Developer's Notes

SEMI P44-1216 Regression Test Cases

Version 1.05

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Contents

Preface

Yotta's Regression Test Cases are meant to test the language of the specification, P44-1216, in an application-nonspecific way. The test cases represent Yotta's best attempt at a literal interpretation of the specification. As an example, although it'll be rare, if ever, that the extent for a chip window will cover one square grid unit yet Yotta tests for the availability of such an allowed, very narrowly expressed, coordinate space. It has been Yotta's experience that, as rare a scenario this might be, its availability will encourage the someone's imagination to use P44 in, legal, ways once inconceivable.
A literal interpretation of the p44 specification has led to contradictions within the P44 specification, itself, and with the parent OASIS® specification SEMI P39-0308. Yotta has had to make note of these contradictions and recommend best practices that can avoid having them present in a P44 file.

The test cases are meant to be a means from which to exercise a common understanding of the p44 specification throughout the mask data preparation/writing community so that all P44 readers and writers behave, predictively, in a similarly compatible way.

The test cases are just like any other P44 implementation. Yotta does not have a P44 reader/writer implementation; just the test cases. They, however, are offered as an unbiased basis from which all P44 reader/writer implementations can be developed. Some developers may choose to disagree with the designations of the test cases. This, however, is the very reason to have them, without bias, which is to establish a common benchmark from which to develop tomorrow's P44 readers and writers. Once there is agreement about these designations, there is a much better chance that all P44 readers and writers will work together well.

Update to May 21, 2017 Release

The following updates have made to the P44-1216 regression Test Cases:

- Allowed
    1. first_cmprssd_pad_record_a_c_p44_geometry_offset.oam
        - An embedded documentation TEXTSTRING record had a string length of 277 characters long. The string has been updated so that it less than 256 characters long.
    2. pads_present_in_p44_file_a_c_pad.oam
        - P44_CHIP_WINDOW was incorrect. The incorrect property values have been replaced by the correct values.
- Mandatory
    1. less_than_cll_bndng_bx_m_f_p44_bounding_box_max.oam
        - S_BOUNDING_BOXES_AVAILABLE was set to '1' when it should have been '2.'
- Ignored
    1. text_string_max_i_c_textstring.oam
        - The string-length for a TEXT record TEXTSTRING had been set to 257 characters. The corrected length is, now, 256 characters.
    2. text_string_max_out_i_f_textstring.oam
        - The string-length for a TEXT record TEXTSTRING had been set to 258 characters. The corrected length is, now, 257 characters.
- Localized
    1. rep_0_coord_val_y_min_4_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.
    2. rep_0_coord_val_y_min_5_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.
    3. rep_0_coord_val_y_min_6_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.
    4. rep_0_coord_val_y_min_7_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.
    5. rep_0_coord_val_y_min_20_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.
    6. rep_0_coord_val_y_min_21_ctrap_32_a_c_lclzd.oam
        - Extraneous PROPERTY record at the end of the P44 file just before the END record. The record has been removed.

Update to May 19, 2017 Release

Eight test cases within the "Figures" folder had the wrong file name designation '_a_c_' and the wrong designation in the embedded documentation. All were changed from CORRECT to FATAL in the embedded documentation and the file name test case designation from '_a_c_' to '_a_f_.'

The cell offsets were incorrect for the following test case:

    bytes_present_a_c_s_max_unsigned_integer_width.oam

. . .

The octal string for a nul within a PROPSTRING record was incorrect for the following test case:

    attr_val_pair_max_sa_ref_cntct_ndprt_i_c_s_gds_prprt.oam

The correct octal string for a nul character is '\000.'

. . .

P44_GEOMETRY_COUNT property-value was incorrect for the following test cases:

    rep_0_coord_val_x_min_23_vert_trap_a_c_figures.oam
    rep_0_coord_val_x_min_24_vert_trap_a_c_figures.oam
    rep_0_coord_val_x_min_25_vert_trap_a_c_figures.oam

Update to May 17, 2017 Release

Two sets of test cases within the "Figures" folder had the wrong file name designation '_a_c_' and the wrong designation in the embedded documentation. All were changed from CORRECT to FATAL in the embedded documentation and the file name test case designation from '_a_c_' to '_a_f_.'

. . .

The property-value for the property, P44_TOP_CELL, was incorrect for the following test case:

    bytes_present_a_c_s_max_unsigned_integer_width.oam

. . .

The property-value for the property, P44_TOP_CELL, was incorrect for the following test case:

    pads_present_in_p44_file_a_c_pad.oam

. . .

The propstring-reference-numbers were incorrect for the following test case and the rest of the test cases within the, Ignored, S_GDS_PROPERTY test cases:

    attr_val_pair_max_sa_ref_cntct_ndprt_i_c_s_gds_prprt.oam

. . .

The prop-string length for the following test case was incorrect:

> attr_val_pair_max_out_sa_ref_cntct_ndprt_i_w_s_gds_prprt.oam

Its length was greater than 256 characters and did not match the test case format of its corresponding test case:

> attr_val_pair_max_sa_ref_cntct_ndprt_i_c_s_gds_prprt.oam

Both issues have been fixed.

. . .

The property-value for P44_GEOMETRY_COUNT was incorrect for the following test cases:

> rep_0_coord_val_x_max_23_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_max_24_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_max_25_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_min_23_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_min_24_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_min_25_vert_trap_a_c_figures.oam
> rep_0_coord_val_x_max_rect_a_c_figures.oam
> rep_0_coord_val_x_min_rect_a_c_figures.oam
> rep_0_coord_val_y_max_rect_a_c_figures.oam
> rep_0_coord_val_y_min_rect_a_c_figures.oam
> rep_0_1_w_h_max_rect_a_c_figures.oam
> rep_0_1_w_max_rect_a_c_figures.oam
> rep_0_1_xy_space_max_rect_a_c_figures.oam
> rep_0_x_dim_max_rect_a_c_figures.oam
> rep_0_x_space_max_rect_a_c_figures.oam
> rep_0_y_dim_max_rect_a_c_figures.oam
> rep_0_y_space_max_rect_a_c_figures.oam
> w_max_rect_a_c_figures.oam

. . .

The (x,y) coordinate and x-space and y-space values were reversed within Cell_name_3 leading to bounding box values outside of the allowed bounding box w/h maximum values that were established by P44_BOUNDING_BOX_MAX.

> rep_0_1_w_max_23_horz_trap_delta_a_a_c_cell_plcmnt.oam
> rep_0_1_w_max_23_horz_trap_delta_b_a_c_cell_plcmnt.oam
> rep_0_1_w_max_24_horz_trap_delta_a_a_c_cell_plcmnt.oam
> rep_0_1_w_max_25_horz_trap_delta_b_a_c_cell_plcmnt.oam

. . .

The x-space value was incorrect for the following test case:

rep_0_x_space_max_25_horz_trap_a_c_figures.oam

Its value has been changed from dx=999999 to dx=4999999 which brought the bounding box for the cell back to within the allowed values set by P44_BOUNDING_BOX_MAX.

. . .

The width of a type 25 ctrapezoid was incorrect for the following test case:

rep_1_xy_space_max_25_ctrap_a_c_cell_plcmnt.oam

The width has been changed from width=1000000 to width=1 which brought back the bounding box for the 3rd-level cell for this test case to within the w/h limits set by P44_BOUNDING_BOX_MAX and the P44 specification, 1mm/1mm.

Update to May 5, 2017 Release

P44_GEOMETRY_COUNT values for rep0*, coordinate_val_xy* w*, h* and w_h* max, max_out and min ctrapezoid, trapezoid and rectangle regression test cases for Cell_name_2 were incorrect. These values have been updated. P44_GEOMETRY_COUNT values for Cell_name_2 were incorrect for the following Allowed and Ignored Test Cases:

byte_offset_nonzero_text_a_c_p44_geometry_offset.oam
bytes_present_a_c_s_max_unsigned_integer_width.oam
lclzd_cmn_cllnms_cmprssd_a_c_p44_common_cell.oam
xyrelative_level_2_cll_a_c_p44_localization_area.oam

All have been updated to the correct value.

. . .

The following test case file name was incorrect:

tool_name_string_length_zero_f_c_p44_conversion_tool.oam

It has been updated to:

tool_name_string_length_zero_a_f_p44_conversion_tool.oam

. . .

The validation scheme had been set to '0' for some of the, Ignored, S_GDS_PROPERTY regressions. They've been updated to a validation scheme of '1.'

Update to January 5, 2017 Release

Yotta had set the P44 version number for the P44 property, P44_VERSION, to P44_0316. It should have been P44-1216 which is the latest version. Furthermore, for this version of test cases, Yotta had set the P44 version to P44-0316 which is incorrect. The correct version is P44-1216. Both errors have been fixed.

. . .

The format for the <date> field within the property P44_CONVESRSION_DATE was incorrect. We've fixed this from MM_DD_YYYY to DD-MM-YYYY. Yotta will be using this field to express the date of the test case update. If Yotta finds that it will need to update the byte offsets for all P44 localization PROPERTY records, it will add a "test case revision date" text string to its embedded documentation. The value for this property has been changed from 01_01_2016 to 29-04-2017.

. . .

The test case, '*all_mandatory_records_ina_ena_mix_s_m_f_oamismask.oas*,' should have had a mix of implicit and explicit string and name references. Unless the *-keep* argument is set while converting text to OASIS, by default, Yotta's OASIS implementation will convert all mixed sets of implicit and explicit reference number assignments to implicit, only. The test case file name flag that tells Yotta to use this argument, as it updates its test cases, is '_k_.'

The test case and file name have been fixed:

> *all_mandatory_records_ina_ena_mix_s_m_f_k_oasismask.oam*

. . .

We've updated one test case which tests the allowed maximum length of a P44 file name that has no file extension. The update changed the maximum allowed length from 64 to 56 characters and changed the test case designation from CORRECT to WARNING.

> OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO_w

In the section, below, called 'File Name,' Yotta explains why the length of such a file name should not be greater than 56 characters.

. . .

The test case file name '*attr_val_pair_max_out_sa_ref_cntct_ndprt_a_w_s_gds_prprt.oas,*' was incorrect. The tested property, S_GDS_PROPERTY, is an ignored (_i_) property in P44, not allowed (_a_). The name of the corrected test case file name is:

> *attr_val_pair_max_out_sa_ref_cntct_ndprt_i_w_s_gds_prprt.oas*

. . .

The embedded documentation for the test case, '*pad_text_in_empty_top_cll_m_c_s_bounding_box.oas.txt,*' has changed from:

> '*PAD and TEXT records are allowed in the top cell. In this case, a PAD and TEXT record are present in an empty the top cell.*'

To:

'In this case, the PAD and TEXT records are part of the top cell. TEXT and PAD records are allowed in the Top cell. A TEXT record's bounding box is ignored. So, it is not contributing to whether the cell is empty. The PAD record is not contributing to whether the bounding box is empty since it is dimensionless. In other words, the cell is empty. A 3rd-level cell cannot be empty. It must contain at least one figure whose width and/or height cannot be zero. A 2nd-level cell cannot be empty because it must reference a 3rd-level cell that cannot be empty. The only other type of cell allowed in P44 is the top cell. A top cell can be empty if it is the only cell in the P44 file. Even though a TEXT and PAD record are present in the cell, the top cell remains empty since it does not reference a non-empty 3rd and/or 2nd-level cell. Last, because the only cell present in the P44 file is the top cell, the file has only one level of cell hierarchy.'

The bounding box flags field for the test case, *'pad_text_in_empty_top_cll_m_c_s_bounding_box.oas.txt,'* has changed from '000' to '010.' The value was incorrect.

SEMI OASIS.MASK Regression Test Cases

P44-1216

Developer's Notes

Overview

SEMI P44 is a photomask layout data specification. It specifies a way to organize layout data so that mask writers, inspection systems and other, aligned, applications can run their operations as efficiently as possible. The specification is complex in its methods and requirements. P44's methods and requirements not only specify how to organize, package and place layout data in an efficient way. It specifies the limits to the breadth of the coordinate space in which the organized, tightly packaged, data will be placed. It, as well, specifies the allowed size of figures, cells, repeated figures and cells, names, strings and cell hierarchy.

Yotta's test cases realize the specification's methods and requirements by breaking down all offered by P44 into meaningful, very discrete, P44 data expressions. They're constructed in a way to teach the user about P44's possibilities and question (query) a P44 reader's ability to gracefully interpret and report about what it had read. They're constructed as well, in a logical way/progression so that any analysis of a test case can be done by hand. The differences between a CORRECT and FATAL test case, in almost all test cases, are one to two bytes.

The company attempts to clarify language used in the specification by coalescing the use of multiple terms that have the same meaning. It defines each but cross-references them and points to just one term. As an example, Yotta does not use the terms "region cells" and "repetition cells." It defines and cross-references them to 2nd-level and 3rd-level cells as the default terms. Yotta will be using the term, "chip window," to mean a drawing window or a drawing area which is to be derived from the figure operation window extraction process listed in Table 1 of the specification. A chip window will be defined as the full extent of the coordinate space after factoring in the coordinate spaces for all layers of a single chip layout. The chip window can be equal to or larger than this extent but, never, smaller. This space is expressed with each P44 file by the property, P44_CHIP_WINDOW. With few exceptions that test chip windows that are larger and smaller than the bounding box of the top cell, each of the rest of Yotta's test cases has this property's property-values set to be equal to the bounding box for the top cell.

Yotta believes that P44 leaves too many implementation options available; worse yet, options that will hinder reaching a stable set of best practices for those using the specification. As examples, P44 allows a mix of implicit and explicit cell referencing methods. It demands that all CELLNAME records must be ordered implicitly by reference number but makes no such requirement for PROPNAME, TEXTSTRING and PROPSTRING records. P44 states that property-value strings can be stored locally or be implied by reference number to a PROPSTRING which stores the prop-string. P44 states that CELLNAME and PROPNAME records, while present, can only be present while in strict mode and their names and cell references cannot be stored locally yet it does not make the same requirement for a PROPERTY record's prop-strings. Again, allowing prop-strings to be stored locally in a PROPERTY record in what is, essentially,

a P44 file in strict mode seems to add considerable complexity to what a reader must properly interpret. Other than to test how the reader interprets such a mix of referencing methods, Yotta's test cases store all names and strings with their CELLNAME, PROPNAME, PROPSTRING and TEXTSTRING records.

There are loosely defined property-value types by P44 that, simply, complicate its use. As an example, allowing the property-value <zone> from the property, P44_CONVERSION_DATE, to be any real number type causes a P44 reader to do more interpretive work than it really should be required to do.

P44 allows the use of TEXT records yet the record is to be ignored by a P44 reader. They are a factor while determining the geometry-offset for the property, P44_GEOMETRY_OFFSET. The extent of their coordinate space, however, is excluded (ignored) by a P44 reader for all cells. Although to be ignored, their syntax and limitations must be interpreted and a formalized response reported by a P44 reader. They influence the byte-offsets for many properties tracked by a P44 reader. Instead of P44 classifying this record as one to be ignored, Yotta believes that P44 should allow a TEXT record but exclude the extent of its coordinate space while determining and reporting the coordinate space for a cell.

Yotta has assumed, here, that a compressed PAD record at the very beginning of a CBLOCK record cannot be used as a byte-offset for CELL, CELLNAME, PLACEMENT and figure records. The rationale, here, is that a PAD record must not be pointed to as the byte-offset locater to any of these records while not compressed. As an example, the property-value for the property, P44_GEOMETRY_OFFSET, must not point to a PAD record that is present after all gathered PLACEMENT records and before the first TEXT or figure records present within a 2nd-level cell.

Yotta's test cases focus on what it believes to be P44 best practices. While being only as much, it attempts to cover all conceivable possibilities that are mandatory, allowed, ignored and prohibited by the specification. Yotta asserts, as best practices, the implicit use of reference numbers for all names, strings and cells, the table-offset structure in strict mode for all names and strings, including TEXTSTRING, LAYERNAME and XNAME flag fields, and asserts the storage of the table-offsets structure in the END record. Generally, Yotta's test cases exercise the capabilities of the latest, approved but yet to be published, SEMI P44-1216 specification.

The test cases, here, will be setting a precedent for the mask layout community using P44. This means that how and what Yotta has set as the designations (i.e. a test case being CORRECT, a WARNING or FATAL) for the test cases have not been vetted and agreed upon, collectively, by its Users. Establishing a consensus about how to rate each type of test case will, dramatically, increase their value to not just the user as a problem-solving tool but also increase their value across multiple platforms and mask tool applications. Yotta will be welcoming input regarding this matter.

In this document is a summary of the test case categories followed by detailed descriptions of each as they relate to Yotta's test case coverage and coverage strategy. This document tells the user how the test cases are constructed/organized - in whole and in part - and tells about what can be expected from them. It offers an overview of what one can expect with each class of test case. Furthermore, each test case has its own, embedded, documentation. The version of the P44 specification, test case designation, P44 sections, figures and tables and a detailed test case description are part of the embedded documentation.

Each test case has a telling file name. The name aids with the analysis and identification of any, problematic, test cases. Yotta maintained a strict use of P39 and P44 terms in the file names. Some needed to be abbreviated but have been listed in a table below that cross-references to their full names.

This document has a table of contents, two definitions sections and an index which Yotta hopes will help with the interpretation of the test cases while gaining a thorough understanding of how P44 can be represented and expressed in the best ways possible.

Test Case Categories

The breadth of the Yotta regression test cases start with a set of corner test cases having the following categories - in alphabetical order:

(1) allowed
(2) file name
(3) ignored
(4) mandatory
(5) prohibited

The corner test cases express the limitations to the language of P44 and express deliberately-set errors to values that should cause the reader to properly interpret and report the errors. If the test case is not properly interpreted, then the embedded documentation explains why the test case should be interpreted as we have.

A sub-category of test cases falls under the main category, 'Allowed.' They are listed here by their rising level of complexity ending with two localized areas where one of the localized areas has only one common cell present.

(1) figures
(2) cell placement
(3) top cell placement
(4) localized area
(5) localized areas
(6) common cells

Each sub-category establishes the limitations of the space specified by the P44 specification. We start with what can be done with figures in a 3rd-level cell and placed in a, 1st-level, top cell. Then, we raise the reach of the 3rd-level cells to the placement of those cells within a 2nd-level cell and top cell. The emphasis being the limits of what can be done as a 2nd-level cell which is limited to a bounding box width and height of 1 mm and a lower-left and upper-right coordinate space of -2^{31} to $+2^{31}-1$. We bring the reach further again where we test the top cell and its ability to handle a processing space greater than 32-bits. These tests occur within the sub-category, 'top cell placement'. This set of test cases can be localized but is not. The data is not contiguously gathered and defined, either.

Each category, thereafter, must, at the very least, have the P44 data contiguously gathered by CELL, CELLNAME and have gathered placement records into one or more localized areas in the top cell. We

start with a set of test cases which only has one localized area (i.e. *Localized Area* test cases). We progress from there to two localized areas (i.e. *Localized Areas* test cases) but having no common cells as defined by P44. Last, we offer test cases that contain two localized areas one, of which, contains only one common cell (i.e. *Common Cell* test cases).

Each sub-category reaches to the outer limits of what can be done with P44 in a progressively complex manner. By the end, a user's reader will be required to properly interpret and match all of the value lists offered by the following properties in use by the P44 specification.

