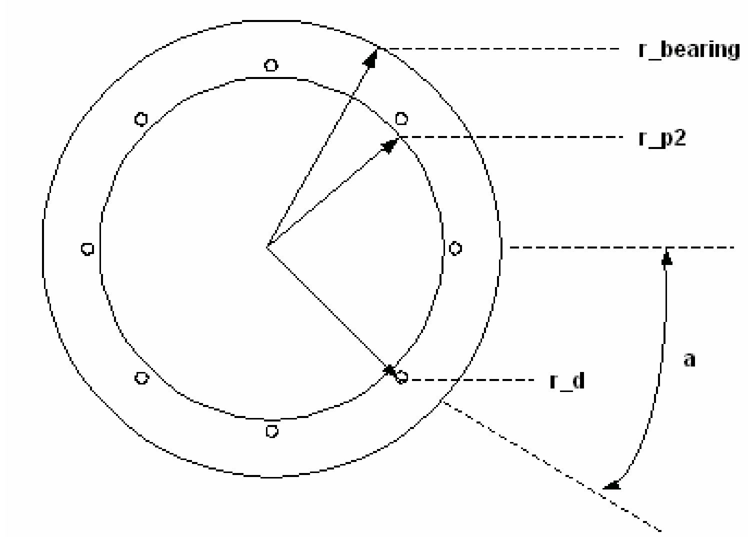


Figure 64 Bearing Element with Parameters

The table below gives the list of parameters required to generate this element:

Serial Number	**Parameter**	**Description**	**Dimensions used as sample**
1	r_bearing	Radius of the bearing	40 µm
2	r_p2	Radius of the POLY2 Layer	30 µm
3	r_d	Radial distance from center of the bearing to center of the dimples	32 µm
4	d_w	Width of the square dimples	2 µm
5	d_r	Radius of the round dimples	1 µm
6	dimple_type	Type of Dimple, Square or Round	0 µm
7	a	Angle between consecutive dimples	45 µm
8	n	Number of dimples	

Table 64 List of Parameters

Note: n is calculated using the formula, n=360/a

7.4 *Vertical Support*

Description:
This script generates part of a vertical support structure used to construct free-standing devices. It implements the bulk of the flap. However to complete the vertical support, staples hinges need to be attached to the base.

Table 65 describes the Layer Information of the Vertical Support:

Serial Number	Layer number Variable	Description	Sample value
1	L_VS	Layer number to draw the vertical support	2
2	L_d	Layer number to draw dimple	3

Table 65 Layer details

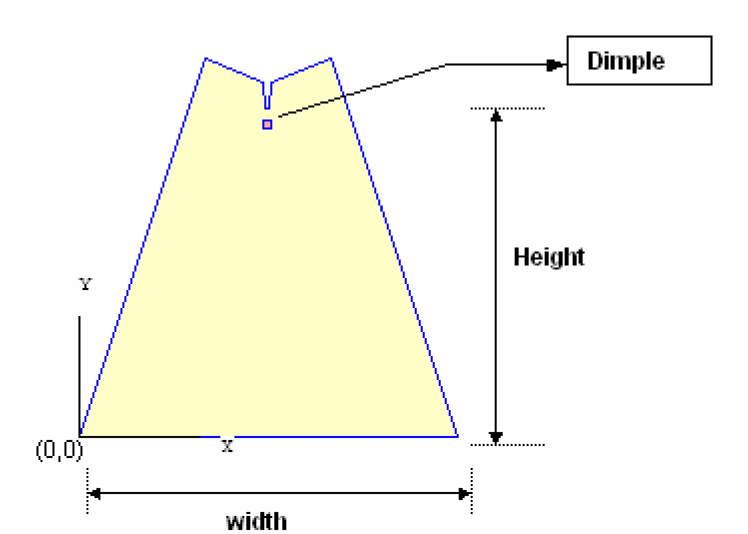


Figure 65 Part and Layer details

Figure 65 shows an IntelliMask generated multilayered mask with the Layer details and for the sample values given in Table 66.
The origin lies on the Lower Left corner of the structure. The overall dimensions are shown in figure 65, while the other parameters are described in Figure 66.

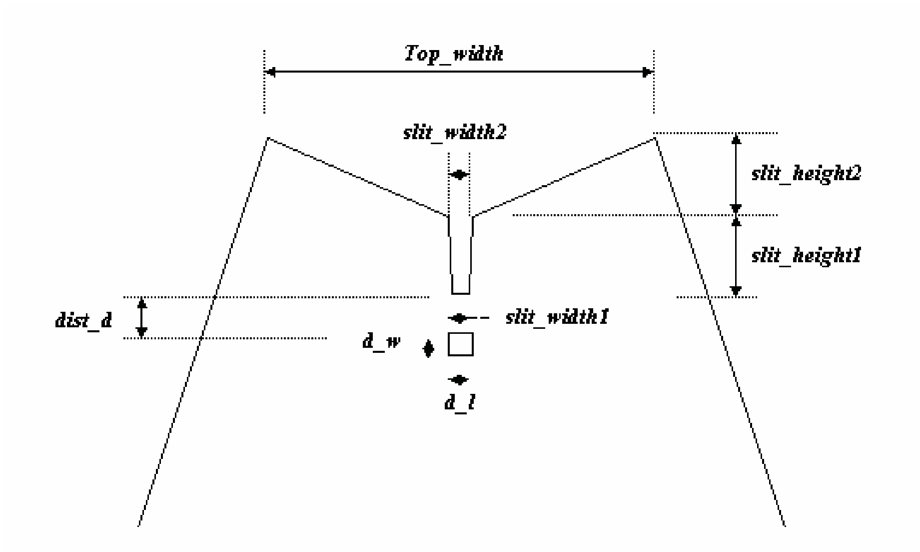


Figure 66 Vertical Support, Parameters of Top Portion (Zoomed In)

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	Height	The distance from the base of the vertical support to the bottom of the slit	130 µm
2	Width	The width of the vertical support at the base	150 µm
3	slit_width1	Width of the slit at the deepest part	2 µm
4	slit_width2	The width of the slit at the upper end	3 µm
5	Top_width	The width of the absolute top of the support	50 µm
6	slit_height1	The height of the slit from the deepest part to the middle	10 µm
7	slit_height2	The height of the slit from the middle to the absolute top of the support	10 µm
8	dist_d	The distance of the dimple from bottom part of the slit	5 µm
9	d_l	The length of the dimple	2 µm
10	d_w	The width of the dimple	2 µm

11	d_r	The radius of dimple	1 µm
12	dimple_type	Type of Dimple, Square or Round	1 µm

Table 66 List of Parameters

7.5 Capacitor

Description:
This script generates the mask layout for a simple parallel plate capacitor. It consists of a top plate with etched holes

Table 67 describes the Layer Information of the Capacitor:

Serial Number	Layer number Variable	Description	Sample value
1	L_gnd	Layer number to draw bottom plate	0
2	L_p	Layer number to draw perforated Top plate	1
3	L_ml	Layer number to draw metal layer	2
4	L_a	Layer number to draw anchors	3

Table 67 Layer details

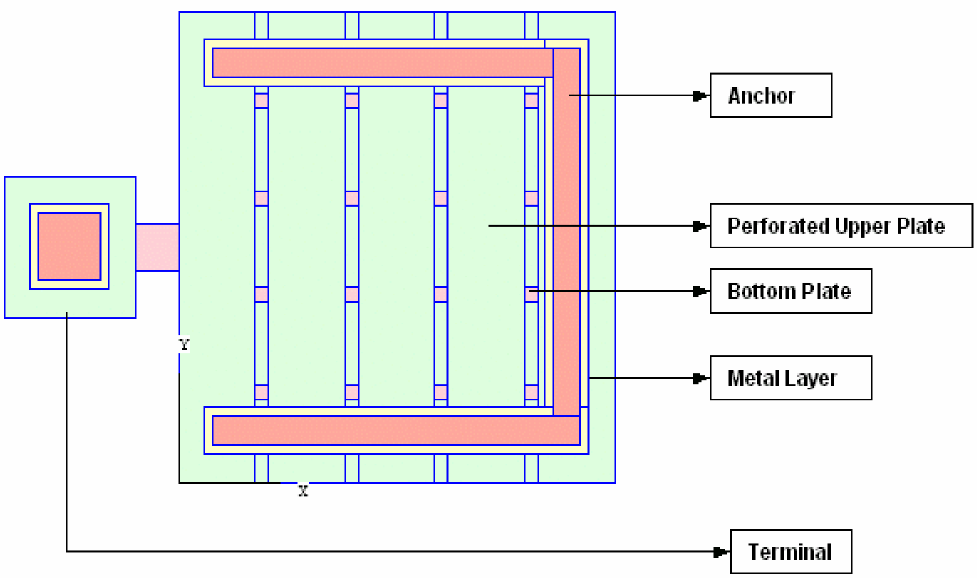


Figure 67 Part and Layer details of Capacitor

Figure 67 shows the multilayered mask for the sample values given in Table 68.

The origin lies on the Lower Left corner of the bottom plate. The various parts of the capacitor structure are shown above.

Part Desription:
For parametric description of the Perforated upper plate, refer the *Perforated Rectangular Plate element* (Element 4.6).
The other parameters are described in the figure below:

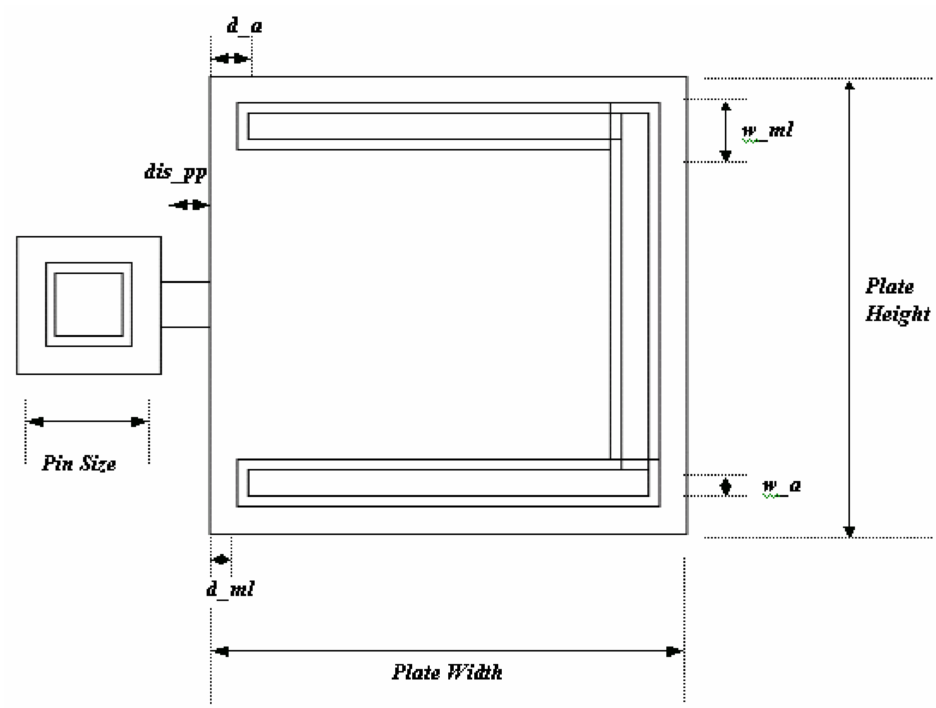


Figure 68 Parameters of Capacitor Element

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	Plate_width	The Width of the Capacitor plate	100 µm
2	Plate_height	The Height of the Capacitor plate	100 µm
3	n_rows	The Number of perforations in a row of the upper plate	4
4	n_columns	The Number of perforations in a column of the upper plate	4
5	hole_width	Width of the perforation of the	3 µm

		upper plate	
6	hole_height	Height of the perforation of the upper plate	3 μm
7	pin_size	The side length of the terminal	30 μm
8	w_ml	The width of metal layer	10 μm
9	w_a	The width of the anchor	6 μm
10	d_ml	The distance of metal layer from plate edge	6 μm
11	d_a	The distance of anchor from plate edge	8 μm
12	dis_pp	The distance between capacitor plate and pin	10 μm

Table 68 List of Parameters

8 Beam and Truss Elements

8.1 *Perforated Rectangular Beam*

Description:
This script generates the mask layout for a Rectangular Perforated Beam. It consists of horizontal and vertical beams connected together with perforations.
This element can be used as a component in the construction of other MEMS like Accelerometers and Gyroscopes.

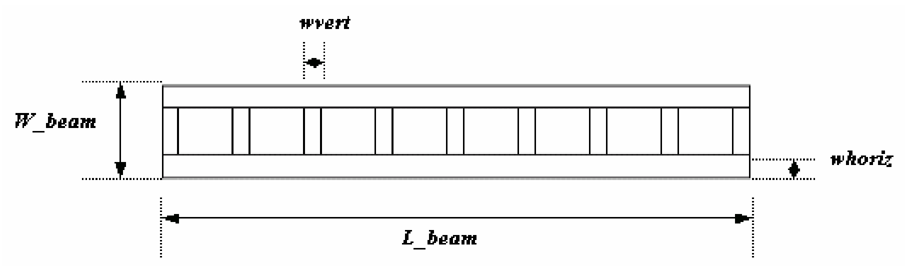


Figure 69 Perforated Beam Element Parametric Illustration

Table 69 describes the Layer Information of the Perforated Beam:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_beam	Layer number to draw perforated beam	7

Table 69 Layer details

Table 70 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_beam	Length of the perforated beam	110 µm
2	W_beam	Width of the perforated beam	20 µm
3	whoriz	Width of the horizontal truss	5 µm
4	wvert	Width of vertical truss	3 µm
5	N	Number of perforations in the beam	8 µm
6	wper	Width of each perforaion	

Table 70 List of Parameters

Note: wper is calculated using the formula,   wper = (L_beam-((N+1)*wvert))/N

The figure below shows the Perforated Beam generated in IntelliMask with the sample dimensions as mentioned in Table 70

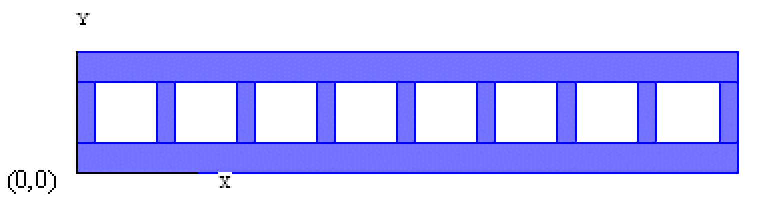


Figure 70 Perforated Beam Element

Figure 70 shows the single layered layout of the perforated rectangular beam. The origin is located at the Lower Left corner of the Beam.

8.2 *Rectangular Perforated Truss Element*

Description:
This script generates the mask layout for a Rectangular Perforated Truss element. It consists of a rigid framework of cross bars connected together with perforations.
This element can be used as a support member in the construction of other MEMS like Accelerometers and Gyroscopes.

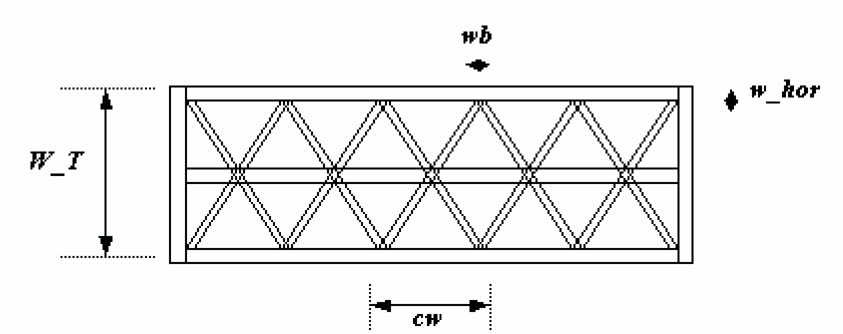


Figure 71 Rectangular Truss Element Parametric Illustration

Table 71 describes the Layer Information of the Perforated Beam:

Serial Number	Layer number Variable	Description	Sample value
1	L_T	Layer number to draw Truss element	7

Table 71 Layer details

Table 72 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	wb	Beam width (The width of each cross beam)	5 μm
2	cw	The width of each cross	60 μm
3	w_hor	The width of horizontal bar	8 μm
4	W_T	Total width of Truss Element	100 μm
5	N	Number of crosses	15

Table 72 List of Parameters

The figure below shows the single layered Perforated Truss Element generated in IntelliMask with the sample dimensions as mentioned in Table 72

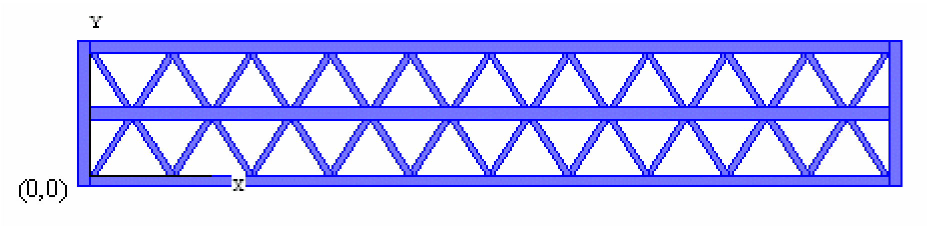


Figure 72 Rectangular Truss Element

Figure 72 shows the layout of the perforated rectangular Truss. The origin is located at the Lower Left corner of the Beam.