1. S_BOUNDING_BOX,
2. S_CELL_OFFSET,
3. P44_BOUNDING_BOX_MAX,
4. P44_GEOMETRY_COUNT,
5. P44_GEOMETRY_OFFSET,
6. P44_CHIP_WINDOW,
7. P44_LOCALIZATION,
8. P44_LOCALIZATION_AREA and
9. P44_COMMON_CELL.

Test Case Designations

Each Yotta test case has been assigned a 'Test Case Designation.' There are three designations:

- CORRECT
  - A test case which a P44 reader should interpret as being correct to read and process as specified by SEMI P44-1216. An example would be a test case that contains a cellname-string that is 256 characters long which is the maximum allowed length for a cellname-string defined by SEMI P44-1216.
- WARNING
  - A test case which a P44 reader should interpret as being correct according to SEMI P44-1216 but being worthy of a warning about the test case not being a best practice. It could be that a coordinate value in the file is approaching a processing space that, if exceeded, will produce unreliable or incorrect results. An example would be Yotta issuing a warning for bounding box calculations that have integers in use that exceed 14 decimal digits of floating point precision.
- FATAL
  - A test case which a P44 reader should interpret as being outside of a specified maximum/minimum value, a missing record that is mandatory, a missing record of pair of allowed records that must be present together, a character string that is not of a specified type, such as an a- or n-string, etc. An example would be a P44 file that does not have the mandatory property, P44_GEOMETRY_COUNT, present.

Yotta's test cases will be the first commercial P44 regression test case product that suggests how a P44 reader should interpret regressive data that it might encounter from P44 writers writing out from other applications and from different applications' suppliers. Yotta offers these designations having a hope that a common understanding materializes about what the designations should be.

Figure Operations Implemented Prior to Writing a P44 File

Yotta can test whether the following, P44-1216, Table 1, Figure Operations have taken place:

- Window extraction
- Layer merge
- Logical operation
- Overlap removal
- The division of polygons into trapezoids

Yotta has assumed that an extracted window is a chip window, also known as a drawing area or a drawing window. It defines the extent of the coordinate space that encompasses all layout data from all layers of a single chip. This window can be larger than or equal to the bounding box of this top cell. For testing purposes, the property-values for the property, P44_CHIP_WINDOW, follow the bounding box coordinate values for the top cell of each P44 file. Yotta has done so to verify the extent of the allowed coordinate space offered by P44 for this property.

Yotta cannot test whether the following figure operations have taken place:

- Sizing
- Scaling
- Mask scaling
- Mirroring
- Inverting
- Rotation

Yotta does, however, provide test cases which include sizing, scaling, mirroring, inverting and rotation as operations requested within a P44 file. Yotta treats these expressions by a P44 file as fatal errors.

The property, P44_FORMAT, is tied to the current state of the Figure Operations table. If the figure operations table changes, so too will the value for this property. Currently, this value is set to '1.' It means the following:

> A property-value of '1' for the property, P44_FORMAT, describes the requirements offered by the figure operations list of Table 1. All of the operations listed, as items, in Table 1, must be completed before a chip's layout data can be written out as a P44 file.

In the future, it may be that trapezoids will not be required to be divided prior to writing of a P44 file. In this case, the property-value for this property will change to '2.'

Mandatory Test Cases

A P44 file is not a P44 file unless it contains certain P39 and P44 record types. These are declared in the P44 specification. Yotta's test cases offer the absence of each of the mandatory record types and treat their absence as fatal errors. Except for the testing of bounding box and coordinate space restrictions for these records, Yotta tests all other P44 restrictions defined for them. String length minimums and maximums, property values that are fixed to a certain value or set of values, property-value restrictions,

restrictions on validation schemes, unit-declaration maximums and minimums, etc. are just some of the P44 restrictions tested by Yotta's test cases.

Yotta has assumed that the P39 record, PROPSTRING, is mandatory as, for the same rationale, are CELLNAME and PROPNAME records. Being that the P44 file will, always, be in strict mode and its referencing system implicit, a property-value that contains a prop-string must be referenced implicitly through, a type 9, PROPSTRING record. The prop-string cannot be stored, locally, with a PROPERTY record even though the P44 specification allows the storage of prop-strings locally.

START/END Records

P44 restricts CELLNAME, PROPNAME and PROPSTRING record types to strict mode whether stored in the START or END record. It does not declare the same restriction for TEXSTRING, LAYERNAME and XNAME record types. With few exceptions, the test cases have all flag fields within the table-offsets structure set to strict mode. Yotta issues a WARNING for the test case exceptions where the flag fields for TEXTSTRING, LAYERNAME and XNAME have been set to a value, '0.' Yotta does not make an attempt to test each separately. The rationale here is that a written out P44 file should be finished and ready to be printed to a photomask. I single writer should be writing this file using a consistent P44 method.

P44 allows the table-offsets structure to be stored in the START or END record. With few exceptions, Yotta's test cases store the table-offsets structure in the END record. Yotta's test cases designate a WARNING for all table-offsets structures stored in the START record. Why? There is no simple way to insert proper table offsets in the START record. One of the reasons for placing the offset-table in the END record is that it will never cause table offsets to change because of variable-length integers. The only safe way for any program to put table offsets in the START record is to insert PAD records after the START record, write the remainder of the file, and then overwrite the original START record with new offsets. Any increase in the length of the START record would be absorbed by overwriting PAD records, assuming there are enough. Table offsets in the START record are not really a useful feature. They should have been omitted from the specification.

CELLNAME Record

P44 restricts the CELLNAME record type to a type '3.' With few exceptions, Yotta's test cases assume that the reference-number for all P39 names and strings are assigned implicitly. Even though P44 allows explicit reference-number assignment for PROPNAME, PROPSTRING and TEXTRING records, Yotta issues a WARNING for a mix of implicit and explicit reference-number numbering systems within the same file.

PROPNAME Record

The P39 record, PROPNAME, must be present in a P44 file for all mandatory PROPERTY records. P44 'allows' the use of reference numbers rather than 'requires' their use which contradicts the requirement by P44 that a PROPNAME record, while present, must be in strict mode. P39 guarantees that, while in strict mode, all cells, names and strings are made by reference number. Therefore, the use of reference numbers by PROPNAME record is required. The storing of a property-name locally must be treated as a fatal error.

PROPSTRING Record

P44 only allows a PROPSTRING record type to be present while it is in strict mode. While in strict mode, P39 guarantees that all references to a corresponding class of objects (i.e. names, strings or cells) are made, exclusively, by reference-number. Because there are mandatory P44 properties

> P44_FORMAT,
> P44_VERSION and
> P44_CONVERSION_DATE

within a P44 file whose value list contains property-value types that are prop-strings, a PROPSTRING will, necessarily, always be present in a P44 file since the property-value string cannot be stored locally while in strict mode.

Currently, the P39 PROPSTRING record has been declared as 'Allowed' in a P44 file. Yotta assumes throughout all of its test cases that the PROPSTRING record MUST be present. The P39 record type, PROPSTRING, must, always, be present within a P44 file. Yotta treats the absence of a, type 9, PROPSTRING for the above mandatory property-values in a P44 file as a fatal error.

CELL Record

A single CELL record, according to P44, can be empty for the top cell, only, but not absent from a P44 file. A P44 file must have, present, at least one, minimally expressed, CELL record, an empty top cell.

The only cell that can be empty is the top cell. There can only be one level of hierarchy while an empty top cell is present. The placement of a second, empty, cell by the top cell is prohibited in a P44 file. Such a file cannot be represented or expressed in or by a P44 file. Yotta treats any 2nd-level and 3rd-level cell without any PLACEMENT or figures or PLACEMENT records present as undefined, prohibited and a fatal error.

An empty top cell can be localized. The property-value, <placement-offset>, for the property, P44_LOCALIZATION_AREA must be fixed to a value, '0.'

There are only three levels of hierarchy that Yotta tests; the top, 2nd-level and 3rd-level cells.

The following defines each level of hierarchy:

(1) 3rd-level cell – can contain figure, PAD and TEXT records. A 3rd-level cell cannot refer to (place) any other cell. Other terms, meaning the same, would be a 'leaf cell,' 'bottom cell' or 'repetition cell.' It must contain at least one figure record. A 3rd-level cell can be placed by the top cell or placed in the top cell from a 2nd-level cell. A placed 3rd-level cell within the top cell defines a unique region of the top cell. It can overlap with other placed cells within the top cell but its figures cannot overlap. A 3rd-level cell can be repeated within the top cell. It can overlap with the other repeated cells within the top cell but its figures cannot overlap.

(2) 2nd-level cell – can contain figures, cell placements, PAD and TEXT records. A 2nd-level cell can refer to any other cell other than itself and the top cell. Another term, meaning the same, would be a 'region cell.' While the property, P44_GEOMETRY_OFFSET, is in use, all cell placements must

be gathered and appear before a cell's figures and TEXT records. A 2nd-level cell defines a unique region of the top cell. A 2nd-level cell can be repeated within the top cell. It can overlap with other repeated cells within the top cell but its figures cannot overlap.

(3) Top cell (not localized) – can contain cell PLACEMENT, PAD and TEXT records in any order of appearance. Another term, meaning the same, would be a '1st-level cell.'

(4) Top cell (localized) – can contain PLACEMENT, PAD and TEXT records. For each localized area, the cell placements (i.e. 2nd-level and/or 3rd-level cells) must be gathered and located in one contiguous location within the top cell. Another term, meaning the same, would be a '1st-level cell.'

PROPERTY Record

P44 declares that a P39 PROPERTY record must be present within a P44 file. Not all PROPERTY record types must be present in a P44 file. For instance, it is not mandatory to have the property, P44_LOCALIZATION, present in a P44 file. If, however, this property is present within a P44 file, it will be mandatory that the property, P44_LOCALIZATION_AREA, is present in the file as well.