8.3 *Diamond Truss Element*

Description:
This script generates the mask layout for a Diamond Truss element. It consists of a rigid framework of cross bars connected together.
This element can be used in the construction of other MEMS like Accelerometers and Gyroscopes.

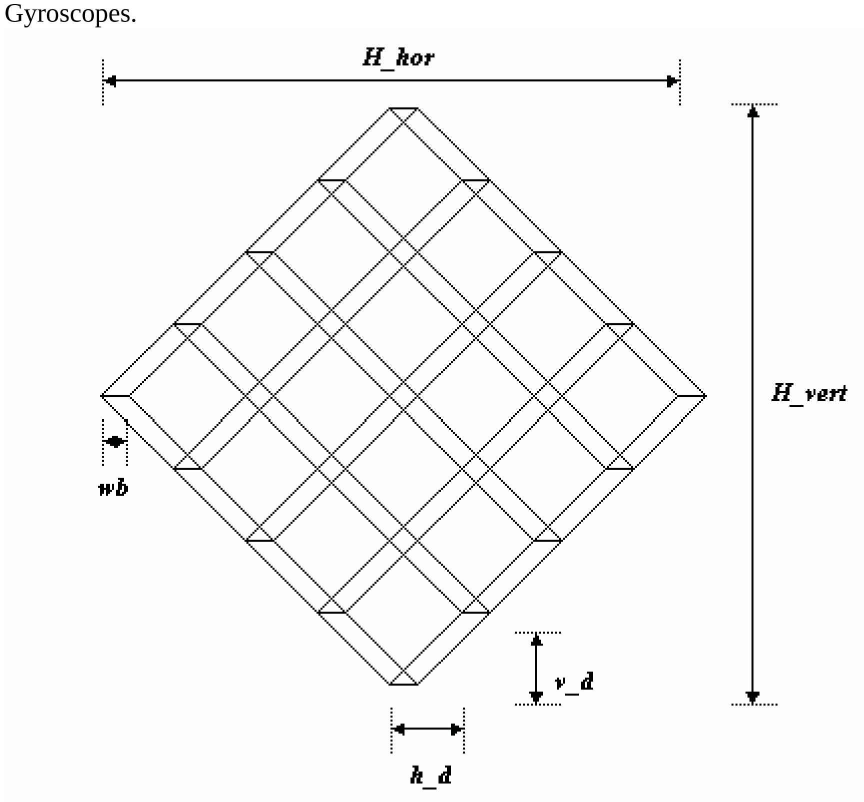


Figure 73 Diamond Truss Element Parametric Illustration

Table 73 describes the Layer Information of the Perforated Beam:

Serial Number	Layer number Variable	Description	Sample value
1	L_T	Layer number to draw Truss element	7

Table 73 Layer details

Table 74 lists the parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	wb	The Width of beam along x-axis	4 µm
2	h_d	The horizontal distance between consecutive beams	10 µm
3	v_d	The vertical distance between consecutive beams	10 µm
4	H_hor	The total horizontal height of the Diamond Truss	
5	H_vert	The total vertical height of the Diamond Truss	
6	N	Number of beams	10

Table 74 List of Parameters

Note:
H_hor is calculated using the formula, H_hor = ((2*N)-2)*(h_d)+wb
H_vert is calculated using the formula H_vert = ((2*N)-2)*(v_d)

The figure below shows the Diamond Truss generated in IntelliMask with the sample dimensions as mentioned in Table 74

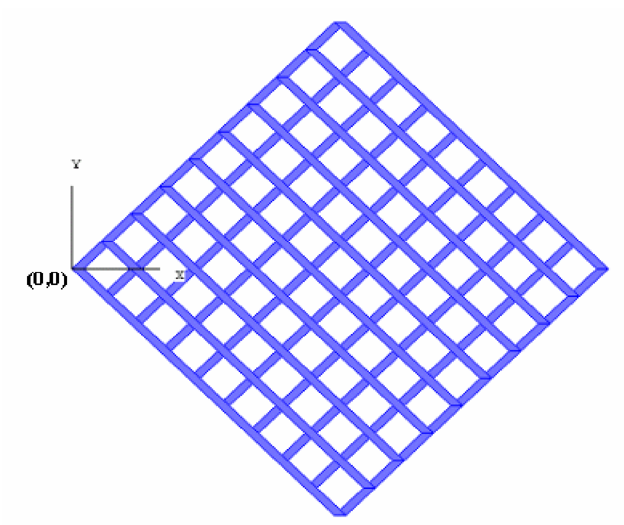


Figure 74 Diamond Truss Element

The above figure shows the layout of the Diamond Truss. The origin is located at the Left centre of the Truss Element. The element shown has 10 beams across in both the directions.

9 Heatuators

9.1 *Bi-Morph*

Description:
This script generates the mask layout for a bi-morph. This is a U-shaped thermal actuator that uses differential thermal expansion to achieve motion along the wafer surface. This actuator implements the Joule Heating Principle When a voltage is applied to the terminals, current flows through the device. However, because of the different widths, the current density is unequal in the two arms. This leads to a different rate of Joule heating in the two arms, and thus to different amounts of thermal expansion.
Table 75 gives the Layer details and Figure 75 shows the part details of this actuator.

Table 75 describes the Layer Information of the Bi-Morph:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw bi-morph	5
2	L_a	Layer number to draw anchor	6
3	L_d	Layer number to draw dimples	7

Table 75 Layer details

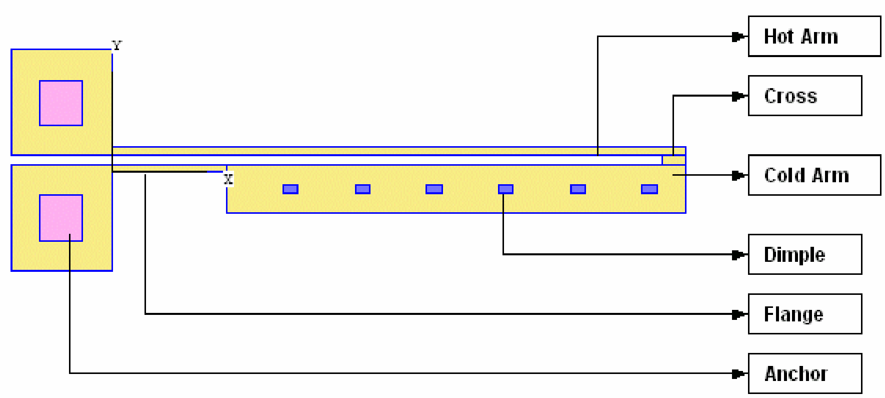


Figure 75 Layer and Part details

Figure 75 shows an IntelliMask generated multilayered mask with the Layer details and for the sample values given in in Table 76.
The origin lies on the Lower Left corner of the flange.

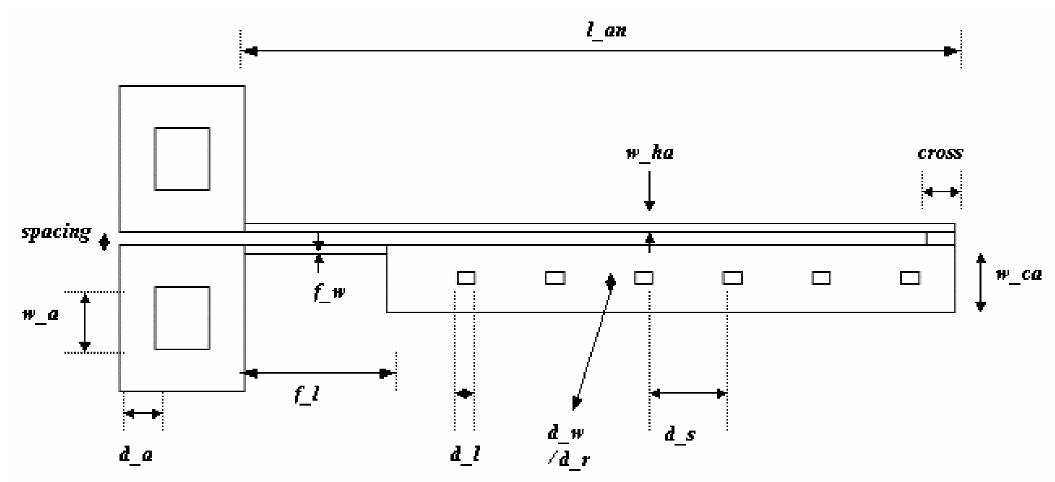


Figure 75 Bi-Morph Element Parametric Illustration

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L	Length from the terminals to the end of actuator	200 µm
2	f_l	Length of flange	40 µm
3	f_w	width of flange	2 µm
4	spacing	space between hot-arm and cold-arm	3 µm
5	w_ca	width of wide part of cold-arm	16 µm
6	w_ha	width of hot-arm	2 µm
7	w_a	width of anchor	15 µm
8	d_a	distance of anchor from edge of frame	10 µm
9	cross	width of the part connecting the hot-arm and cold-arm	8 µm
10	d_s	spacing between dimples	20 µm
11	d_r	radius of dimple	2 µm
12	d_l	length of rectangular dimple	5 µm
13	d_w	width of rectangular dimple	3 µm
14	N	Number of dimples	6

15	dimple_type	type of dimple, Round or Rectangle	1 µm

Table 76 List of parameters

Note:
For round dimple enter dimple_type = 0
For rectangular dimple enter dimple_type = 1

9.2 *Multi Bi-Morph*

Description:
This script generates the mask layout for an array of *bi-morph elements*.
The array of bi-morphs are linked together using a connector. The array can be used to provide larger displacements in comparison to the single bi-morph element.

Table 77 gives the Layer details and Figure 77 shows the Layer details of the multilayered Bi-Morph array as generated in IntelliMask

Table 77 describes the Layer Information of the Multi Bi-Morph :

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw bi-morphs	5
2	L_a	Layer number to draw anchor	6
3	L_d	Layer number to draw dimples	7

Table 77 Layer details

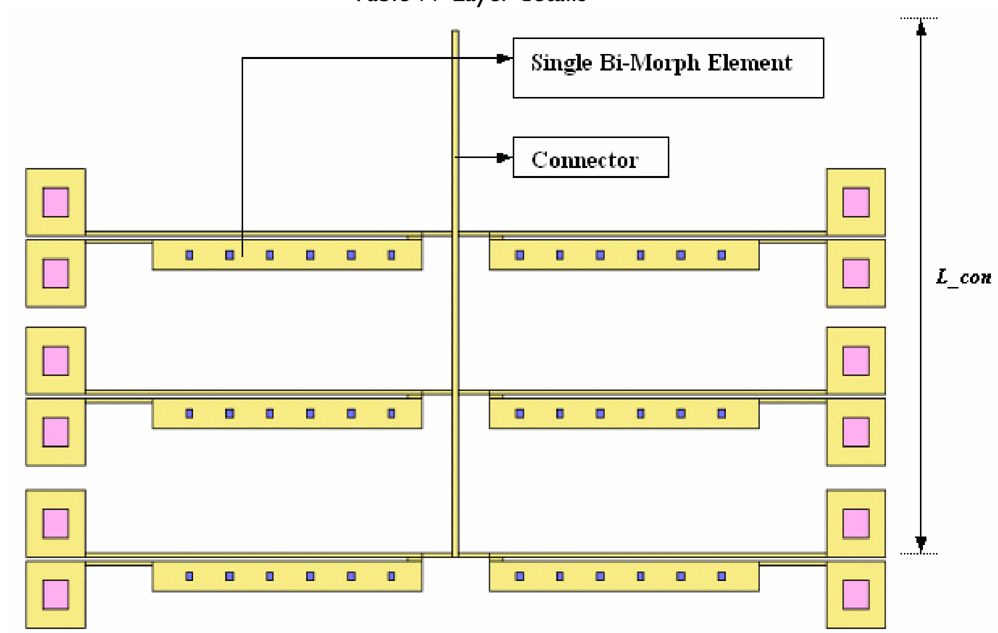


Figure 77 Layer and Part details of Multi Bi-Morph

Figure 77 shows an array of 3 bi-morphs on each side of the central connector as generated in IntelliMask for the sample values given in Table 76 and Table 78.

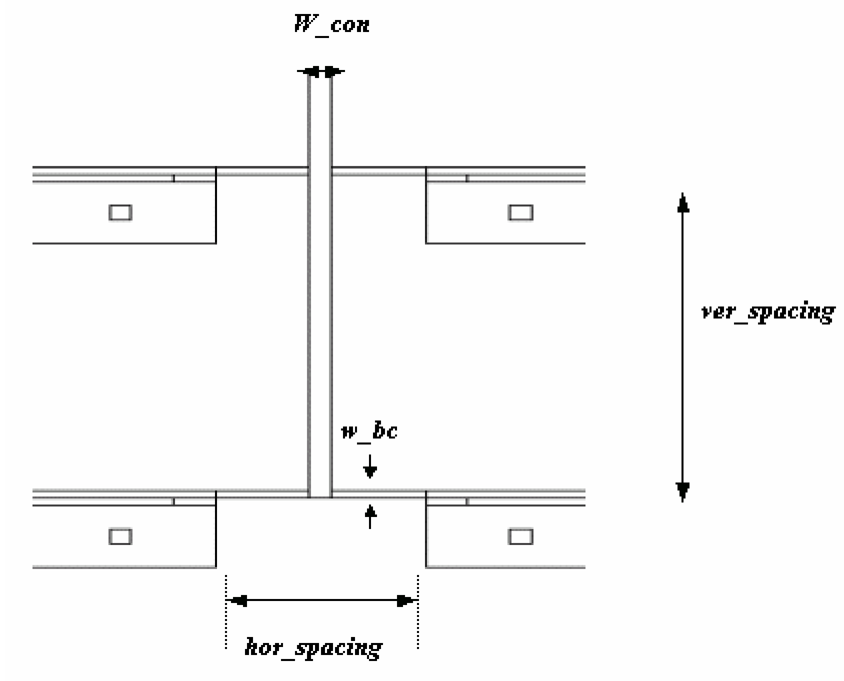


Figure 78 dimensions of the connector of the Multi Bi-Morph

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	hor_spacing	horizontal spacing between bi-morphs (tip to tip), along the x-direction	40 µm
2	ver_spacing	vertical spacing between bi-morphs, along the y-direction	85 µm
3	w_con	width of connector	4 µm
4	L_con	length of connector	350 µm
5	w_bc	width of element connecting bi-morph to connector	2 µm
6	M	No of bi-Morphs	4

Table 78 List of parameters

Note: Refer the *Bi-Morph element* for list of the other parameters.

9.3 *Vertical Heatuator*

Description:
This script generates the mask layout for an array of *a vertical heatuator*.
This is a thermal actuator that uses differential thermal expansion similar to the horizontal heatuator but achieves motion in the direction perpendicular to the wafer surface. When a voltage is applied to the terminals, current flows through the device. However, because of the different widths, the current density is unequal in the two arms. This leads to a different rate of Joule heating in the two arms, and thus to different amounts of thermal expansion.
Table 79 gives the Layer details and Figure 79 shows the part details of the vertical thermal actuator.

Table 79 describes the Layer Information of the Vertical Heatuator:

Serial Number	Layer number Variable	Description	Sample value
1	L_p1	Layer number to draw POLY1	1
2	L_p2	Layer number to draw POLY2	2
3	L_ml	Layer number to draw metal	3
4	L_d	Layer number to draw dimples	4

Table 79 Layer details

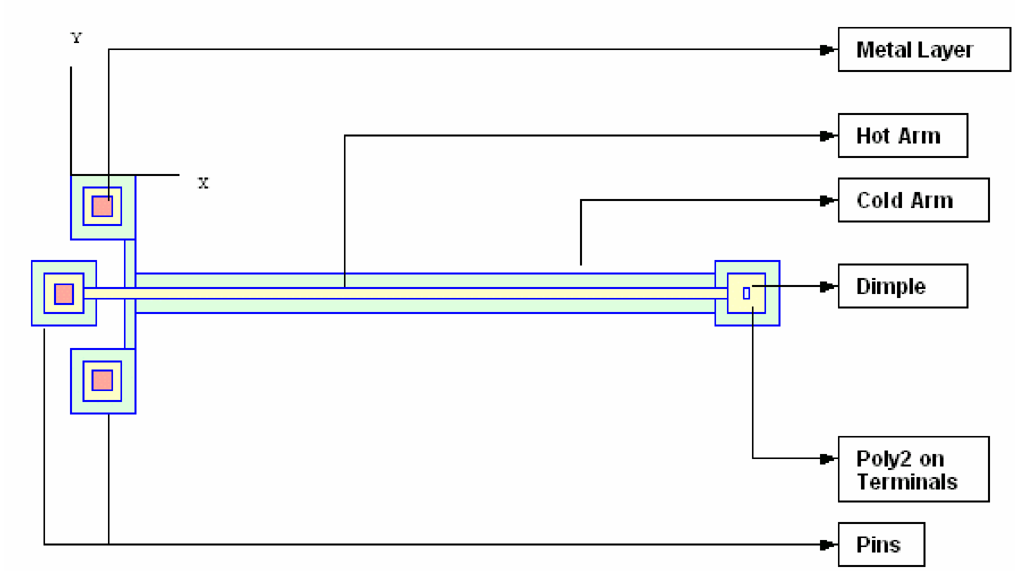


Figure 79 Layer and Part details

Figure 79 shows the multilayered mask with the Layer details and Part details for the sample values given in Table 80.
The origin is located on the Upper Left corner of the Top Terminal.