S_BOUNDING_BOXES_AVAILABLE Record

P44 requires that all cells, including the top cell, report a bounding box along with its corresponding CELLNAME record. If this property reports a value of '0,' it means that no cells have a reported bounding box. If this property reports a value of '1,' it means that not all cells have a corresponding bounding box reported. If the property reports a value of '2,' it means that all cells have a reported bounding box. Any property-value for this property, other than a value of '2,' must be treated as a fatal error.

S_BOUNDING_BOX Record

The w/h values for the P39 property, S_BOUNDING_BOX, can be less than or equal to 1 mm for all 2nd- and 3rd-level cells. The placement of a figure or cell at these levels cannot exceed a 32-bit processing space. The same w/h property-values cannot exceed a 64-bit processing space for the bounding box of the top cell. Only an empty top cell can have a w/h value of zero.

The smallest bounding box w/h allowed by P44 is 1/1 at a unit-declaration of 1000000. The largest bounding box width/height allowed for 2nd- and 3rd-level cells is 1 mm. The largest bounding box width/height allowed for the top cell is 999999999999999/999999999999999 at a unit-declaration of 1000.

The lower left-most and upper right-most corner of a 2nd- and 3rd-level cell's bounding box cannot exceed the 32-bit coordinate space. The lower left-most and upper right-most corner of the top cell cannot exceed a 64-bit value that would lead to mask layout errors caused by the rounding of floating point numbers to integers. Yotta has assumed that all mask layout operations will be converting integers to and from floating point numbers a minimum of 3 times.

P44 does not allow the referencing of cells from another p44 file. Therefore, all of this property's flags fields that are related to a cell being referenced in another P44 file (i.e. flags fields 001, 101, 011 and 111) are prohibited in a P44 file.

All cell bounding boxes are required to be known for all cells within a P44 file. Therefore, all flags fields where the flag defines the bounding box as unknown (i.e. flags fields 100 and 110) are prohibited in a P44 file.

A bounding box cannot be undefined, except for the top cell. An empty top cell means that there are no other cells in the P44 file. An empty top cell can contain placed and repeated TEXT and PAD records but not text placed by another 2nd- or 3rd-level cell. The corresponding bounding box cannot include in its interpretation of the empty top cell the bounding box of placed or repeated TEXT records.

Only two flags fields are allowed by P44 for this property. They are 000 and 010.

The bounding boxes for all TEXT records placed within all non-empty cells, including the top cell, are ignored and, thus, not part of the values reported for this property.

S_CELL_OFFSET Record

A value of '0' for the property, S_CELL_OFFSET, means that the CELL record is not present in the P44 file being read but, instead, present in another, external, P44 file. P44 prohibits the use of externally referenced cells for all, three, cell levels. All cells that comprise the full mask layout must be present in the same P44 file and present in the top cell.

P44_FORMAT and P44_VERSION Records

As a P44 file is being ingested, it will be important to know whether the file format and version that had been written by a P44 writer matches the format and version used by a P44 reader. The property, P44_FORMAT, has its value fixed to '1.' The property, P44_VERSION, has a fixed property-value of P44-1216. If the values do not match, Yotta reports as a fatal error.

If the property-value for P44_FORMAT has changed, so too must have the property-value for P44_VERSION. As an example, P44-FORMAT cannot be fixed to '2' and P44_VERSION still be P44-1216.

Yotta believes that this property is superfluous and prone to error. Still, though, Yotta tests for the current fixed values.

P44_CHIP_WINDOW Record

This P44 property, P44_CHIP_WINDOW, declares a chip layout by the extent of its coordinate space for all placed cells for all layers within the top cell, excluding all TEXT record coordinate data. This window is populated from a window extraction process that has been noted as part of the figure operations Table, 1; an operation that must be completed before a writer writes out to a P44 file. The coordinate values for this property can define a space whose extent is greater than or equal the bounding box of the top cell in a P44 file but cannot be less than the coordinate space for its bounding box. The chip window in this specification is also referred to as a drawing area or drawing window.

This property is fixed to '0' only while the top cell is empty. The smallest four chip windows having the smallest coordinate values have the following (x1,y1,x2,y2) coordinates (0,0,1,1), (0,0,1,-1), (-1,-1,0,0) and (-1,1,0,0). The negative-most coordinate values for this property are (-999999999999999,-999999999999999) and the positive-most values are (999999999999999,999999999999999).

For testing purposes, this property's property-values follow the coordinate space of the bounding box of the P44 file test case top cell. In practice, however, this property will be arbitrarily defined and equal to or larger than the extent of the coordinate space for all layers within a chip-level design.

P44_TOP_CELL_NUMBER Record

All references to names, strings and cells must be defined by a reference numbering system that is implicit. Therefore, a top cell reference-number of '0' can only be present while the cell is empty and no other cells are present.

P44_CONVERSION_DATE Record

Yotta tests the zone field for the property, P44_CONVERSION_DATE, at different real number property value types. It issues a warning designation for the real number property-values, 2-5, and issues a CORRECT designation for zone fields expressed by real types 0, 1, 6 and 7. Yotta issues a fatal designation for property-value types 8, 9, 13 and 15.

There seems to be an unnecessary amount of complexity surrounding the definition of this property from a test case development standpoint; particularly for the zone field which is defined, broadly, as a 'real number.' There seems to be no rationale for the use of any P39 real number type other than a real type 6 or 7. Even a real type 7 is unnecessary. These two real number types, however, allow for both positive and negative fractions of an hour.

P44_GEOMETRY_OFFSET_AVAILABLE

The P44 property, P44_GEOMETRY_OFFSET_AVAILABLE, must be present within a P44 file but its values (0 or 1) define whether the property, P44_GEOMETRY_OFFSET, is present for all 2nd-level cells within the P44 file. A value of '0'means that its corresponding property is not present in the P44 file. A value of '1' means that the corresponding property, P44_GEOMETRY_OFFSET, must be present for all 2nd-level cells within the P44 file.

P44_GEOMETRY_COUNT

The property, P44_GEOMETRY_COUNT, must be present in a P44 file. The property must be present for all cells, including the top cell. The property-value for the top cell must always be '0.'

String length, type and property-value restrictions

Yotta tests P44 string length, string type and property-value type restrictions. Yotta has assumed, by these particular test cases, that any restriction not met will be treated as a fatal error.

A string or name present within a P44 file must be an implied string. Any string that is not implied is treated as a fatal error by Yotta.

Allowed Test Cases

Yotta treats a P44 'Allowed' test case as having some meaningful impact on the output by the mask writer whether the impact related to the physical layout of the mask data or the efficiencies by which the allowed layout data is handled by mask writers, inspection systems and other processes that are aligned with the writing and inspection of the mask layout data.

There are two classes of test cases for this category. The first tests the maximums and minimums specified for the allowed records as they relate to layer and datatype, placement angle/rotation and flip, prohibited repetition types, name string length maximum and minimum values, name string property-value types, allowed and prohibited variants of localized and common cells within localized areas, use-variants for P44_GEOMETRY_OFFSET, discontiguous record placements for non-localized P44 data, etc.

The second class of test cases tests a P44 reader's ability to match its interpretation of the test cases with P44's property-value lists stored by the test cases. They, progressively, bring together all of what P44 has to offer from non-localized data to localized data having common cells. The test case data resides at P44's allowed furthest reaches for mask layout data. Particularly notable is the emphasis of the test cases on the interplay of the property-value lists, both mandatory and allowed, by P44. They must match as a whole. Yotta attempts to touch every corner/edge of the four quadrants of the Cartesian coordinate system. The notable property-value lists tested are:

(1) S_BOUNDING_BOX,
(2) S_CELL_OFFSET,
(3) P44_BOUNDING_BOX_MAX,
(4) P44_GEOMETRY_COUNT,
(5) P44_GEOMETRY_OFFSET,
(6) P44_CHIP_WINDOW,
(7) P44_LOCALIZATION,
(8) P44_LOCALIZATION_AREA and
(9) P44_COMMON_CELL.

The difference between a test case that is designated by Yotta as CORRECT versus a WARNING or a FATAL error is one to two grid units. Yotta believes that its test cases are organized enough in their intent that any troubling test cases can be hand-analyzed and hand-verified. From the starting test case category called 'Figures' to the ending category called 'Common Cells,-' the test cases build on hierarchy, the contiguous gathering of data, the limits pertaining to 2nd- and 3rd-level cells versus the top cell, localized cells - both with and without common cells - and single and multiple localized areas.

The purpose of these test cases is to ensure that every point of the processing space allowed by P44 has been touched which, Yotta hopes, will give some comfort about how its P44-enabled operations will interpret layout geometry in the field.

Immediately following is additional information about each sub-category. We start by showing the map of the processing space we test. Then, we discuss each of them, individually.

32- and 64-bit Coordinate Space
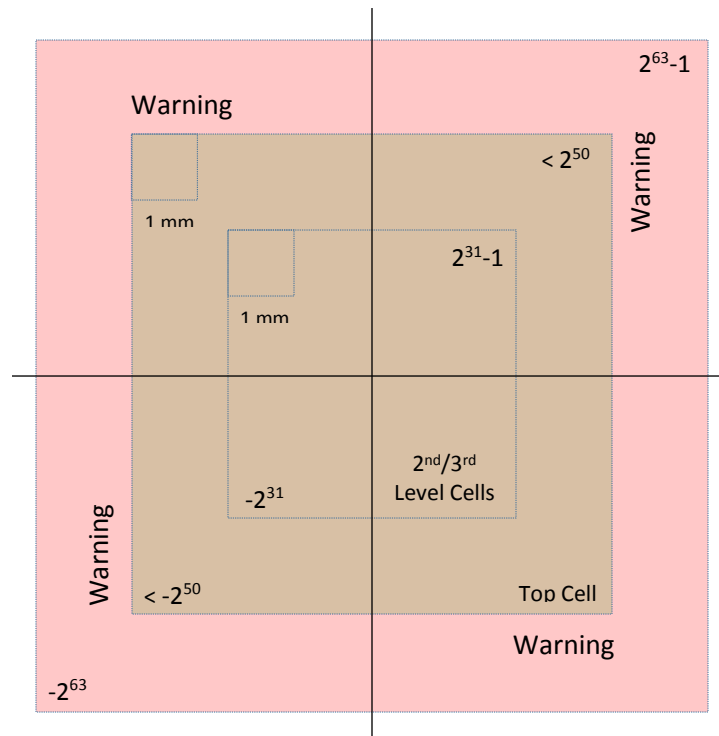
This figure attempts to place the relationships between the various coordinate values in play within a P44 file.