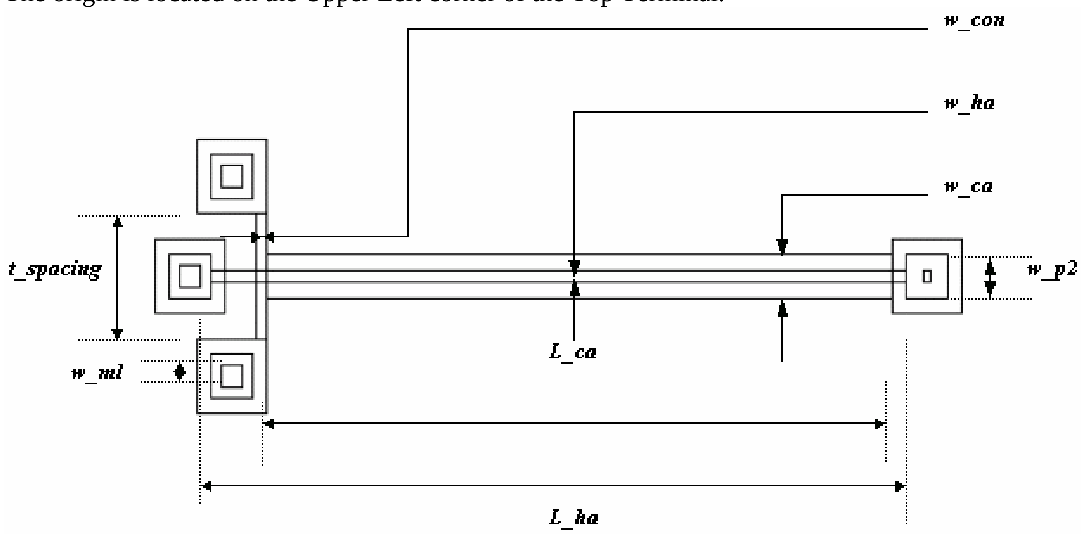


Figure 80 Vertical Heatuator Parameters

The table below gives the list of parameters required to generate this element. :

Serial Number	Parameter	Description	Dimensions used as sample
1	L_ca	Length of the cold arm	180 µm
2	L_ha	Length of the hot arm	200 µm
3	w_ca	width of the cold arm	12 µm
4	w_ha	width of the hot arm	3 µm
5	pin_size	side length of the terminals	20 µm
6	w_p2	width of POLY2 layer on terminals	12 µm
7	w_ml	width of the metal layer on terminals	6 µm
8	d_l	Length of the dimple	2 µm
9	d_w	width of the dimple	3 µm
10	t_spacing	spacing between terminals of the cold arm	34 µm
11	w_con	width of the element connecting the terminals of the cold arm	5 µm

Table 80 List of Parameters

9.4 *Tiptuator*

Description:
This script generates the mask layout for a Tiptuator, which is a thermal in plane actuator similar to the horizontal heatuator.
It consists of bent beams, which is connected to a shuttle at the center and terminals at the ends. See figure 81 for part details. When voltage is applied to the terminals the bent-beams get heated up. To account for the beams expansion, the beam buckles. The buckling motion can be used for actuation.

Table 81 describes the Layer Information of the Tiptuator:

Serial Number	Layer number Variable	Description	Sample value
1	L_t	Layer number to draw Tiptuator structure	3
2	L_ml	Layer number to draw metal Layer	5
3	L_a	Layer number to draw anchors	6
4	L_d	Layer number to draw dimples	7

Table 81 Layer details

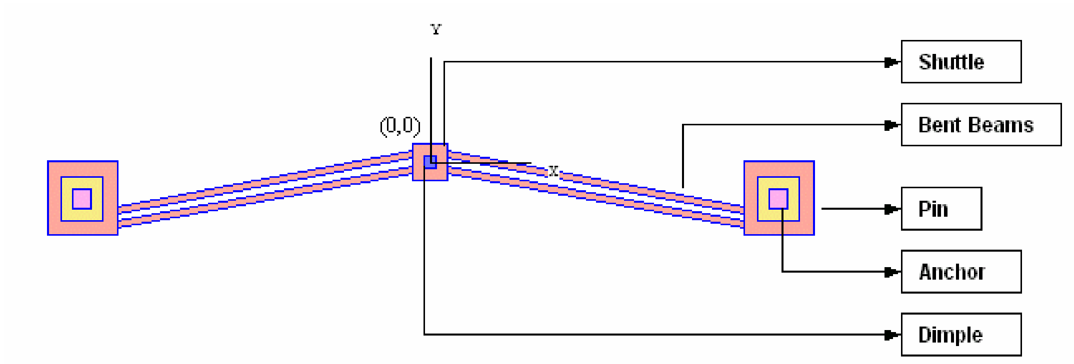


Figure 81 Layer and Part details of Tiptuator

Figure 81 shows the 4 layered mask of the Tiptuator with the Layer details and Part details for the sample values given in Table 82. Here each color represents a layer.
The origin is located at the center of the shuttle member.

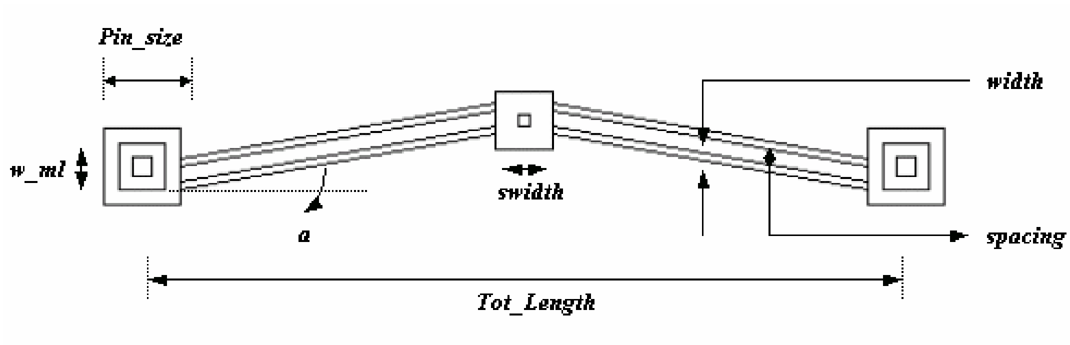


Figure 82 Tiptuator Parameters

The table below gives the list of parameters used to generate the Tiptuator. :

Serial Number	Parameter	Description	Dimensions used as sample
1	Tot_Length	The distance between the beam's anchors	200 µm
2	width	The width of the bent-beams	2 µm
3	spacing	The space between the bent-beams	2 µm
4	swidth	The width of the shuttle, which is the central portion connecting the beams	10 µm
5	dwidth	The width of the dimple	3 µm
6	a	Angle between the a parallel line connecting the beam's anchors and the beam itself	10 degrees
7	pin_size	The width of the terminals	20 µm
8	w_ml	The width of the metal Layer	12 µm
9	w_a	The width of the anchors	5 µm
10	N	The number of beams	2 µm

Table 82 List of Parameters

10 Spring Elements

10.1 *Folded Spring*

10.1.1 Type1a (End Point Anchor)

Description:
This script generates the mask layout for a serpentine spring element.
The spring is implemented as, a number of bars connected on alternating ends at right angles. One end of the spring is anchored to the wafer, while the other end has only a half bar, which may be connected to other structural members say proof-mass.

Table 83 describes the Layer Information of the Folded Spring, Type 1a:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw the folded spring	0
2	L_a	Layer number to draw the anchor	1

Table 83 Layer details

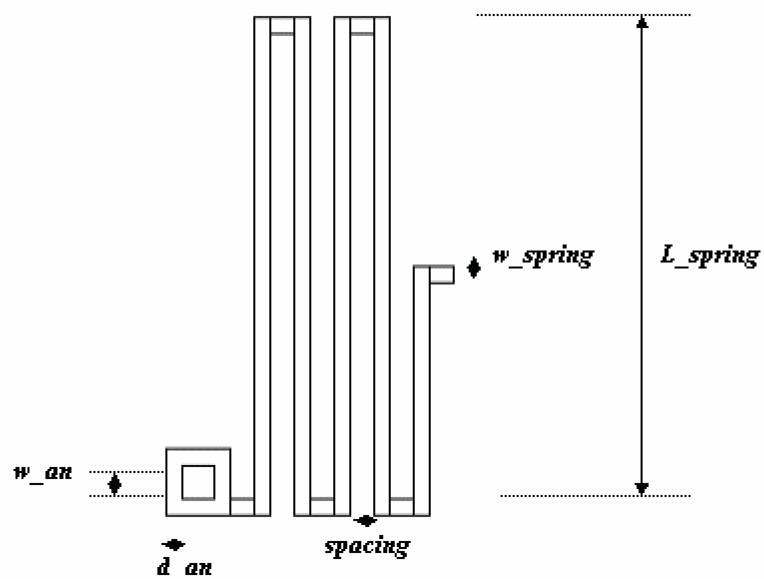


Figure 83 Parameters of the Folded Spring (Type 1a)

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_spring	Length of the spring	500 µm
2	w_spring	Width of the spring	8 µm
3	spacing	The inter-tether spacing	15 µm
4	n_springs	Number of folds of the spring	3.5
5	w_an	Width of the spring anchor	20 µm
6	d_an	Distance of the anchor from frame edge	10 µm

Table 84 List of Parameters

Note: n_springs should be entered in the form of x.5, where x=1,2,3,...as the final bar is only half the total spring length.

Figure 84 shows the Folded Spring element generated in IntelliMask with the sample dimensions shown in Table 84

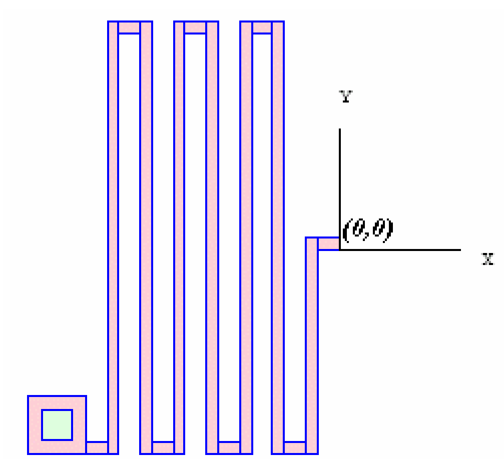


Figure 84 Folded Spring (Type 1a)

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the Right extreme as the starting point.

10.1.2 Type1b (End Point Anchor)

Description:
This script generates the mask layout for a serpentine spring element.
The spring is implemented as, a number of bars connected on alternating ends at right angles. One end of the spring is anchored to the wafer, while the other end may be connected to other structural members say proof-mass.
This spring is different from Type 1a in the fact that the length and width of this spring are orthogonal that of type 1a as evident from figure 84a.

The Layer Information is same as spring type 1a described in *Table 83*.

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_spring	Length of the spring	500 μm
2	w_spring	Width of the spring	8 μm
3	spacing	The inter-tether spacing	15 μm
4	n_springs	Number of folds of the spring	3
5	w_an	Width of the spring anchor	20 μm
6	d_an	Distance of the anchor from frame edge	10 μm

Table 84a List of Parameters

Figure 84a shows the Folded Spring element generated in IntelliMask with the sample dimensions shown in Table 84

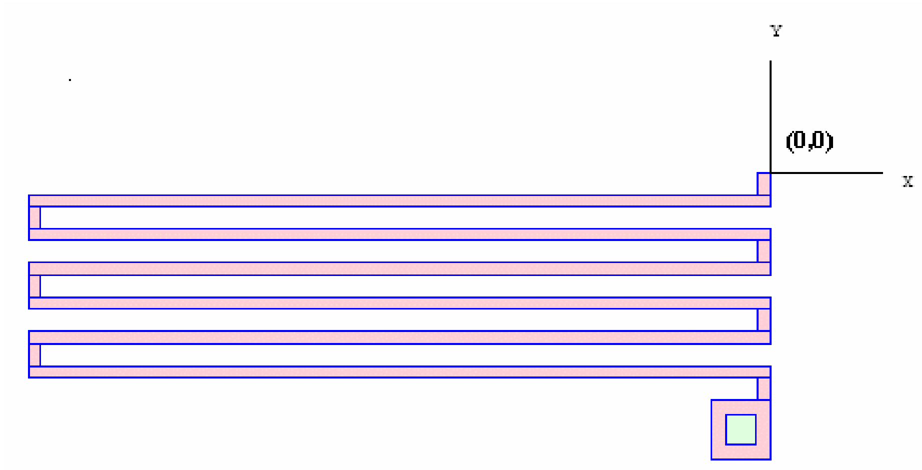


Figure 84a Folded Spring (Type 1b)

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the Right extreme of the springs.

10.1.3 Type2 (Mid Point Anchor)

Description:
This script generates the mask layout for a serpentine spring element with Mid Point Anchor.
One end of the spring with a half bar is anchored to the wafer, while the other end may be connected to other structural members say proof-mass.

The Layer Information is same as *spring type 1a* described in *Table 83*

The List of parameters is also similar to type 1a described in *Table 84*

Figure 84b shows the Type2 Folded Spring element generated in IntelliMask with the sample dimensions given in *Table 84*.

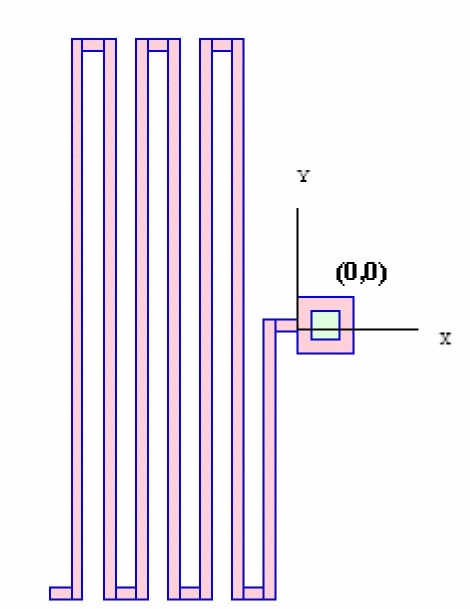


Figure 84b Folded Spring (Type 2)

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the Right extreme of the bars as the starting point.

10.1.4 Double Anchored Spring

Description:
This script generates the mask layout for a double anchored serpentine spring element. The spring is implemented as, a number of bars connected on alternating ends at right angles. The two ends of the spring is anchored to the wafer. There is a central prong dividing the spring into symmetrical halves.
This is a Mid Point anchor type spring.

The Layer Information is same as *spring type 1a* described in *Table 83*.

The table below gives the list of parameters and values required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_spring	Length of the spring	400 µm
2	w_spring	Width of the spring	8 µm
3	spacing	The inter-tether spacing	20 µm
4	n_springs	Number of folds of the spring	2.5
5	w_an	Width of the spring anchor	20 µm
6	d_an	Distance of the anchor from frame edge	10 µm
7	L_prong	Length of the central prong	500
8	w_prong	width of central prong	10 µm

Table 84c List of Parameters

Note: n_springs should be entered in the form of x.5, where x=1,2,3,...as the final bar is only half the total spring length.

Figure 84c shows the Folded Spring element generated in IntelliMask with the sample dimensions given in Table 84c.
The figure also depicts the parameters used to draw the central prong.

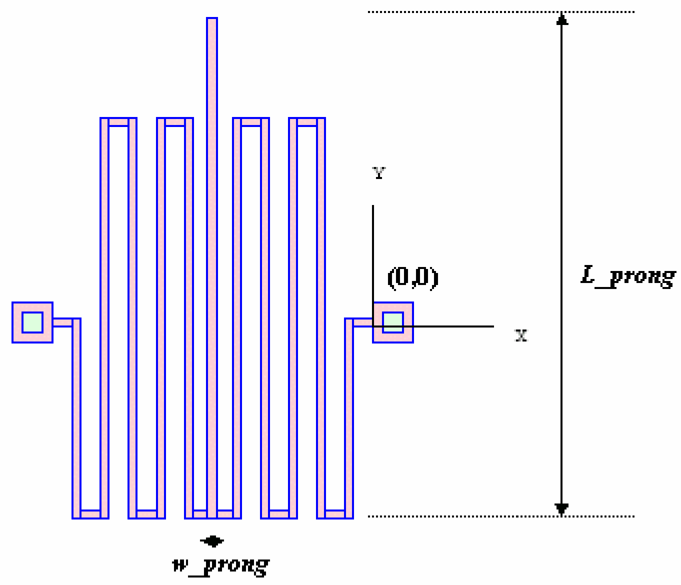


Figure 84c Double Anchored Folded Spring

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the Right extreme of the bars as the starting point.