Yotta's test cases test the furthest reaches of a 64-bit processing space without round-off error becoming a factor. The bounding box width and height values for 2nd- and 3rd-level cells can be no greater than 1 mm. They, however, may be placed so that the upper-right most coordinates of such a placed cell do not exceed 2^{31}-1 and the lower-left most coordinates do not exceed -2^{31}.

2nd-and 3rd-level cells can be placed within a top cell so that their left- and right-most coordinates do not exceed an arbitrarily-set numerical value, 14 decimal digits long, (+/-) $9.99999999999999 \times 10^{14}$. Yotta has assumed that, generally, it can be expected that integer data will be converted to and from double-precision floating point numerical representations. Beyond this value, such a conversion can lead to incorrect results. At this value, Yotta issues a warning pointing out that, beyond this value, there is a significant chance the rounding off of floating point numbers to integers will contribute to incorrect results.

Although Yotta has arbitrarily set the minimum/maximum to this value, it is not clear whether mask tools universally use floating point numbers. Until the company receives requests to increase this arbitrarily-set value, Yotta will maintain this value as the maximum integer value allowed within a 64-bit coordinate space.

Figures Test Cases

Top Cell

3rd-level cell

*R-1   R-2   R-3

Cell Content:
. 1 to 4 figures
. Repetitions 0-3
. TEXT records
. No PAD records

*R – repetition, including variants of R-0 type
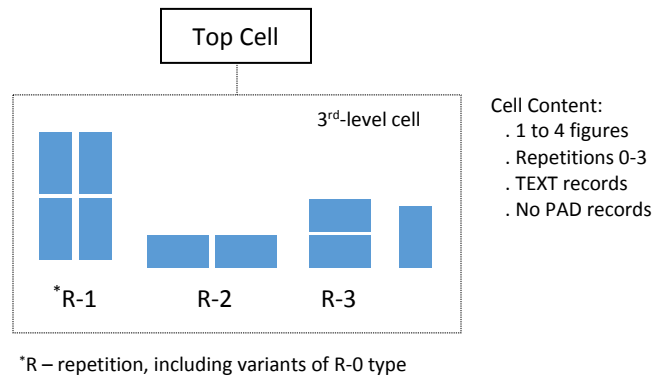
The '*Figures*' test cases have a theme. There are two levels of hierarchy. There can be one to four figures per 3rd-level cell. 2nd-level cells are not present. The 3rd-level cells are placed by the top cell only. P44_LOCALIZATION and P44_LOCALIZATION_AREA are not present.

Test cases are present that exercise figure-based repetition types 0-3 at their minimum and maximum repetition, x- and y-space, values. Yotta tests figure repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 2nd- or 3rd-level cell size having a width/height of '1.'

These *Figures* test cases reach the outer 32-bit, four-quadrant, limits of the Cartesian coordinate system and bounding box width and height of 1 mm, for a 3rd-level cell, allowed by P44.

Cell Placement Test Cases

Top Cell

2nd-level cell

R-2   R-3

Cell Content:
. 1 to 4 placements
. No figures
. Repetitions 0-3
. No TEXT records
. No PAD records

3rd-level cell   3rd-level cell

Cell Content:
. 1-4, 3rd-level cells
. 1 figure per cells
. No repetitions
. TEXT records
. No PAD records

*R – repetition, including variants of R-0 type
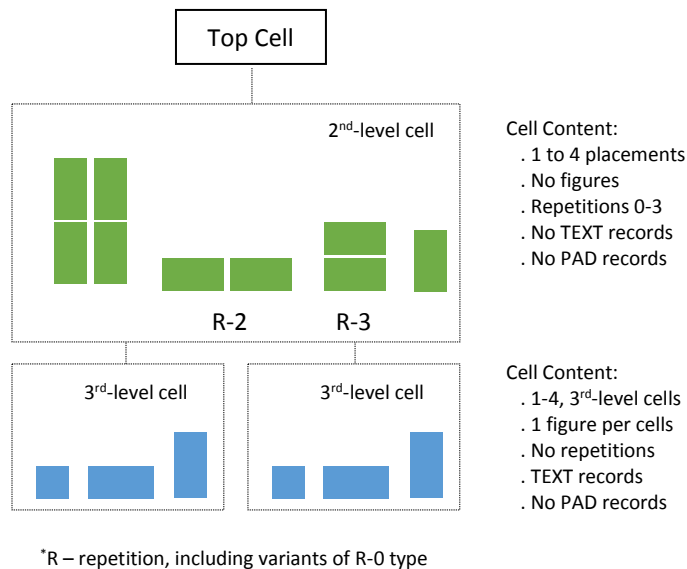
The *'Cell Placement'* test cases have a theme. There can be one to four placements per 2nd-level cell without figures. There will be one 2nd-level cell per test case. The P44 properties, P44_LOCALIZATION and P44_LOCALIZATION_AREA, are not present.

Test cases are present that exercise 2nd-level cell placement repetition types 0-3 at the minimum and maximum repetition, x- and y-space, values. Yotta tests repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 2nd- or 3rd-level cell size having a width/height of '1.'

These *Cell Placement* test cases reach the outer 32-bit, four-quadrant, limits of the Cartesian coordinate system and bounding box width and height of 1 mm, for a 2nd-level cell, allowed by P44.

Top Cell Placement Test Cases

*R – repetition, including variants of R-0 type
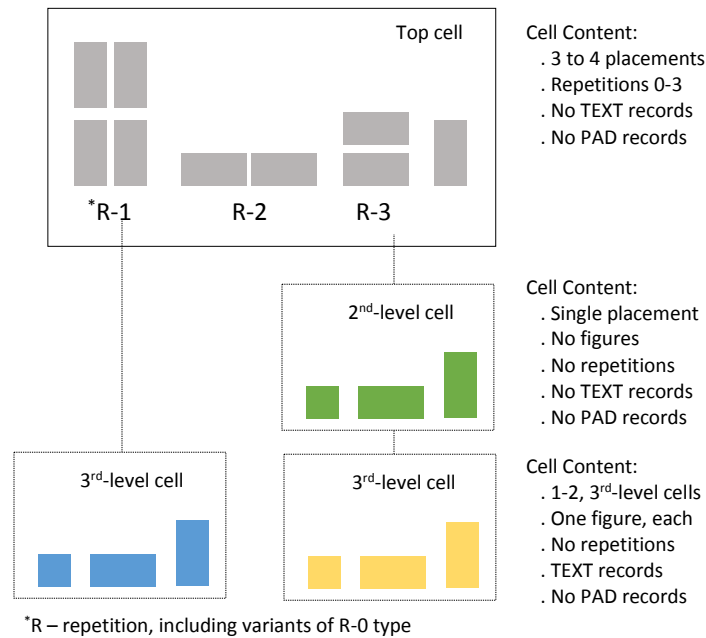
The '*Top Cell Placement*' test cases have a theme. There are three levels of hierarchy. The layout geometry carries from the *Common Cell* and *Localized Areas* test cases.

P44_LOCALIZATION and P44_LOCALIZATION_AREA are not present. The 2nd- and 3rd-levels cells have not been gathered and contiguously defined; unlike the cells that have been contiguously defined within the *Common Cell* and *Localized Areas* test cases. Without the property, P44_LOCALIZATION, being specified, cells can be present in any order within the P44 file and placed in any order within the top cell.

Test cases are present that exercise top cell placement repetition types 0-3 at their minimum and maximum repetition, x- and y-space, values. Yotta tests repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 2nd- or 3rd-level cell size having a width/height of '1.'

These *Top Cell Placement* test cases reach the outer 32- and restricted 64-bit, four-quadrant, limits of the Cartesian coordinate system allowed by P44.

Localized Area Test Cases

Top cell

Cell Content:
. 1 to 4 placements
. 1 localized area
. Repetitions 0-3
. No TEXT records
. No PAD records

*R-1   R-2   R-3

One localized area

Cell Content:
. 1-4, 3rd-level cells
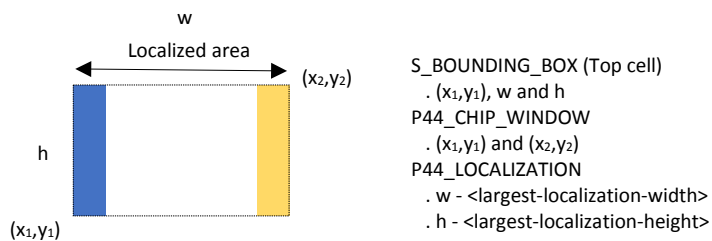. No repetitions
. TEXT records
. No PAD records

*R – repetition, including variants of R-0 type
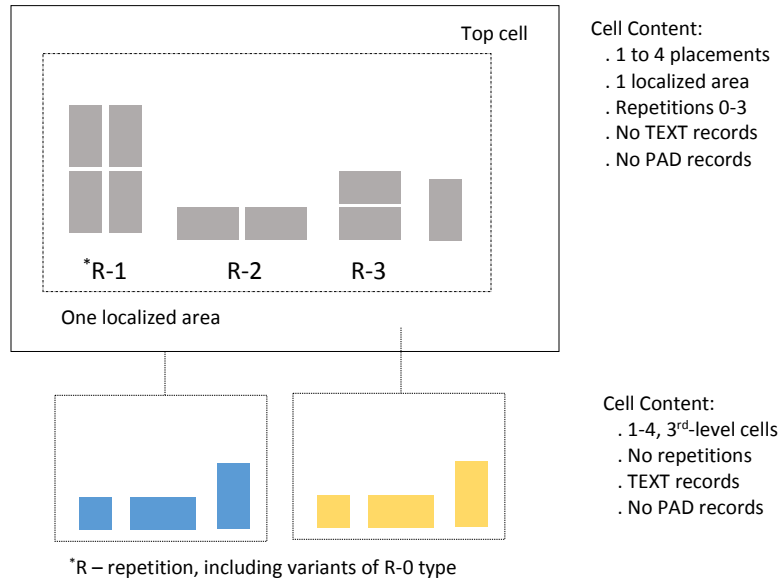
The '*Localized Area*' test cases have a theme. There are two levels of hierarchy. There is a single localized area. It may contain one to four placed 3rd-level cells. There are no 2nd-level cells amongst these test cases.