10.2 *Diagonal Spring*

Description:
This script generates the mask layout for a diagonal spring element.
The spring is implemented as, a number of bars connected on alternating ends at right angles in a diagonal fashion. One end of the spring is anchored to the wafer, while the other end may be connected to other structural members say proof-mass.

Table 85 describes the Layer Information of the Diagonal Spring:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw the diagonal spring	4
2	L_a	Layer number to draw the anchor	5

Table 85 Layer details

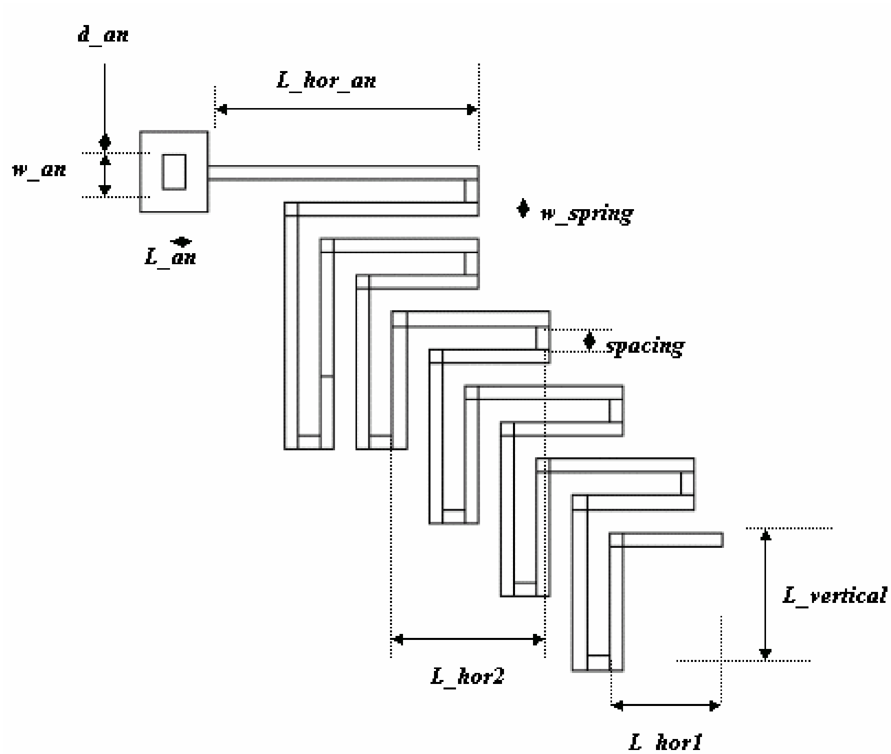


Figure 83 Parameters of the Diagonal Spring

The table below gives the list of parameters required to generate this element:

Serial Numbe r	Parameter	Description	Dimensions used as sample
1	L_hor1	Length of the horizontal component of the spring adjacent to the proof mass	50
2	L_vertical	Length of vertical components of the spring	60
3	L_hor2	Length of other horizontal components of the spring	70
4	L_hor_an	Length of the horizontal component of the spring adjacent to the anchor	120
5	L_an	Length of the anchor	10 µm
6	w_spring	Width of the spring	6 µm
7	spacing	The inter-tether spacing	10 µm
8	n_springs	Number of folds of the spring	10
9	w_an	Width of the spring anchor	15 µm
10	d_an	Distance of the anchor from frame edge	10 µm

Table 86 List of Parameters

Figure 86 shows the Folded Spring element generated in IntelliMask with the sample dimensions shown in Table 86.

The figure shows the two-layered mask layout wherein each layer is represented by a different color. The mask is drawn considering the origin at the Right extreme of the bars as the starting point.

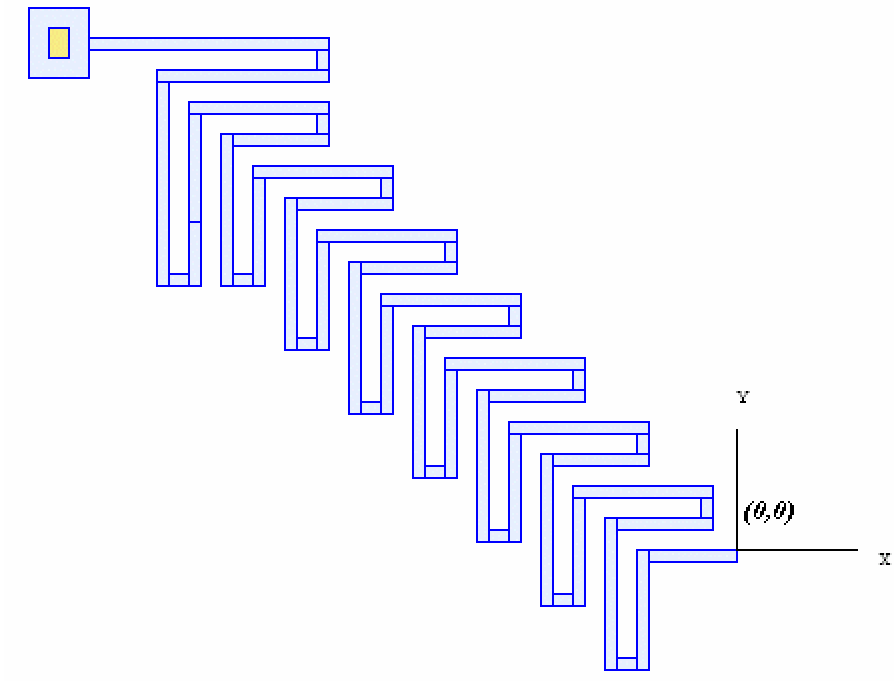


Figure 86 The Diagonal Spring Element

10.3 *Suspension Lobster*

Description:
This script generates a Lobster Suspension Element. A suspension is a spring like element, which is designed to be compliant along its length. However, it is stiff in the perpendicular direction. Linear actuation elements can be connected to the shuttle yokes to create a linear resonator.

Table 87 describes the Layer Information of the Lobster:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw the Suspension Lobster	5
2	L_a	Layer number to draw anchors	7

Table 87 Layer details

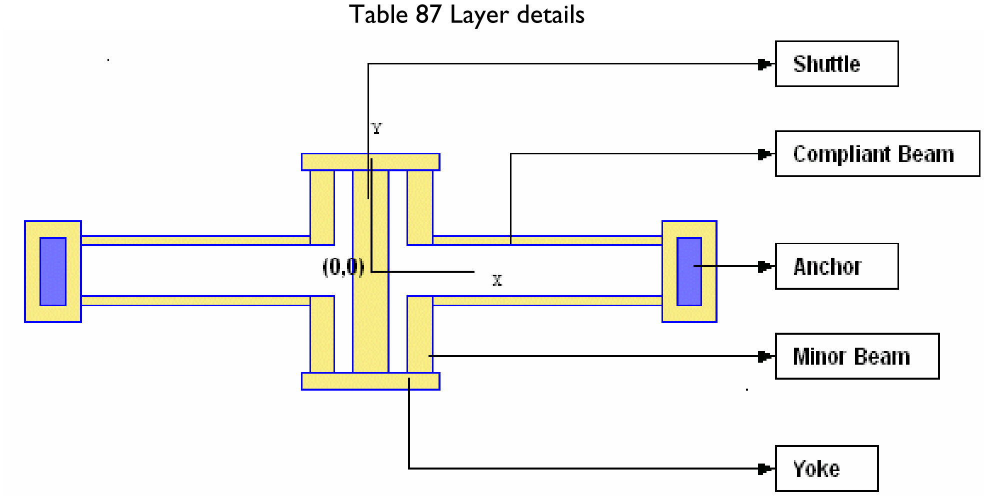


Figure 87 Part and Layer details of Lobster Element

Figure 87 shows the multilayered mask for the sample values given in Table 88. The origin lies at the center of the shuttle. The various parts of the capacitor structure are described above.

The parametric Illustration of the Lobster element is shown below.:

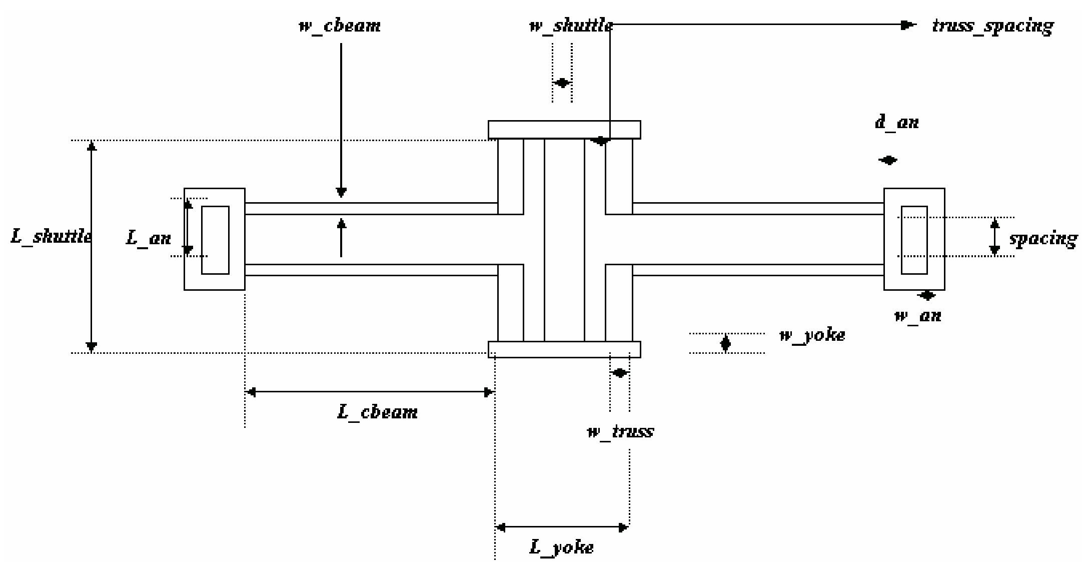


Figure 88 Parameters of Lobster Element

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L_cbeam	Length of compliant the beams	100 µm
2	w_cbeam	width of compliant the beams	3 µm
3	spacing	spacing between compliant beams	15 µm
4	w_truss	width of the minor beams	8 µm
5	truss_spacing	spacing between minor beams and shuttle	6 µm
6	L_shuttle	Length of the shuttle	60 µm
7	w_shuttle	width of the shuttle	12 µm
8	L_yoke	Length of the yoke	45 µm
9	w_yoke	width of the yoke	5 µm
10	w_an	The width of the anchor	8 µm
11	L_an	The Length of the anchor	20 µm
12	d_an	The distance of anchor from the edge of the anchor frame	5 µm

Table 88 List of parameters

11 Inertial Device Elements

11.1 *Comb Drive Resonator*

Description:
This script generates a Linear Comb Drive Resonator Element. It is made of *Linear Comb Drives (Element 2.1)* and *Linear Folded Beam Suspension Element (Element 3.4)*. See figure 89 for the Part Description of the Resonator.

Table 89 describes the Layer Information of the Comb Drive Resonator:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number to draw the Resonator	1
2	Lf	Layer number of fixed comb	2
3	La	Layer number to draw anchors	3

Table 89 Layer details

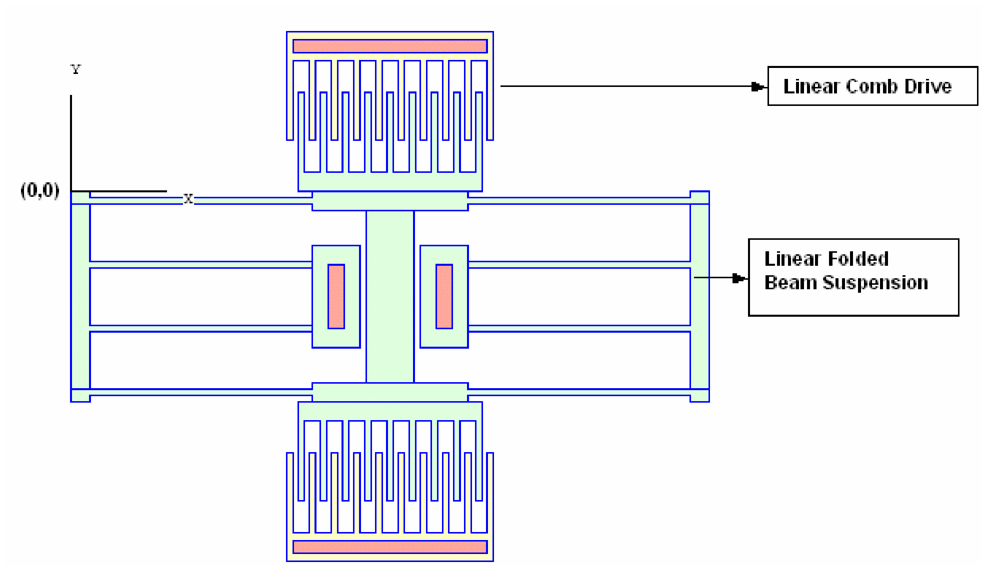


Figure 89 Part and Layer details of Resonator Element

Figure 89 shows the multilayered mask for the sample values given in Table 90. Here each of the 3 layers is represented by a different color.
The origin lies at the Extreme Left of the Linear Folded Beam Suspension Element.

For the parametric Illustration of the Resonator parts please refer.

a) *Linear Comb Drives (Element 2.1)*
b) *Linear Folded Beam Suspension Element (Element 3.4)*

The table below gives the description of parameters required to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Linear Comb Drive			
1	airgap	Air gap between fingers	3µm
2	fwidth	Width of comb fingers	4µm
3	sywidth	Stator yoke width	18µm
4	rywidth	Rotor yoke width	12µm
5	flength	Length of comb fingers	60µm
6	rsoverlap	Stator-rotor finger overlap	30µm
7	numComb	Number of combs of stator	10
8	anwidth	Width of anchors	8µm
Linear Folded Beam Suspension Element			
1	lbeam	Length of the beam	150µm
2	wbeam	Width of the beam	4µm
3	beamsep	separation between the beams	50µm
4	wbar	width of the connecting bar	12µm
5	swidth	width of the shuttle	30µm
6	wanchor	width of the anchor support	10µm
7	Lanchor	Length of the anchor support	40µm
8	d	distance of anchor from the edge	10µm
9	wsyoke	width of the shuttle yoke	12µm

10	lsyoke	Length of the shuttle yoke	98µm

Table 89 List of parameters

11.2 *Transverse Comb Drive Element*

Description:
This script generates a Transverse or Lateral Comb Drive Element. It consists of a movable set of comb fingers attached to the proof mass and anchored set of comb fingers in a closely spaced interdigited fingers manner to provide the electrostatic force of attraction. The Transverse Comb Drive element is used for sensing and actuation purposes in devices such as accelerometers and gyroscopes.

Table 90 describes the Layer Information of the Transverse Comb Drive Element:

Serial Number	Layer number Variable	Description	Sample value
1	Lf	Layer number to draw Transverse combs	1
2	La	Layer number to draw anchors	6

Table 90 Layer details

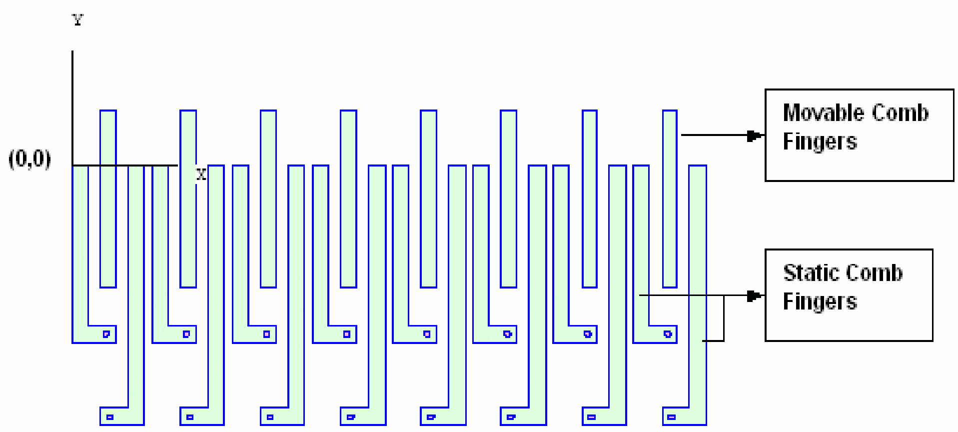


Figure 90 Part and Layer details

Figure 90 shows the two-layered mask for the sample values given in Table 91.
The origin lies at the left extreme fixed finger which is considered as the starting point of the element.