The bounding box for the localized area will be determined by width and height for the bounding box of the top cell. The two fields for P44_LOCALIZATION, <largest-localization-width> and <largest-localization-height>, should be the top cell bounding box width and height. The field for P44_LOCALIZATION, <largest-localized-area-cell-volume>, should be the cell volume of all 3rd-level cells. It's bounding box and coordinate space should never fall outside of the bounding box of the top cell.

w

Localized area

(x_2,y_2)

h

(x_1,y_1)

S_BOUNDING_BOX (Top cell)
. (x_1,y_1), w and h
P44_CHIP_WINDOW
. (x_1,y_1) and (x_2,y_2)
P44_LOCALIZATION
. w - <largest-localization-width>
. h - <largest-localization-height>

Test cases are present that exercise top cell placement repetition types 0-3 at the minimum and maximum repetition, x- and y-space, values for P44. Yotta tests repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 3rd-level cell size having a width/height of '1.'

These *Localized Area* test cases reach the outer 32- and a restricted 64-bit, four-quadrant, limits of the Cartesian coordinate system allowed by P44.

Localized Areas Test Cases

Top cell

Cell Content:
- . 3 to 4 placements
- . 3 localized cells
- . 2 localized areas
- . Repetitions 0-3
- . No TEXT records
- . No PAD records

*R-1   R-2   R-3   Localized area #1

*R-1   R-2   R-3   Localized area #2

2nd-level cell   2nd-level cell

Cell Content:
- . 1 placement
- . No figures
- . No repetitions
- . No TEXT records
- . No PAD records

3rd-level cell   3rd-level cell

3rd-level cell

Cell Content:
- . 2, 3rd-level cells
- . 1 figure per cell
- . No repetitions
- . TEXT records
- . No PAD records

*R – repetition, including variants of R-0 type

The *'Localized Areas'* test cases have a theme. There are three levels of hierarchy. The layout geometry carries from the *Common Cell* test cases but manage, differently, how the cells in the top cell are localized. There are two localized areas. One localized area contains a single, 3rd-level, cell. The second contains two placements of a single, 2nd-level, cell. The cell placement of the second localized area in the top cell may share two edges with the other localized cells, with no figures overlapping.

w

Localized area #1

(x_2,y_2)

h

(x_1,y_1)

Localized area #2

S_BOUNDING_BOX (Top cell)
  . (x_1,y_1), w and h
P44_CHIP_WINDOW
  . (x_1,y_1) and (x_2,y_2)
P44_LOCALIZATION
  . w - <largest-localization-width>
  . h - <largest-localization-height>

The bounding box for the two localized areas will be determined by the width and height for the first localized area within the top cell. The two fields for P44_LOCALIZATION, <largest-localization-width> and <largest-localization-height>, should be hand-derivable from the first localized area. The field for P44_LOCALIZATION, <largest-localized-area-cell-volume>, should be hand-derivable from the first localized area. It's bounding box and coordinate space should never fall outside of the largest localized area width and height of the first localized area. Any other mismatched values for these fields should be treated as a fatal error.
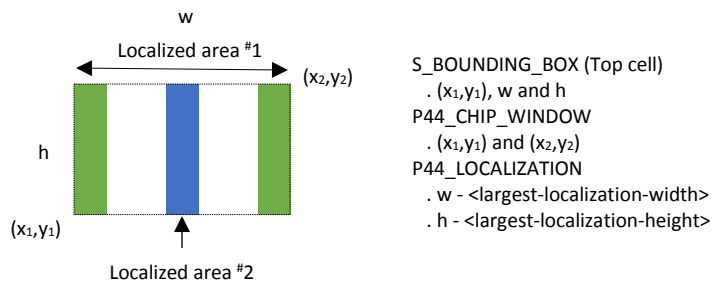
Test cases are present that exercise top cell placement repetition types 0-3 at the minimum and maximum repetition, x- and y-space, values for P44. Yotta tests repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 2nd-or 3rd-level cell size having a w/h of '1.'

These *Localized Areas* test cases reach the outer 32- and 64-bit, four-quadrant, limits of the Cartesian coordinate system allowed by P44.

Common Cell Test Cases

*R – repetition, including variants of R-0 type

The *'Common Cell'* test cases have a theme. There are three levels of hierarchy. The layout geometry carries from the *Localized Areas* test cases but manages, differently, how the cells in the top cell are localized. There are two localized areas. One localized area contains one localized cell and one common cell. The second contains only one common cell. The placement of the second localized area in the top cell may share two edges with the other localized and common cell, with no overlap.
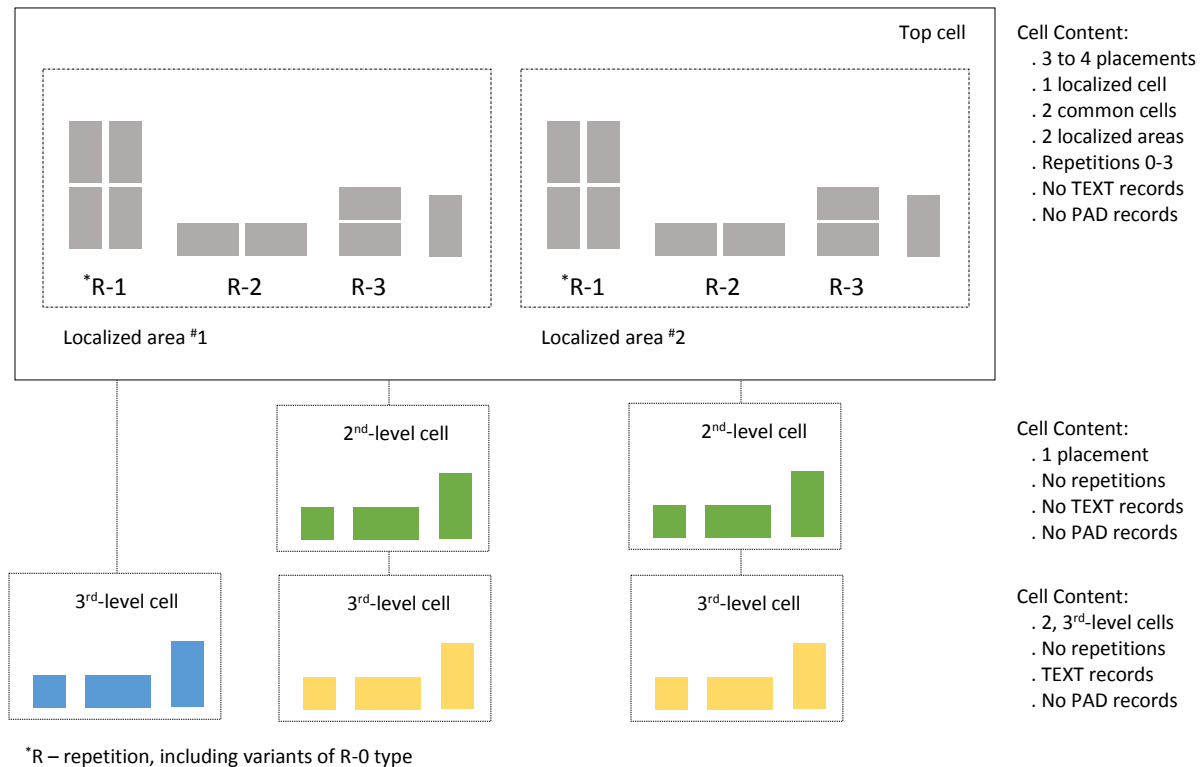
The bounding box for the two localized areas will be determined by the width and height for the first localized area within the top cell. The two fields for P44_LOCALIZATION, <largest-localization-width> and <largest-localization-height>, should be hand-derivable from the first localized area. The field for P44_LOCALIZATION, <largest-localized-area-cell-volume>, should be hand-derivable from the first localized area since the value for the second localized area will, always, be zero. Any other mismatched values for these fields should be treated as a fatal error.
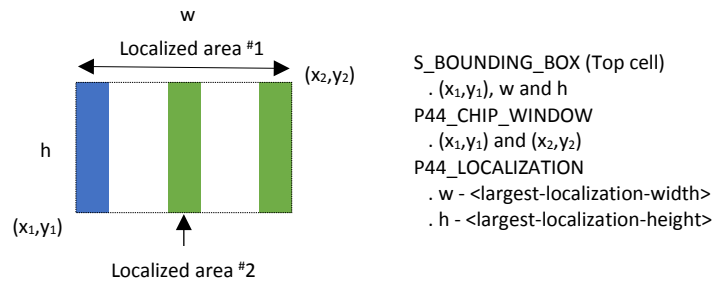
Test cases are present that exercise repetition types 0-3 at the minimum and maximum repetition, x- and y-space, values for P44 at the top cell only. Yotta tests repetition values, xdim and ydim, to a maximum value of 1000000 at a unit-declaration of 1000 which is the maximum for a 2nd- or 3rd-level cell size having a width/height of '1.'