The parametric Illustration of the Transverse comb drive element is shown below taking three sets of fingers.

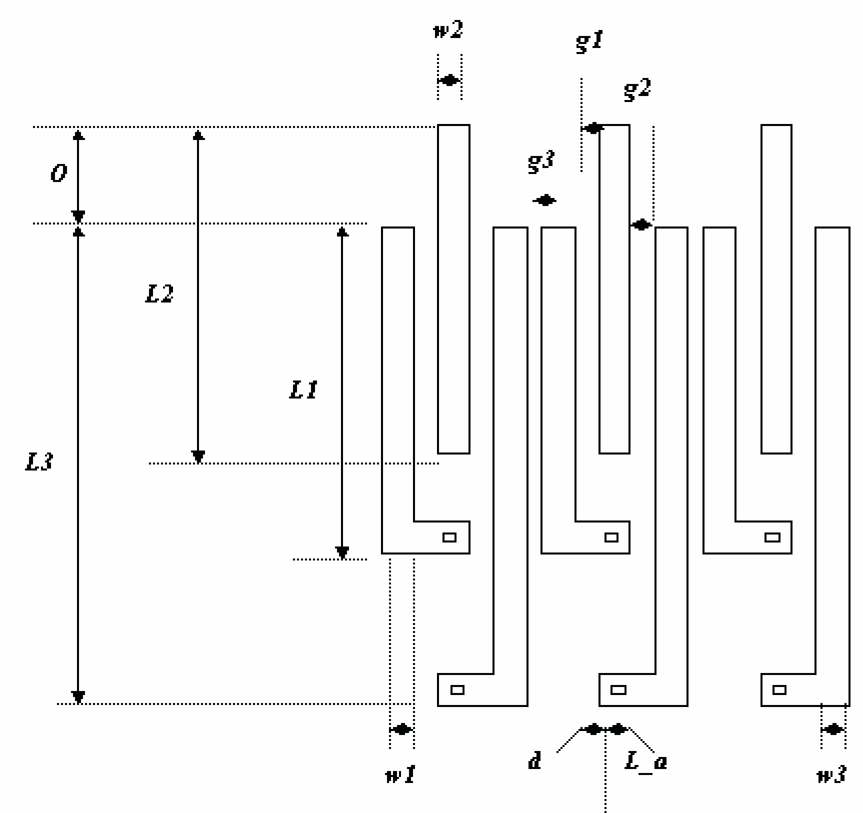


Figure 91 Parameters of Transverse Comb

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	L1		130 µm
	L2	Length of the combs	130 µm
	L3		190 µm
2	O	Comb overlap	90 µm
3	g1		10 µm
	g2	Comb spacings	10 µm
	g3		6 µm
4	w1		13 µm
	w2	Width of the comb fingers	12 µm
	w3		13 µm
5	N	Number of movable fingers	10 µm
6	L_a	Length of anchor	5 µm

7	W_a	Width of anchor	3 µm
8	R	Radius of curvature of anchor	0 µm
9	d	Distance of anchor from the edge	5 µm

Table 91 List of parameters of Transverse Comb

11.3 *Perforated Circular Plate*

Description:
This script generates a Circular perforated plate Element. It consists of circular ribs and rectangular ribs with radial perforations as shown in figure 92.
It is used as a circular proof mass in inertial devices like radial gyroscopes.

Table 92 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_p	Layer number to draw perforated plate	2
2	L_d	Layer number to draw dimples	6

Table 92 Layer details

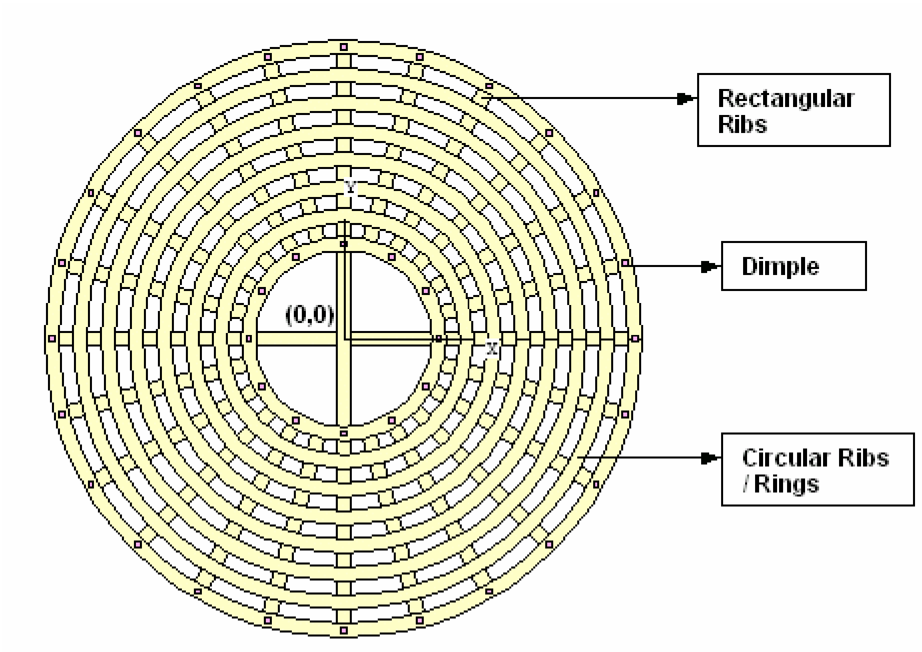


Figure 92 Part and Layer details

Figure 92 shows the two-layered mask for the sample values given in Table 93.
The origin lies at the center of the plate which is considered as the starting point for generating the element.

The parameters of the perforated plate are illustrated in figure 93.

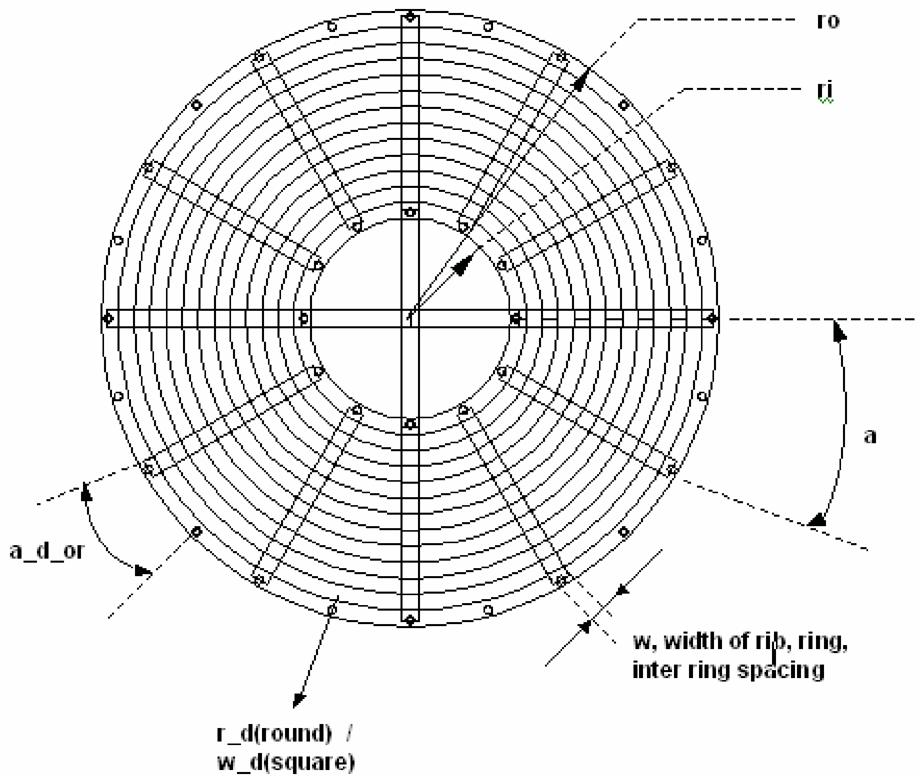


Figure 93 Parameters of Perforated Circular Plate

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	ri	Inner radius of the perforated plate	50 µm
2	w	Width of the rings, ribs as well as inter-ring spacing	8 µm
3	ro	Outer radius of the perforated plate	170 µm
4	a	Angle between the ribs	15 µm
5	r_d	Radius of the dimples	2 µm
6	w_d	Width of square dimples	3 µm
7	a_d_ir	Angle between the dimples on the innermost ring	30 degrees

8	a_d_or	Angle between the dimples on the Outermost ring	15 degrees
9	dimple_type	Type of Dimple, Round or Square	0
10	n	Number of ribs	
11	n_r	Number of rings	
12	n_d_ir	Number of dimples on the innermost ring	
13	n_d_or	Number of dimples on the Outermost ring	

Table 93 List of parameters

Note:
For round dimple enter dimple_type = 0
For rectangular/Square dimple enter dimple_type = 1

The derived parameters are calculated using the formulae below:

a) n = 360/a
b) n_r = (((ro-ri)/w)+1)/2
c) n_d_ir = 360/a_d_ir
d) n_d_or = 360/a_d_or

11.4 *Rotary Spring*

Description:
This script generates a Rotary Spring Element. It consists of series of circular ribs/rings which are connected via interconnects as shown in figure 94.
It is used as a circular proof mass in inertial devices like radial gyroscopes.

Table 92 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_RS	Layer number to draw the Rotary Spring	7

Table 94 Layer details

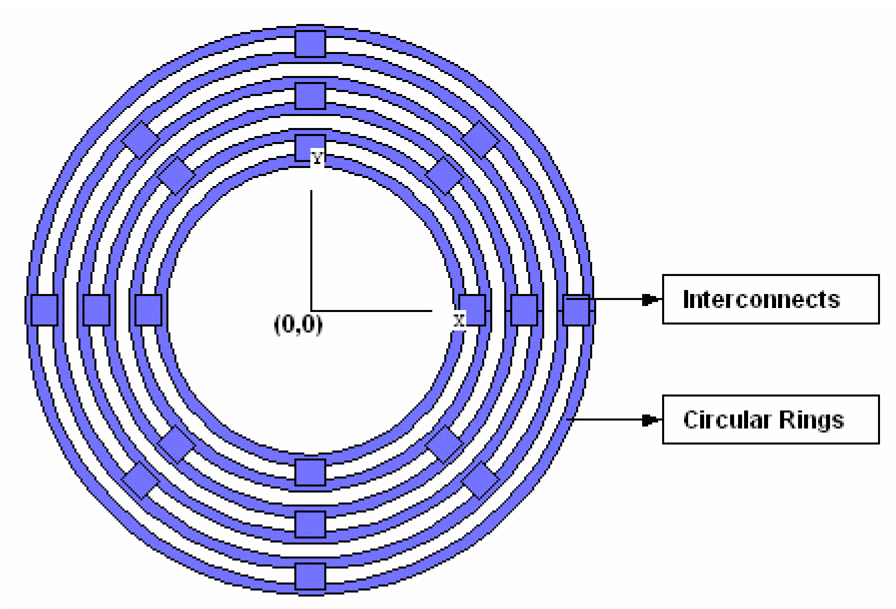


Figure 94 Part and Layer details

Figure 94 shows the single layered rotary spring element generated in IntelliMask with the sample values given in table 95.
The origin is located at the center of the Spring element.

The parameters of the Rotary Spring are illustrated in figure 95.

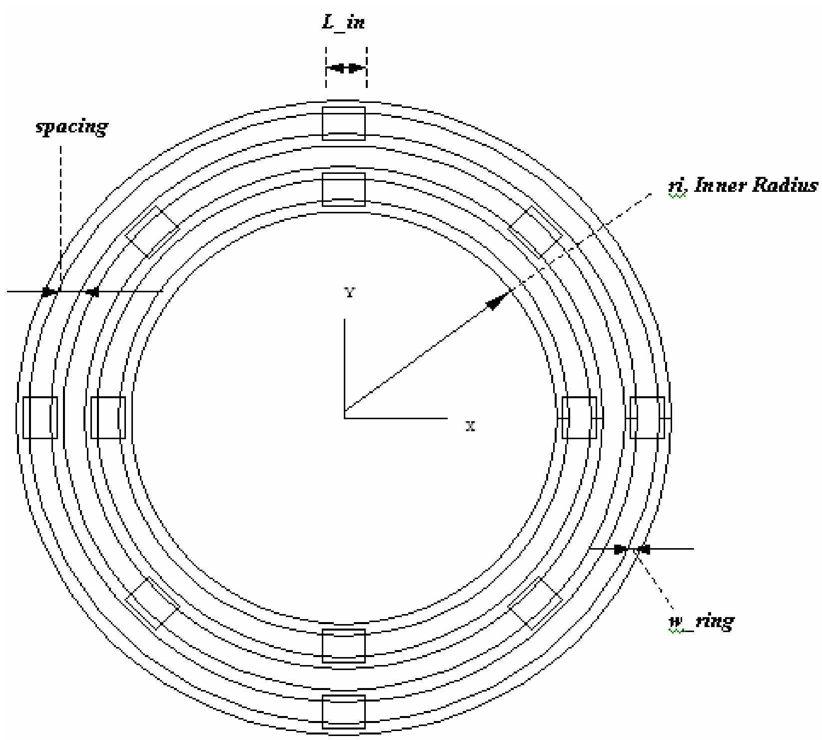


Figure 95 Parameters of Rotary Spring

The table below gives the list of parameters required to generate this element:

Serial Number	Parameter	Description	Dimensions used as sample
1	ri	The inner radius of the rotary spring	100 µm
2	w_ring	The width of the each ring of the spring	8 µm
3	ro	The Outer radius of the rotary spring	
4	spacing	The spacing between consecutive rings	10 µm
5	n_rings	The number of rings of the spring	6 µm
6	L_in	Length of the inter-connects	20 µm

Table 95 List of parameters

Note:
ro is calculated using ro = (n_rings)*(w_ring)+(n_r-1)*spacing.

11.5 *Accelerometers*

11.5.1 Accelerometer1

Description:
This script generates an accelerometer device. It consists of Banks of transverse combs on either sides of a central perforated proof mass. The perforated masses are connected to folded springs that are anchored to the substrate as shown in figure 96.

Table 96 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_Structure	Layer number to draw structure	1
2	Layer_anchor	Layer number to draw anchor	2

Table 96 Layer details

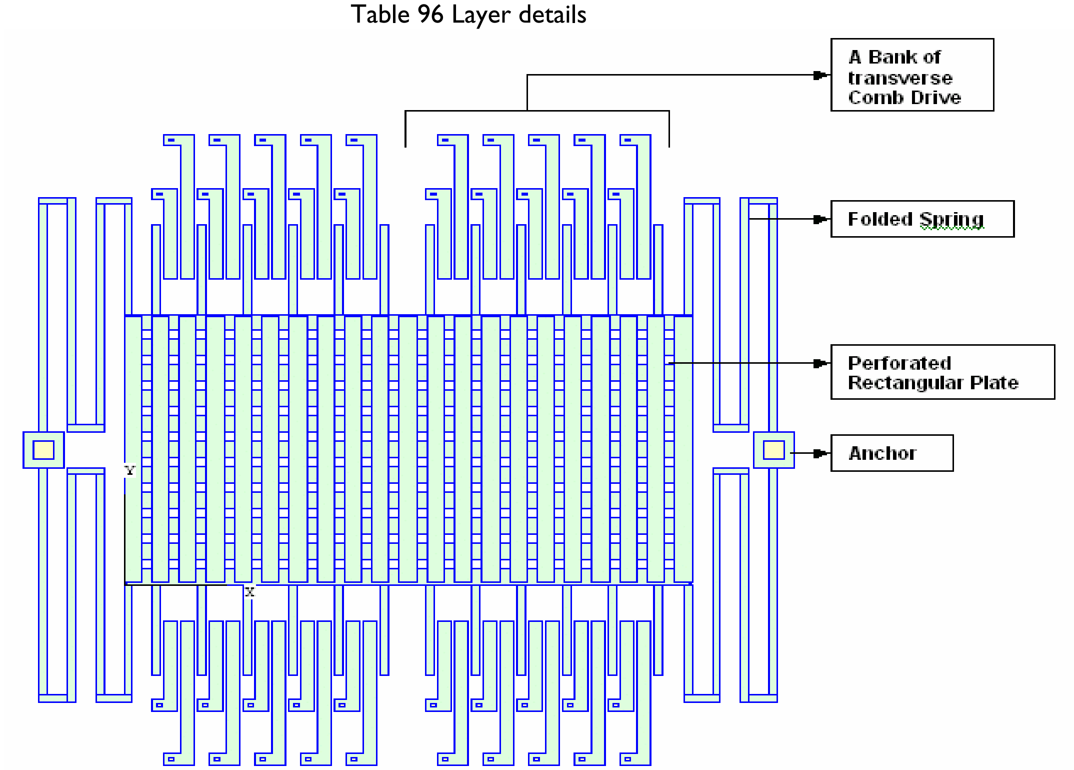


Figure 96 Part and Layer details of Accelerometer1

Figure 96 shows the multilayered mask for the sample values given in Table 97 as generated in IntelliMask.
The origin lies at the Lower Left corner of the Perforated Plate Element.

For the parametric Illustration of the parts of the Accelerometer please refer.

a) Perforated Rectangular Plate (Element 4.6)
b) Folded Spring Elements (Element 10.1)
c) Transverse Comb Drive (Element 11.2)

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Perforated Rectangular Plate			
1	Plate_width	Width of the plate	1320 µm
2	Plate_height	Height of the plate	460 µm
3	Corner_radius	Radius of curvature of plate	2 µm
4	n_rows	Number of perforations in a row	30
5	n_columns	Number of perforations in a column	10
6	hole_width	Width of the perforation	10 µm
7	hole_height	Height of the perforation	10 µm
Folded Spring Element			
1	L_spring	Total Length of the spring	260 µm
2	w_spring	Width of the beam	8 µm
3	n_folds	Number of folds of the spring	2
4	spacing	The inter-tether spacing	20 µm
5	w_an	width of spring the anchor	20 µm
6	d_an	width of the anchor support	10 µm
Transverse Comb Drive Element			
1	L1	Length of the combs	100 µm

	L2		100 µm
	L3		160 µm
2	O	Comb overlap	60 µm
3	g1 g2 g3	Comb spacings	4 µm 4 µm 3 µm
4	w1 w2 w3	Width of the comb fingers	8 µm 13 µm 13 µm
5	N	Number of movable fingers	6
6	L_a	Length of anchor	5 µm
7	W_a	Width of anchor	3 µm
8	R	Radius of curvature of anchor	0 µm
9	d	Distance of anchor from the edge	5 µm
9	M	Number of comb banks	4

Table 97 List of parameters of the 3 components of Accelerometer1

11.5.2 ADXL

Description:
This script generates an ADXL accelerometer device. It consists of transverse combs on either sides of a central perforated proof mass and also supplementary proof masses. The perforated masses are connected to folded springs that are anchored to the substrate and the motion of the proof masses are restricted by stoppers as shown in Figure 98.
The ADXL products are the foundation for Analog Devices' accelerometer family, and utilize the *iMEMS* surface micromachining process. They are Available in low-*g* or high-*g* sensing ranges, *iMEMS* accelerometers are used to measure position, motion, tilt, shock, and vibration in a broad array of applications

Table 98 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_Structure	Layer number to draw structure	5
2	Layer_anchor	Layer number to draw anchor	6

Table 98 Layer details

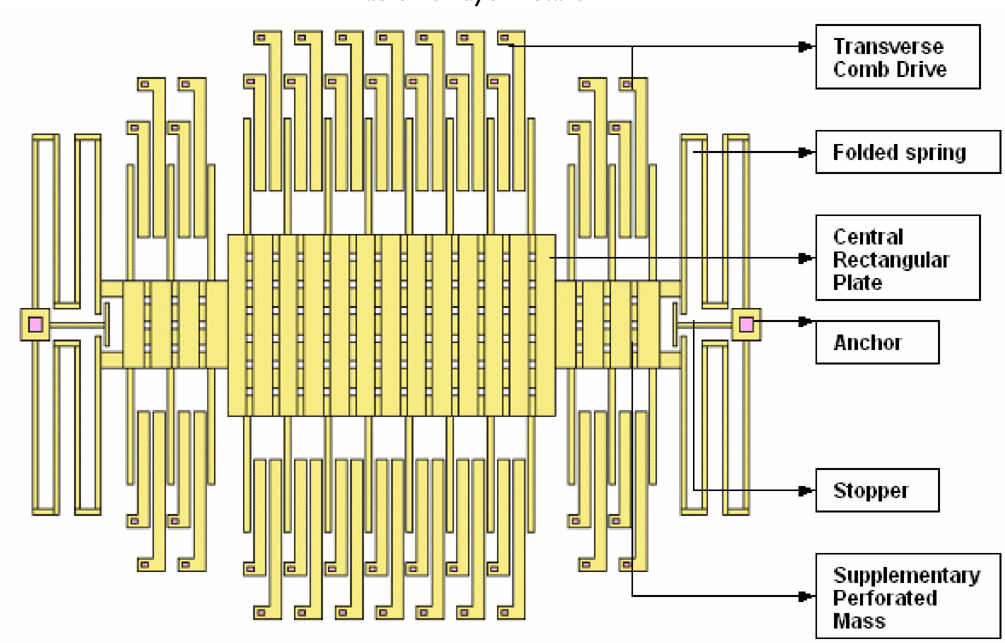


Figure 98 Part and Layer details of ADXL

Figure 98 shows the multilayered mask for the sample values given in Table 99 as generated in IntelliMask. Each of the 2 layers is represented by a different color.

For the Part Description of the ADXL please refer.

a) *Perforated Rectangular Plate (Element 4.6)*
b) *Folded Spring Elements (Element 10.1)*
c) *Transverse Comb Drive (Element 11.2)*

The other parameters are illustrated taking sections of the ADXL in the figures below:

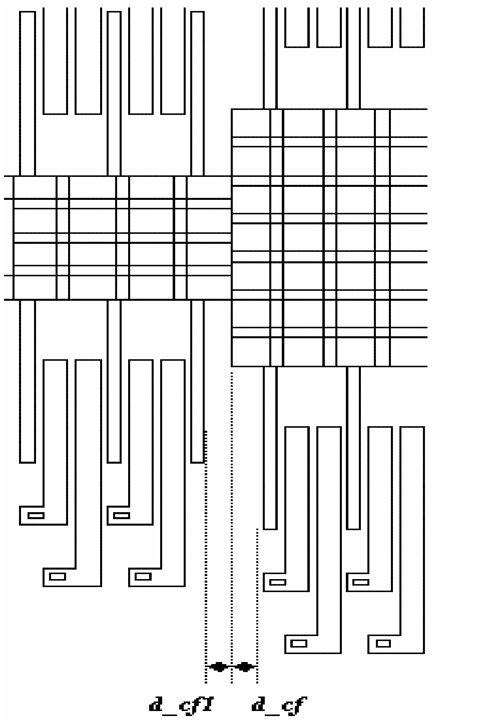


Figure 99a

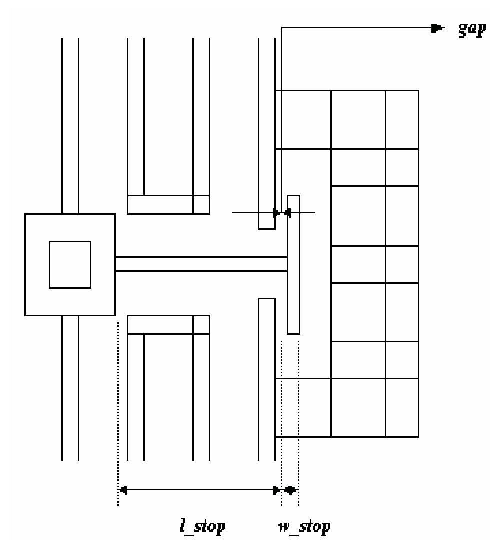


Figure 99b

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Perforated Rectangular Plates			
1	Plate_width	Width of the Central Perforated Mass	400 µm
2	Plate_height	Height of the Central Perforated	150 µm

		Mass	
3	n_rows	Number of perforations in a row of the Central Perforated Mass	14
4	n_columns	Number of perforations in a column of the Central Perforated Mass	6
5	hole_width	Width of the perforation	8 µm
6	hole_height	Height of the perforation	8 µm
7	PW	Width of the supplementary perforated masses	100 µm
8	PH	Height of the supplementary perforated masses	75 µm
9	nr	Number of perforations in a row of the supplementary perforated masses	4
10	nc	Number of perforations in a column of the supplementary perforated masses	3
Folded Spring Element			
1	L_spring	Total Length of the spring	150 µm
2	w_spring	Width of the beam	4 µm
3	n_folds	Number of folds of the spring	2
4	spacing	The inter-tether spacing	12 µm
5	w_an	width of spring the anchor	10 µm
6	d_an	width of the anchor support	6 µm
7	l_stop	Length of the spring stopper element	30 µm
8	w_stop	Width of the spring stopper beam	3 µm
9	gap	Gap between the spring and the stopper element	2 µm
Transverse Comb Drive Element			
1	L1 L2 L3	Length of the combs	100 µm 100 µm 140 µm
2	O	Comb overlap	80 µm
3	g1		3 µm

	g2 g3	Comb spacings	3 µm 2 µm
4	w1 w2 w3	Width of the comb fingers	5 µm 9 µm 9 µm
5	N	Number of fixed set of combs on the central plate	12
6	N1	Number of fixed set of combs on the supplementary plates	2
7	L_a	Length of anchor	5 µm
8	W_a	Width of anchor	3 µm
9	d	Distance of anchor from the edge	3 µm
10	d_cf	Distance of the first movable comb finger from the central and plate edge.	12 µm
11	d_cf1	Distance of the first movable comb finger from the supplementary plate edges	10 µm

Table 99 List of parameters of the 3 components of ADXL

11.6 *GyroScopes*

11.6.1 Rotary GyroScope1

Description:
This script generates a Rotary GyroScope device.
It consists of a Circular perforated Proof Mass which is connected to Radial comb Drives spaced at 90 degrees to each other. The structure is anchored to the substrate with the help of T-Susupensions as shown in Figure 100.

Table 100 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_p	Layer number to draw Circular perforated plate and Comb Drives	1
2	L_a	Layer number to draw anchors	6
3	L_d	Layer number to draw dimples	7

Table 100 Layer details

Figure 100 shows the multilayered mask for the sample values given in Table 101. Each Layer is represented by a different color.
The origin lies at the center of the perforated circular plate, which is considered as the starting point for generating the element.

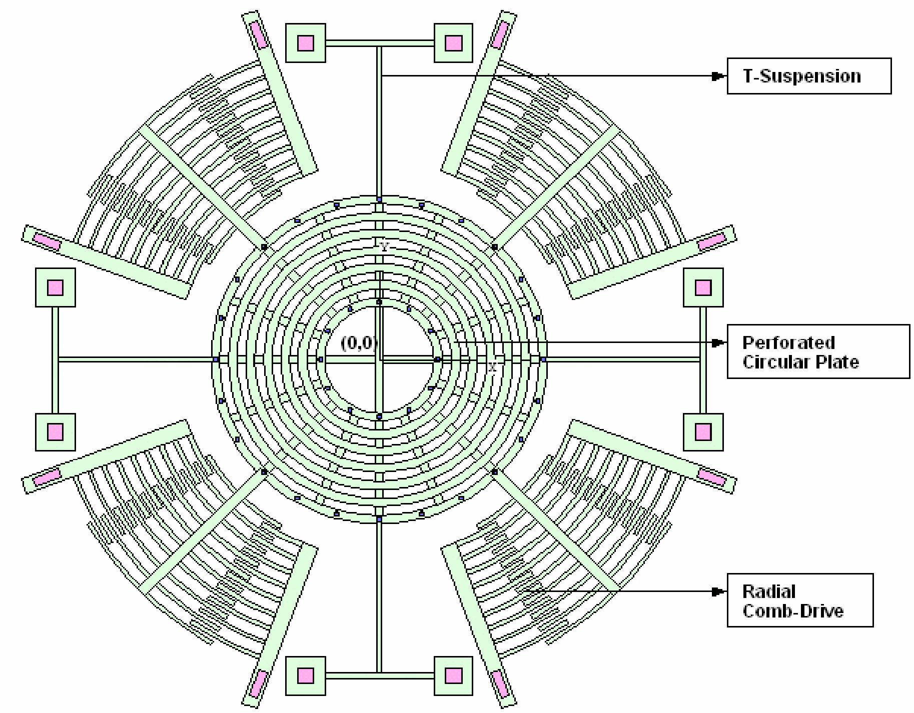


Figure 100 Part and Layer details of Rotary GyroScope1

For the Part Description of the Rotary Gyroscope please refer

a) Perforated Circular Plate (Element 11.3)

The other parts are described below

b) T-Suspension

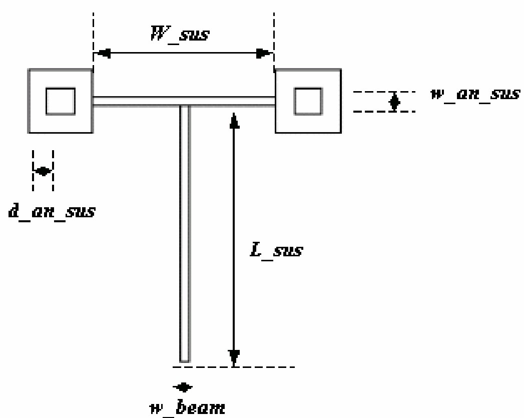


Figure 101a Parameters of the T-Suspension

c) Radial Comb Drive Bi-Directional

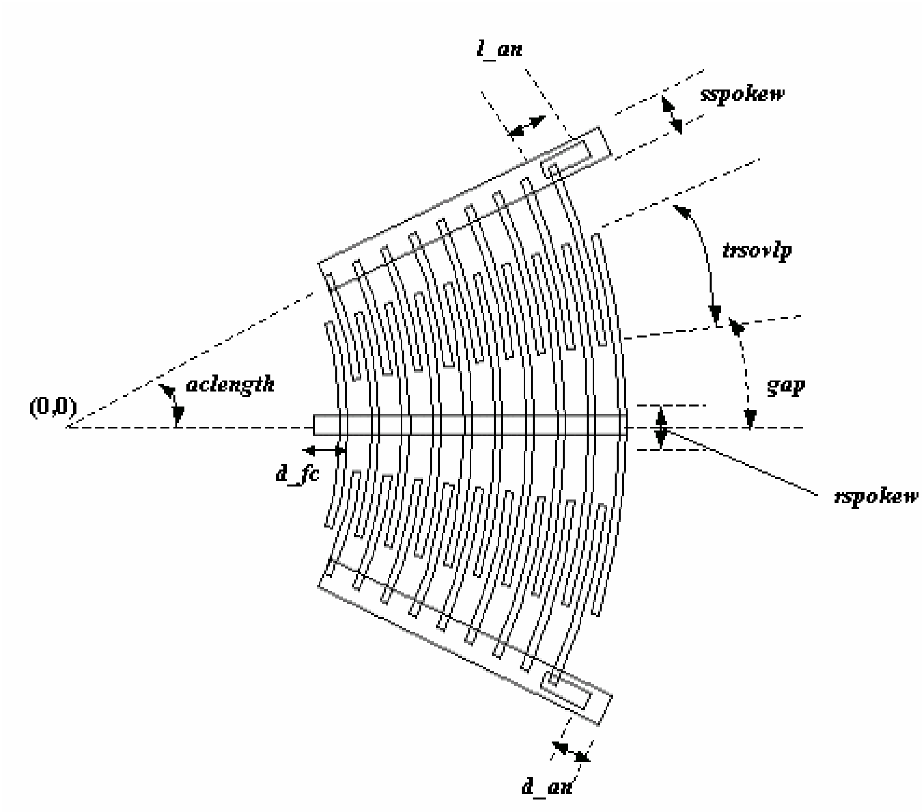


Figure 101b Parameters of the Radial Comb Drive

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Perforated Circular Plate			
1	ri	Inner radius of the perforated plate	50 µm
2	w	Width of the rings, ribs as well as inter-ring spacing	8 µm
3	ro	Outer radius of the perforated plate	154 µm
4	a	Angle between the ribs	22.5 degrees
5	r_d	Radius of the dimples	2 µm

6	w_d	Width of square dimples	3 µm
7	a_d_ir	Angle between the dimples on the innermost ring	30 degrees
8	a_d_or	Angle between the dimples on the Outermost ring	15 degrees
9	dimple_type	Geometry of Dimple, Round or Square	1

T-Suspension

1	L_sus	Length of the T-Suspension	140 µm
2	w_beam	Width of the T-Suspension	5 µm
3	W_sus	Width of the beams of the T-Suspension	100 µm
4	w_anchor	Width of anchors of the T-Suspension	15 µm
5	d_anchor	Distance of anchor from edge of anchor frame of the T-Suspension	10 µm

Radial Comb Drive Element

1	aclength	Active angular comb length of each sector	25 degrees
2	fwidth	Width of comb fingers	4 µm
3	airgap	Airgap between adjacent comb fingers	3 µm
4	rspokew	Rotor spoke width	10 µm
5	sspokew	Stator spoke width	15 µm
6	trsovlp	Angular stator-rotor finger overlap	5 degrees
7	n_combs	Number of comb fingers on the rotor	10
8	L_stator	Length of the stator	160 µm
9	d_fc	Distance between the innermost comb-finger and the outermost ring of the perforated plate	25 µm
10	l_an	Length of the anchor of the stator spoke	25 µm
11	w_an	Width of the anchor of the stator spoke	8 µm
12	d_an	Distance of the anchor edge from the stator edge	10 µm
13	gap	Gap between the stator and the overlap region of fingers	

14	sfingerlength	Length of the comb fingers, degrees
15	rri	Inner radius of rotor
16	L_rotor	Length of the rotor

Table 101 List of parameters of the 3 components

Note:
The formulae for the parameters derived are given below:

1) gap = (aclength-trsovlp)/2
2) sfingerlength= gap+trsovlp
3) rri = ro+d_fc
4) L_rotor = d_fc+(2*n_combs-1)*fwidth+(2*n_combs-2)*airgap

11.6.2 Rotary GyroScope2

Description:
This script generates a Rotary GyroScope device. It consists of Radial Comb Drives spaced equally around a central rotor ring. The Rotary Spring element connects the proof mass to the Outer Supporting frame of the device as shown in Figure 102

Table 102 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_G	Layer number to draw Rotary GyroScope	7

Table 102 Layer details

Figure 102 shows the IntelliMask generated layout of the Rotary Gyroscope. All the constituent members lie on a single layer. The origin is located at the center of the GyroScope, which is considered as the starting point for generating the element layout.