These *Common Cell* test cases reach the outer 32- and restricted 64-bit, four-quadrant, limits of the Cartesian coordinate system allowed by P44.

PAD Record

A P39 PAD record is allowed in P44. There are no restrictions to its location within a P44 file. There, however, are restrictions that prevent a PAD record from being referenced by some P44 properties.

A PAD record cannot be used as a byte-offset value for any of the property values defined by the following P44 property types:

- P44_LOCALIZATION
- P44_LOCALIZATION_AREA
- P44_GEOMETRY_OFFSET
- P44_COMMON_CELL

whether the PAD is the first record within a referenced set of records that are compressed.

In other words, a PAD record cannot be referenced as a pointer to a byte-offset by any of the above P44 properties.

A PAD record's byte volume cannot be excluded from a <cell-volume> calculation.

PROPNAME Record

P44, optionally, allows the use of reference numbers within a P44 file. This infers that locally-stored property names can be used.

In P44, the table-offsets structure can only declare the flag field for this property as strict. Therefore, property names cannot be stored locally.

PROPSTRING Record

P44, optionally, allows the use of the PROPSTRING record. By only allowing this property, P44 infers that locally-stored property strings can be used.

P44 restricts the use of the name records, CELLNAME and PROPNAME to strict mode only. Because, essentially, the P44 file is in strict mode for these records, it should carry that all names, strings and cells cannot store a name or string locally. This would include property-value prop-strings. They must not be stored locally with a PROPERTY record while the rest of the P44 file is, necessarily, in strict mode.

PROPSTRING records must be present in a P44 file for the following mandatory P44 properties:

- P44_CONVERSION_DATE,
- P44_FORMAT and
- P44_VERSION

All mandatory P44 properties must be present within a P44 file. Therefore, the PROPSTRING record is one that must, also, be present within a P44 file.

XYABSOLUTE and XYRELATIVE Records

P44 optionally allows the use of the P39 records, XYABSOLUTE and XYRELATIVE. While these records are present, a P39 reader may not interpret its data in the same way as a P44 reader. If the P44 file is localized, a P39 reader, likely, will return different (i.e. incorrect) layout results while there are more than two localized areas within the P44 file.

The modal variable, xymode, must be reinitialized to absolute mode prior to the reading of each localized area. xymode must not be reinitialized while an XYRELATIVE record is present within a localized area unless it is followed by an XYABSOLUTE record. xymode must not be reinitialized anywhere within 2nd- and 3rd-level cells except at the beginning of these cells or where the record, XYABSOLUTE, follows an XYRELATIVE record.

xymode for TEXT records must be properly interpreted according to the restrictions defined by the P44-1216 specification but not be included in the property-values that define the coordinate space for any cell.

PLACEMENT Record

P44, optionally, allows the use of the P39 record, PLACEMENT, for 2nd-level cells, whose bounding box cannot exceed a w/h of 1 mm. A 2nd-level cell can be placed anywhere within a 32-bit processing space as long as its figures do not overlap with the figures from another figure or cell. The right- and/or left-most coordinates for the placed cell cannot exceed this space.

For the top cell, a placed 2nd- or 3rd-level cell's bounding box w/h cannot exceed 1 mm. The cell can be placed anywhere within the restricted 64-bit space as long as its figures do not overlap with the figures from another cell. Yotta has set the maximum 64-bit bounding box w/h value at $9.99999999999999 \times 10^{14}$. The right- and/or left-most coordinates for the placed cell should not exceed this space while there is a

chance that floating point calculations will take place while using the coordinate data within a P44 file or even using floating point calculations during the figure operations described in Table 1 of the P44-1216 specification.

CTRAPEZOID, RECTANGLE and TRAPEZOID Records

P44 allows for the use of three types of P39 figures, namely, CTRAPEZOID, RECTANGLE and TRAPEZOID. All other P39 figures (i.e. PATH, CIRCLE, POLYGON and PATH) must not be present in a P44 file.

The maximum w/h for a P44 figure is 1 mm. A figure can, optionally, be present in 2nd- and 3rd-level cells only. A 3rd-level cell cannot be present within a P44 file without a figure being present in that cell. Empty 3rd-level cells (i.e. such a cell without a figure) are prohibited in P44. The only cell that can be present without a figure in a P44 file is the top cell.

A 2nd-level cell can contain multiple placements of 1mm 3rd-level cells throughout a 32-bit processing space as long as there is no overlap between the figures within the cells or the native figures within this cell. A top cell can contain multiple placements of 1 mm 3rd-level cell as long as there is no overlap between the figures within the cells.

Figures cannot be present in a P44 file where the value for width or height is zero. Zero-area figures having non-zero w/h cannot be present as well.

Zero-area trapezoid types 6-7 and 14-15 are present wherever the non-zero width and height (w/h) are equal. A zero-area, type 23, trapezoid will be present wherever both deltas are either positive or negative and their width and height are the same values as the deltas. Yotta tests this equality and treats it as a fatal error.

Yotta's test cases make use of the variants of fundamental shapes of P39 record types - CTRAPEZOID, TRAPEZOID and RECTANGLE - to test variations in cell size at varying coordinate values set within repetition types 0-3.

There are 33, unique, shapes that Yotta uses for its test cases. At a unit-declaration of 1000, they are:

Shape	Type(s)	width/height
CTRAPEZOID	0-3, 8-11, 16-19, 24 and 25	1/1
CTRAPEZOID	4-7, 20-21	2/1
CTRAPEZOID	12-15, 22-23	1/2
TRAPEZOID	23-25 delta-a/delta-b (0,0)	1/1
RECTANGLE	S=0	1/1

For 2nd- and 3rd-level cell maximum width and height, Yotta has divided the values by two and multiplied them by 1000000 grid units. As an example, for a cell that uses a trapezoid type '5' as a maximized variant for a cell's size, w/h for the cell bounding box would be 1000000/500000 at a unit-declaration of 1000.

Yotta tests the values for x- and y-space at the minimum and maximum values allowed by P44 for all cells including the top cell. As an example, here are 32- and 64-bit top cell placements that test a 3rd-level cell whose width and height are '1000000.'

> 17 PLACEMENT CNXYRAA0 refNum=1 angle=real0(0) x=-1073741824 y=-1073741824 rep=rep1[xdim=2 ydim=2 dx=2146483647 dy=2146483647]

> 17 PLACEMENT CNXYRAA0 refNum=1 angle=real0(0) x=-500000000000000 y=-500000000000000 rep=rep1[xdim=2 ydim=2 dx=999999998999999 dy=999999998999999]

The value lists for the P39 property, S_BOUNDING_BOX, are:

> 28 PROPERTY 01010CNS refNum=1 count=(5) integer8(0) integer9(-1073741824) integer9(-1073741824) integer8(2147483647) integer8(2147483647)

> 28 PROPERTY 01010CNS refNum=1 count=(5) integer8(0) integer9(-500000000000000) integer9(-500000000000000) integer8(999999999999999) integer8(999999999999999)

The value lists for the property, P44_CHIP_WINDOW, are;

> 28 PROPERTY 01000CN0 refNum=4 count=(4) integer9(-1073741824) integer9(-1073741824) integer9(1073741823) integer9(1073741823)

> 28 PROPERTY 01000CN0 refNum=4 count=(4) integer9(-500000000000000) integer9(-500000000000000) integer9(499999999999999) integer9(499999999999999)

The smallest x- and y-space value tested is '1.'

CBLOCK Record

P44 allows for the use of the P39 CBLOCK record, with restrictions. If the P44 property, P44_GEOMETRY_OFFSET is present within a P44 file, a single CBLOCK record cannot include PLACEMENT, TEXT and P39 figure record types. 2nd-level cell PLACEMENT records must be compressed separately from TEXT and figure records.

TEXT and figure records can be compressed in the same 2nd-level cell CBLOCK record. The order of the TEXT and figures within the CBLOCK record can have any order. They do not need to be gathered as contiguous sets of figures and TEXT records. This applies to localized P44 files and P44 files that are not localized.

The first record within such a CBLOCK record cannot be a PAD record while the property, P44_GEOMETRY_OFFSET, is present.

If a P44 file is localized, a CBLOCK record cannot contain more than one localized area. A CBLOCK record cannot contain localized CELL and CELLNAME record data for more than one localized area. A top cell's, CELL and CELLNAME record data cannot be compressed with localized 2nd- and 3rd-level CELL and CELLNAME record data.

The same restriction exists for common CELL and CELLNAME record data. 2nd- and 3rd-level common cell data cannot be compressed with 2nd- and 3rd-level localized CELL and CELLNAME data. It, as well, cannot be compressed in the same CBLOCK that contains compressed top cell, CELL and CELNAME, record data.

All localized record data must be compressed separately so that offsets can be set for localized cells, common cells and the top cell, CELL and CELLNAME, record data. While compressed together, the offsets cannot be set to these localized sets of data. A PAD record cannot be the first record within a CBLOCK record that compresses localized data.

With the exception of a localized or non-localized P44 file that has the property, P44_GEOMETRY_OFFSET, present, the use of a CBLOCK record in a P44 file follows the specification for the CBLOCK record set by P39-0308. In other words, all PLACEMENT, figure and TEXT records can be compressed in one CBLOCK record. The record need not be gathered into groups of record types nor do they need to be in any particular order. PAD records can be present as the first record in a CBLOCK record.

S_TOP_CELL Record

P44 allows for the presence of the property, S_TOP_CELL, in a P44 file. Its property-value cannot be stored locally as an n-string (i.e. a P39 type 12 property-value). It must be an implied n-string (i.e. a type 15 property-value only).

S_MAX_SIGNED_INTEGER_WIDTH and S_UNSIGNED_INTEGER_WIDTH Records

These records appear to have little value to the P44 specification unless the values within the P44 file exceed an integer byte length of 8. At this time, P44 allows the use of both signed and unsigned integers that are 8 bytes long.