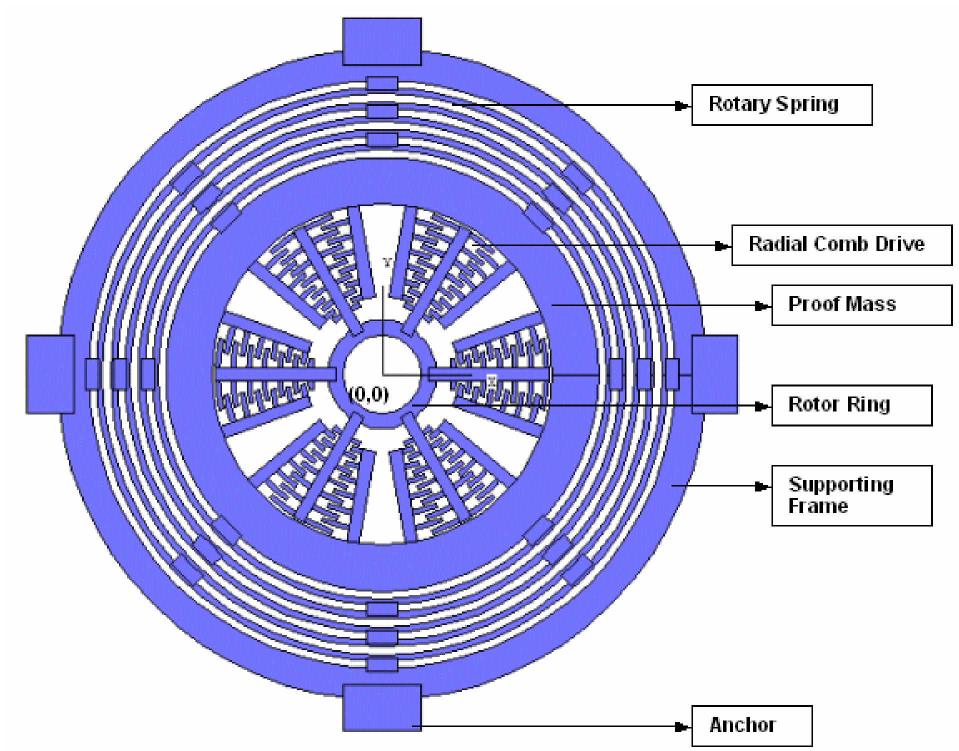


Figure 102 Part Description of Rotary GyroScope2

Part Description:

a) Rotary Spring Element (Element 11.4)
b) Radial Comb Drive in Rotary GyroScope1 (Element 11.6.2)

The other parameters pertaining to the Proof mass, Outer Frame and the anchors are illustrated below.

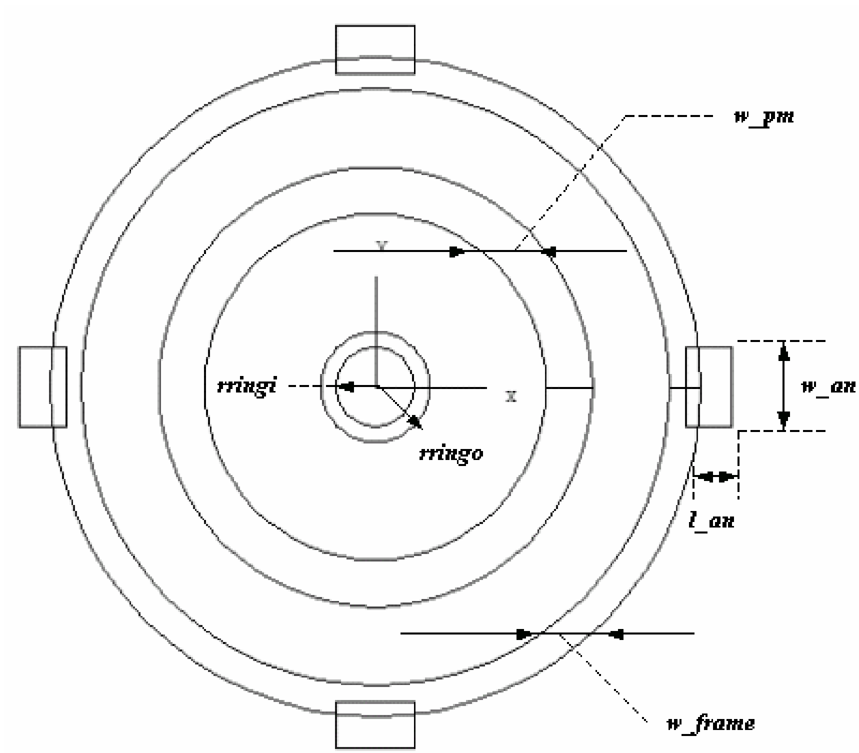


Figure 103 Rotary GyroScope2 (Parts)

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Rotary Spring with Frame			
1	w_ring	The width of each ring of the spring	4 µm
2	spacing	The spacing between consecutive	5 µm

		rings	
3	n_rings	The number of rings of the spring	7
4	L_in	Length of the inter-connects	20 µm
5	w_pm	The width of the proof mass	30 µm
6	w_frame	The width of the frame	20 µm
7	theta	Angle between consecutive rotary combs	60 degrees
8	l_an	Length of the anchor of the frame	20 µm
9	w_an	Width of the anchor of the frame	50 µm
10	ri	The inner radius of the rotary spring	
11	ro	The outer radius of the spring	
12	ri_frame	Inner radius of the frame	

Radial Comb Drive Element

1	rringi	Inner radius of rotor ring	25 µm
2	rringo	Outer radius of rotor ring	35 µm
3	rsi	Inner radius of stator comb	50 µm
4	aclength	Active angular comb length of each sector	20 degrees
5	fwidth	Width of comb fingers	3 µm
6	airgap	Airgap between adjacent comb fingers	2 µm
7	rspokew	Rotor spoke width	8 µm
8	sspokew	Stator spoke width	8 µm
9	trsovlp	Angular stator-rotor finger overlap	5 degrees
10	n_combs	Number of comb fingers on the rotor	7 µm
11	L_stator	Length of the stator	60 µm
12	d_fc	Distance between the innermost comb-finger of the rotor and the rotor ring	
13	w	Width of the rotor ring	
14	gap	Gap between the stator and the overlap region of fingers	
15	sfingerlength	Length of the comb fingers, degrees	
16	rri	Inner radius of rotor	
17	L_rotor	Length of the rotor	

Table 103 List of parameters of the components

Note:
The formulae for the parameters derived are given below:

1) ri = rsi+L_stator+w_pm+spacing
2) ro = (n_rings)*(w_ring)+(n_r-1)*spacing
3) ri_frame =rsi+L_stator+w_pm+(n_rings*w_ring)+((n_rings+1)*spacing)1)

4) w = rringo-rringi
5) gap = (aclength-trsovlp)/2
6) sfingerlength = gap+trsovlp
7) rri = rsi-fwidth-airgap
8) d_fc = rri-rringo
9) L_rotor = d_fc+(2*n_combs-1)*fwidth+(2*n_combs-2)*airgap

11.6.3 GyroScope 2

Description:
This script generates a GyroScope device. It consists of a series of Linear Comb Drives attached to the Active Mass and Series of Transverse Comb Drives attached to the Passive Mass which are used as sense capacitors. It consists of 4 suspension systems which connect the Active Mass to the Passive Mass as well As the Substrate.as shown in Figure 104. The Suspension System configuration provides two Degrees of Freedom in the drive and sense directions for the Active Proof Mass and the Passive Proof Mass.

Table 104 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	Ls	Layer number to draw Structure	5
2	La	Layer number to draw anchors	6

Table 104 Layer details

Figure 104 shows the multilayered IntelliMask generated layout of the Gyroscope device. The figure also illustrates the various Parts of the device.
The origin is located at the center of the Gyroscope, which is considered as the starting point for generating the element layout.

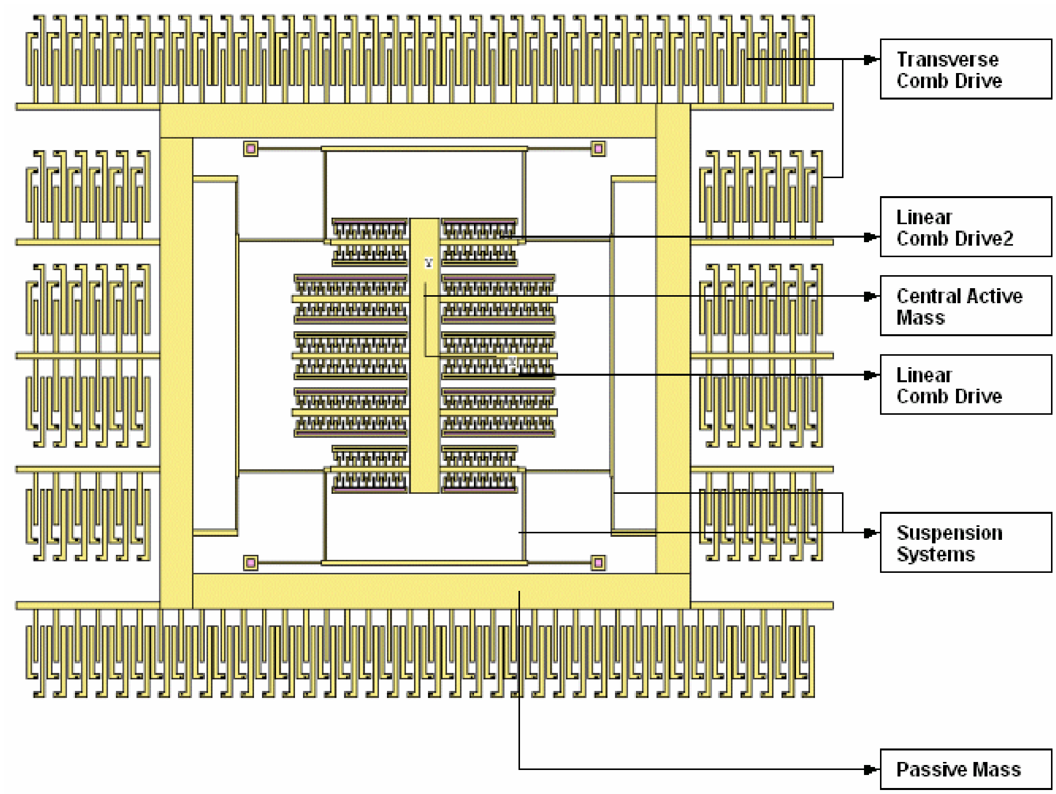


Figure 104 Part and Layer Description of GyroScope2

Part Description:

a) *Linear Comb Drive (Element 2.1)*
b) *Transverse Comb Drive (Element 11.2)*

The other parameters pertaining to the Active and Passive Proof masses and the Suspension Systems are illustrated in the figure below.

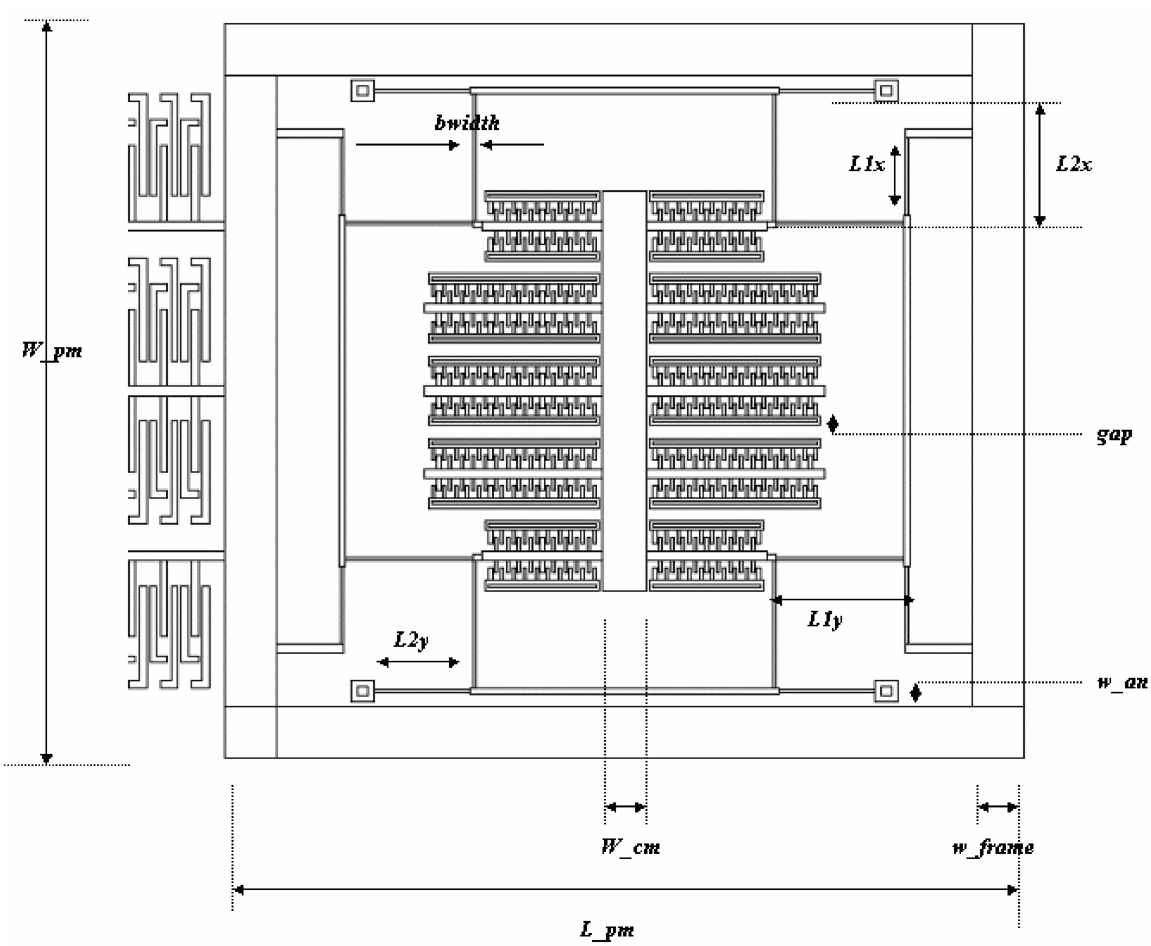


Figure 105 Parameters of GyroScope2

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Linear Comb Drive and Central Active Mass			
1	gap	vertical gap between LinearCombDrives	20 μm
2	W_cm	Width of the central mass	70 μm
3	airgap	Gap between the interdigitated fingers	4 μm

4	fwidth	The finger width	5 µm
5	sywidth	Width of the stator yoke	15 µm
6	rywidth	Width of the Rotor yoke	15 µm
7	flength	Length of the finger	20 µm
8	rsoverlap	Rotor-Stator finger overlap	8 µm
9	anwidth	Width of the anchors	5 µm
10	da	Distance of the anchor from edge	5 µm
11	numComb	Number of combs of stator	20
12	numComb2	Number of combs of lowermost/uppermost stator	15
Passive Mass			
1	L_pm	Length of Passive mass	1380 µm
2	W_pm	Width of Passive mass	1300 µm
3	w_frame	frame width of Passive mass	80 µm
Suspension Systems			
1	bwidth	width of beams along drive and sense directions	5 µm
2	L1x L1y	Lengths of beam in suspension connecting Active and Passive mass	120 µm 200 µm
3	L2x L2y	Lengths of beam in suspension connecting Active mass and Substrate	200 µm 150 µm
4	w_an	width of suspension anchors	15 µm
5	d_an	distance of anchor from edge	10 µm
Transverse Comb Drive Element			
1	L1 L2 L3	Length of the combs	120 µm 120 µm 160 µm
2	O	Comb overlap	80 µm
3	g1 g2 g3	Comb spacings	6 µm 6 µm 5 µm
4	w1 w2 w3	Width of the comb fingers	11 µm 10 µm 11 µm
5	N	Number of movable fingers on Transverse CombDrive	10

6	M	Number of movable fingers on Top/Bottom ends of Transverse CombDrive	49
7	L_a	Length of anchor	5 µm
8	W_a	Width of anchor	3 µm
9	R	Radius of curvature of the anchor	1 µm
10	d	Distance of anchor from the edge	4 µm

Table 105 List of parameters of the components

11.6.4 Tuning Fork Gyroscope

Description:
This script generates an In-Plane solid mass Tuning Fork Gyroscope device.
Tuning fork gyroscopes contain a pair of masses that are driven to oscillate with equal amplitude but in opposite directions. When rotated, the Coriolis force creates an orthogonal vibration that can be sensed by a variety of mechanisms.
The device generated has a pair of proof masses to which Linear comb drive devices are attached and which act as the Drive electrodes for the device. The sense electrodes and Tuning electrodes lie close to the proof masses as shown in Figure 106. The proof masses are connected to beams that are attached to the substrate via anchors of Perforated rectangular beam Elements.

Table 106 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	L_s	Layer number to draw Structure	4
2	L_a	Layer number to draw anchors	5

Table 106 Layer details

Figure 106 shows the multilayered IntelliMask generated layout of the Gyroscope device. The figure gives the Part details of the device.
The origin is located at the center of the Gyroscope, which is considered as the starting point for generating the element layout.

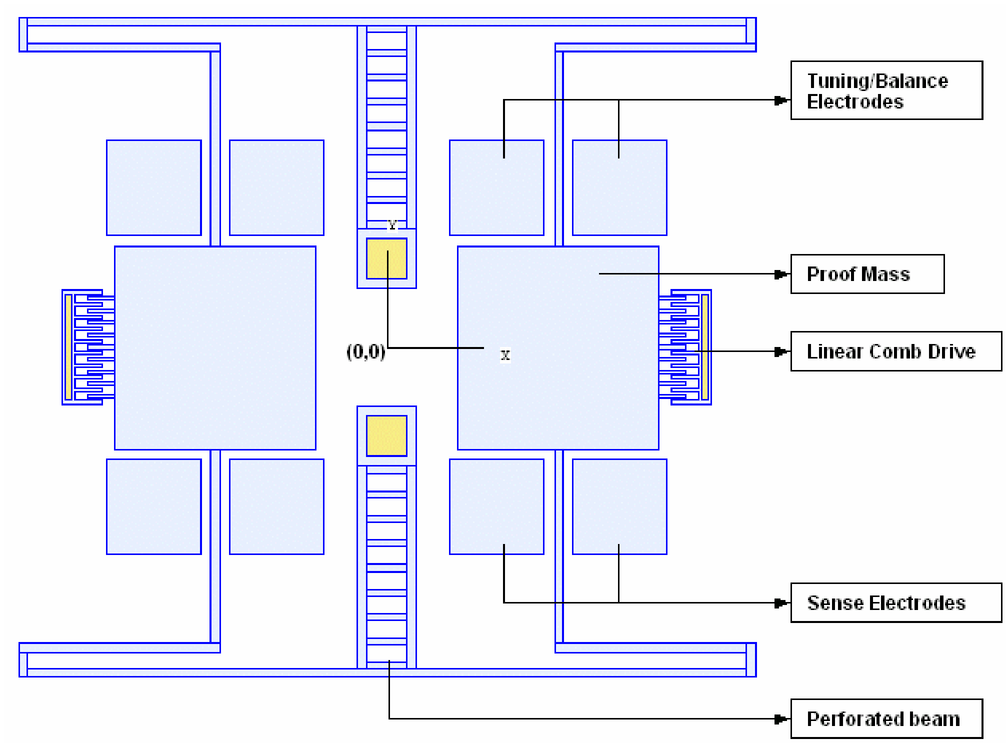


Figure 106 Part and Layer Description of Tuning Fork GyroScope

Part Description:

a) Linear Comb Drive (Element 2.1)
b) Perforated Rectangular Beam (Element 8.1)

The other parameters illustrating the Proof masses, Beams and the electrodes are shown in the section of the figure below.

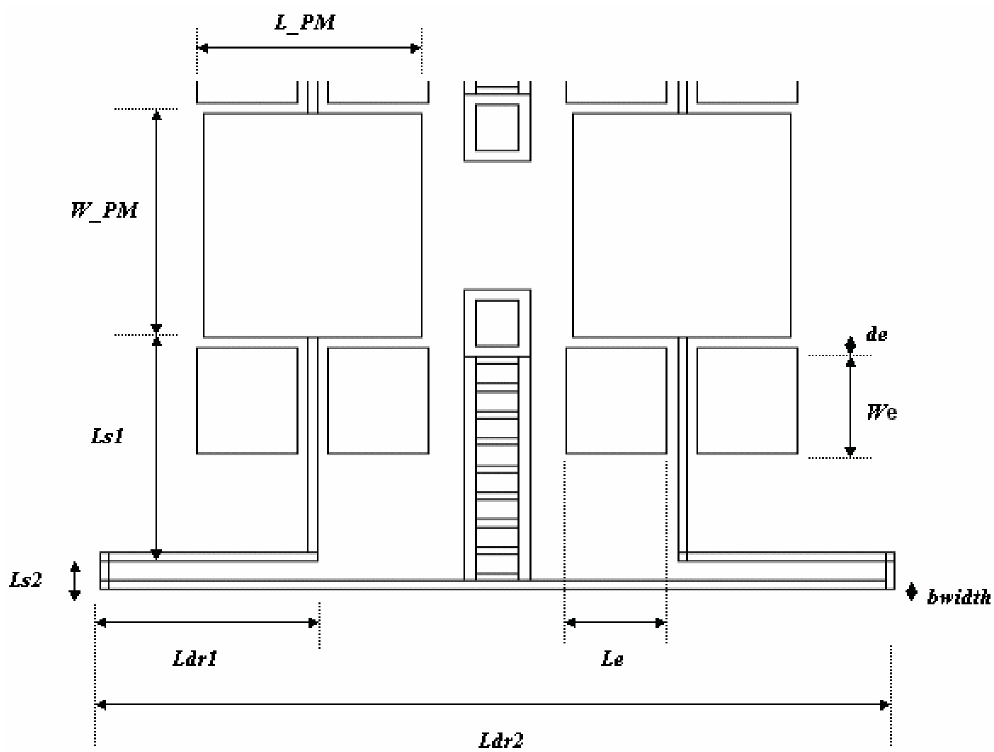


Figure 107 Parameters of Tuning Fork GyroScope

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Linear Comb Drive			
1	airgap	Gap between the interdigitated fingers	3 μm
2	fwidth	The finger width	4 μm
3	sywidth	Width of the stator yoke	18 μm
4	flength	Length of the finger	40 μm
5	rsoverlap	Rotor-Stator finger overlap	20 μm
6	anwidth	Width of the anchors	8 μm
7	d	Distance of the anchor from edge	5 μm
8	numComb	Number of combs of stator	15
Perforated Rectangular Beam			

1	L_beam	Length of the perforated beam	300 µm
2	whoriz	width of the horizontal beams	10 µm
3	wvert	width of the vertical beam	15 µm
4	N	Number of perforations along the length	8
5	w_a	Width of the anchor	60 µm
6	d_a	distance of anchor from edge	15 µm
TFG (Beams and Electrodes)			
1	L_PM	Length of Proof Mass	400 µm
2	W_PM	Width of Proof Mass	400 µm
3	Ls1 Ls2	Lengths of beam along sense direction	500 µm 40 µm
4	Ldr1 Ldr2	Lengths of beam along drive direction	300 µm 1400 µm
5	bwidth	width of the beams	12 µm
6	We	Length of the electrodes	150 µm
7	Le	Width of the electrodes	150 µm
8	de	Distance of the electrode from Proof Mass edge	10 µm

Table 107 List of parameters of the components

11.6.5 Vibratory Gyroscope

Description:
This script generates a Vibratory Gyroscope device.
The device has a central proof mass to which Linear comb drive devices are attached and which act as the drive electrodes. The central proof mass is attached to adjoining proof masses, which are connected to a Perforated rigid frame via folded spring elements. The rigid frame has the sense comb electrodes attached to it. The rigid frame is connected to an Outer frame by folded springs.

Table 108 describes the Layer Information of the Element:

Serial Number	Layer number Variable	Description	Sample value
1	Layer_plate	Layer number to draw Structure	3

Table 107 Layer details

Figure 108 shows the single layered IntelliMask generated layout of the Vibratory Gyroscope device. The figure gives the Part details of the device.
The origin is located at the Lower left corner of the central perforated plate of the Gyroscope, which is considered as the starting point for generating the element layout.

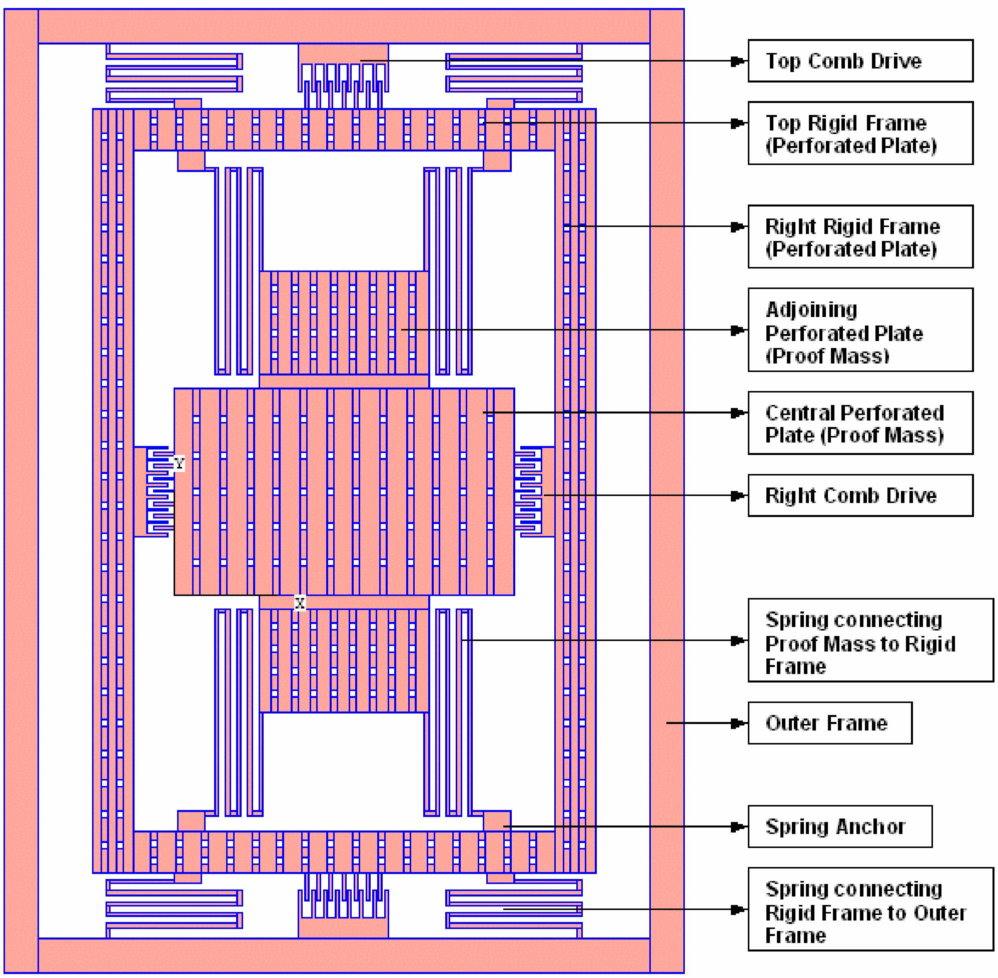


Figure 108 Part and Layer Description of Vibratory GyroScope

Part Description:

a) *Linear Comb Drive (Element 2.1)* – for top, bottom ,right and left comb drives.
b) *Perforated Rectangular Plate (Element 4.6)* - for the Rigid Frame, central and adjoining perforated plates.
c) *Folded Spring Elements (Element 10.1)* – for springs connecting the Proof Mass to Rigid Frame and spring connecting Rigid Frame to Outer Frame.

The other parameters are illustrated in the figure below taking a small lower section of the device.

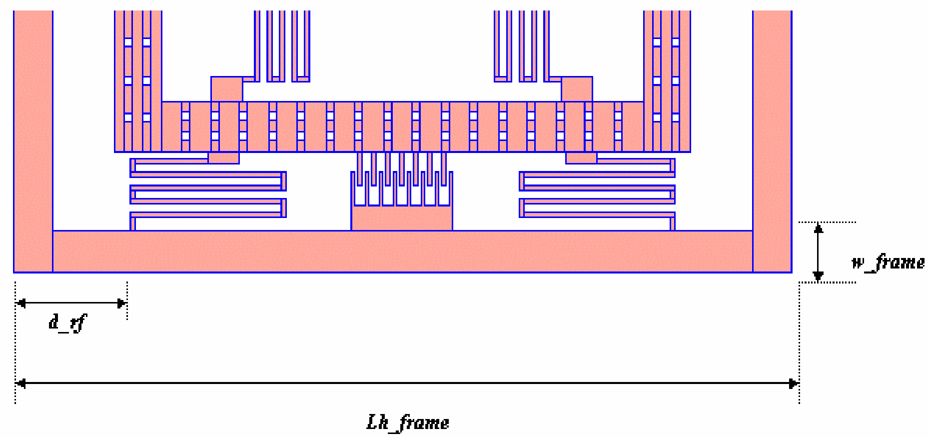


Figure 109 Parameters of Vibratory GyroScope

The table below gives parameters and sample values used to generate this element

Serial Number	Parameter	Description	Dimensions used as sample
Linear Comb Drives (Left and Right)			
1	airgap	Gap between the interdigitated fingers	5 µm
2	fwidth	The finger width	4 µm
3	sywidth	Width of the stator yoke	20 µm
4	flength	Length of the finger	40 µm
5	rsoverlap	Rotor-Stator finger overlap	20 µm
6	numComb	Number of combs of stator	15
Linear Comb Drives (Top and Bottom)			
1	airgap1	Gap between the interdigitated fingers	4 µm
2	fwidth1	The finger width	5 µm
3	sywidth1	Width of the stator yoke	50 µm
4	flength1	Length of the finger	50 µm
5	rsoverlap1	Rotor-Stator finger overlap	15 µm
6	numComb1	Number of combs of stator	15
Perforated Rectangular Plates / Proof Masses			
1	Plate_width	Width of the Central Perforated Mass	600 µm
2	Plate_height	Height of the Central Perforated Mass	400 µm
3	n_rows	Number of perforations in a row of	12

		the Central Perforated Mass	
4	n_columns	Number of perforations in a column of the Central Perforated Mass	5
5	hole_width	Width of the perforation	10 µm
6	hole_height	Height of the perforation	10 µm
7	PW1	Width of the adjoining proof masses	300 µm
8	PH1	Height of the adjoining proof masses	200 µm
9	nr1	Number of perforations in a row of the adjoining proof masses	8
10	nc1	Number of perforations in a column of the adjoining proof masses	4
11	h_rect	Height of rectangle connecting the central proof mass and adjoining masses	30 µm
Parameters of Rigid Frames (top and Bottom)			
1	pw2	Width of the rigid frames	
2	ph2	Height of the rigid frames	60 µm
3	nr2	Number of perforations in a row of the rigid frames	16
4	nc2	Number of perforations in a column of the rigid frames	2
Parameters of Rigid Frames (Right and Left)			
5	pw3	Width of the rigid frames	60 µm
6	ph3	Height of the rigid frames	
7	nr3	Number of perforations in a row of the rigid frames	2
8	nc3	Number of perforations in a column of the rigid frames	24
Parameters of Springs connecting Proof Masses to Rigid Frame			
1	L_spring	Total Length of the spring	400 µm
2	w_spring	Width of the beam	8 µm
3	n_springs	number of folds of spring	6
4	spacing	The inter-tether spacing	15 µm
5	w_an	width of spring the anchor	30 µm
6	La	Length of spring anchor	40 µm

Parameters of Springs connecting Rigid Frames to Outer Frame

1	L_spring1	Total Length of the spring	250 µm
2	w_spring1	Width of the beam	8 µm
3	n_springs1	number of folds of spring	4
4	Spacing1	The inter-tether spacing	15 µm
5	La1	Length of spring anchor	40 µm
6	d_rf	Distance of spring edge to Outer Frame edge	150 µm
7	Lh_frame	Length of Outer Frame in x-direction	1400 µm
8	w_frame	Width of frame ring	50 µm

Table 109 List of parameters of the components

Note:
The formulae for the parameters derived are given below:

1) pw2 and ph3 are calculated from other dependant parameters
2) n_springs and n_springs1 should be even numbers.