This value could be arbitrarily set to a byte value that warns of integers that exceed the value (+/-) 999999999999999 which, Yotta has set as the integer value where, beyond this value, there is a significant chance for errors created by the rounding off of floating point numbers to signed and unsigned integers. The largest double-precision floating point number is 2^{54}. Integers larger than this will be rounded off while double-precision floating point calculations are in use. Yotta has taken this into consideration and has set the maximum size of a signed- and unsigned-integer to be less than 2^{50}.

S_MAX_STRING_LENGTH Record

This record is allowed within a P44 file. It gives the P44 reader a heads-up about the string lengths for the strings present within the file. Any value less than or equal to a string length of 256 should be allowed within a P44 file. Any value greater than a string length of 256 should be reported by the reader as a fatal error.

P44_CONVERSION_TOOL Record

P44 allows for the tracking of the name of the tool that had written the P44 file along with the tool's version number. Yotta believes that this property should always be present in a P44 file – as are

P44_VERSION and P44_FORMAT - but P44 treats it as a property that need not be present within a P44 file.

The property-values for these two properties must be implied a-strings (i.e. a type 13 property-value type). P44-1216 allows type 10 property values which would allow prop-strings to be stored locally. Yotta treats any string that is not implied as a fatal error.

P44_LOCALIZATION Record

If a P44 file is to be localized, the property, P44_LOCALIZATION, must be present. The values list for this property is:

(1) <largest-localization-width>
(2) <largest-localization-height>
(3) <largest-localized-area-cell-volume>
(4) <common-cell-volume>
(5) <localization-area-count>
(6) <top-cell-cellname-offset>.

For testing purposes, only, Yotta has assumed that the first two values will be based on the largest w/h values derivable from the bounding boxes of all localized areas present within the top cell of a P44 file. The third value is derivable by deriving and comparing the cell volume of each localized area defined by the property, P44_LOCALIZATION_AREA. If two or more localized areas contain only common cells, the value will be zero.

All property-values for this property will be zero while the top cell is empty; except for the sixth value which will point to the empty top cell's CELLNAME record.

All TEXT placements in all cells, including the top cell, cannot be factored into the coordinate values defined by this property. They must be read and interpreted, properly, according to the restrictions set forth by P44-1216 but, otherwise, ignored.

P44_GEOMETRY_OFFSET Record

The property, P44_GEOMETRY_OFFSET, may be present in a P44 file. It must be present in 2nd-level cells while the value for the property, P44_GEOMETRY_OFFSET_AVAILABLE, is set to '1.' This property need not be present in 3rd-level cells because no PLACEMENT records can be in 3rd-level cells. According to P44-1216, this property is unnecessary in the top cell because figures cannot be present, there. Their presence at these cell levels is optional.

PLACEMENT records must be gathered and be listed first within a 2nd-level cell followed either by TEXT or figure records. There is no order required for the TEXT and/or figure records that follow. The value reported for this property should be the first TEXT or figure the P44 reader reads in a cell. As an example, if a TEXT record is the first record encountered after the gathered PLACEMENT records, the value for this property must point to this TEXT record. If no figure is present within a 2nd-level cell but a TEXT record is present, the property-value must point to the TEXT record else be a fatal error. In other words, there is

no allowance by P44 for a 2nd-level cell that has no figures but, at least, one PLACEMENT record and a TEXT record. The TEXT record cannot be arbitrarily ignored.

While this property is present, gathered PLACEMENT records cannot be compressed with any TEXT and/or figure records. They must be compressed by separate CBLOCK records. Only TEXT and/or figures can be present within the same CBLOCK record.

PAD records cannot precede compressed TEXT and/or figure records while this property is present. Yotta treats the presence of a PAD at this position within a CBLOCK record as a fatal error. Any other position within this type of CBLOCK record is OK.

P44_LOCALIZATION_AREA Record

If the property, P44_LOCALIZATION, is defined, the P44 property, P44_LOCALIZATION_AREA, must be defined as well.

There can be a localized empty top cell. The value for <placement-offset> for the property, P44_LOCALIZATION_AREA, must be set to zero. All other value lists for the property must be zero. Otherwise, there can be a minimum of one localized 3rd-level cell having a minimum of one figure present having a non-zero (w/h) value of 1/1 mm or less.

All TEXT placements in all cells, including the top cell, cannot be factored into the coordinate values defined by this property. They must be properly interpreted, according to the restrictions specified by the specification P44-1216, by a P44 reader but their coordinate values not factored into the extent of the coordinate space for any localized area within the top cell.

P44_COMMON_CELL Record

A common cell is a 2nd- or 3rd-level cell which has been placed in, at least, two localized areas. The same cell placed twice within the same localized area and in no other localized area is not defined as a common cell.

Two or more localized cells that only contain one or more common cells must have the values <cell-offset> <cell-volume> <cellname-offset> <cellname-volume> for the property, P44_LOCALIZATION_AREA, set to zero.

A localized area where there is more than one localized area having only common cells present will never have the largest localized area cell volume. The value for this localized area will, always, be zero.

Ignored Test Cases

According to P44-1216, P39 records that are defined to be 'Ignored' are those that are not expected to be used by mask tools. An ignored P39 record does not mean that the record need not be syntactically correct or adhere to the maximum and minimum values specified by this specification. Before being ignored, the record must be properly interpreted by a P44 reader. This requirement is to ensure that the P44 file does not have data that is corrupt or outside of the limitations/restrictions that have been set by P44 for the ignored record types.

textstring-, layername- and xname-flags in the START/END records

P44 declares the textstring-, layername- and xname-flag, flag fields, in the table-offsets structure, as ignored whether a value of '0' or '1.' This, however, is a practice that is inconsistent with the requirement that the CELLNAME, PROPNAME and PROPSTRING flag fields must be in strict mode which is a value of '1.'. If any of the ignored records are in strict mode, the reader must make certain that they are contiguously gathered in one location before being ignored.

Furthermore, P44 states that a CELLNAME record's reference-numbers must be defined implicitly while in strict mode. Yotta has assumed that, because this record must have an implicitly defined reference-number system and be in strict mode, all names, strings and cells within a P44 file must have the same implicitly defined reference numbering system and be in strict mode. Therefore, although ignored according to P44, a TEXT record that is present must not store its text-string locally and its referenced text-string must not use an explicit reference numbering system.

A layername-string is the only string that can be stored locally with its corresponding LAYERNAME record. While the flag field for this record is in strict mode, the reader must properly interpret all LAYERNAME records as being gathered into one contiguous location.

Although an XNAME record cannot be present in a P44 file, its flag field in the table-offsets structure must be interpreted properly before being prohibited simply because the table-offsets structure in a P44 file must be interpreted properly as a whole. While in strict mode, all prohibited XNAME records present in the file must be gathered into one location within the P44 file.

Although allowed, the mixing of strict and non-strict modes within the same P44 file is not recommended. Yotta has assumed that any P44 file written out is a finished P44 file ready to be printed on a mask. A single P44 writer should not be mixing strict and not strict modes within the same P44 file. Doing so unnecessarily adds complexity to what a P44 reader must interpret. Although, such a mix is allowed in P44, Yotta issues a warning for all variations of these flags while present in both strict and non-strict mode.

LAYERNAME Record Types 11 and 12

P44 allows for the presence of the P39 record, LAYERNAME, but must be ignored once properly interpreted by the P44 reader. This means that all restrictions declared by P44-1216 must be met before the record is ignored.

TEXT Record

According to P44, all TEXT records are to be ignored. Generally, this statement conflicts with the use of a TEXT record in a 2nd- level cell as a pointer to figures within a cell for the property, P44_GEOMETRY_OFFSET. If a 2nd-level cell contains at least one PLACEMENT record and no figures and contains a TEXT record gathered after the cell's PLACEMENT record, the byte-offset to the first TEXT record is not ignored and the value for the property set to the byte-offset to the first TEXT record.

In P44, all TEXT records must be properly interpreted by a P44 reader according the specifications stated as its restrictions according to P44-1216. Once met, the coordinate space for all TEXT records must be ignored.

The byte -offset to a TEXT record that is present before a localized area cannot be the value for <placement-offset> whether the TEXT record has been compressed along with the placed localized cells. In other words, the TEXT record must not be included as the first record in a compressed localized area CBLOCK record. The TEXT record can be placed anywhere else within the localized CBLOCK record. TEXT records may be arbitrarily included anywhere in a compressed top cell while the P44 file is not localized.

P44-1216 allows the use of multiple text layers which conflicts with the, similar, restriction for figures which can only be present in one layer within a P44 file. Yotta treats as a fatal error any TEXT records present having more than one text layer within a P44 file.

P44-1216 allows the use of repetition types 4-11 for TEXT records. This allowed use conflicts with the restriction for all figures and PLACEMENT records within a P44 file. It states that a figure can be repeated only by repetition types 0-3. Yotta treats, as a fatal error, any TEXT record in a P44 file that repeated by repetition types 4-11.

Because the records CELLNAME, PROPNAME and PROPSTRING must be in strict mode in a P44 file, none of their corresponding names and strings can be stored locally. Yotta has assumed that since a vast majority of the P44 file will be in strict mode, a text-string cannot be stored, locally, within a TEXT record. The text-string must be referred by a TEXTSTRING record. While a TEXT record is present, a corresponding TEXTSTRING record must be present. Yotta treats a locally stored text-string as a fatal error.

TEXTSTRING Record

P44 allows the use of the P39 record, TEXTSTRING, but the record must be ignored once properly interpreted by the P44 reader. A TEXTSTRING record cannot be ignored if a TEXT record is present. A TEXTSTRING can be ignored while no TEXT records are present. Yotta's embedded documentation populates one or more, type 5, TEXTSTRING records. They can be ignored. As an example, a TEXTSTRING record cannot be ignored while the property, P44_GEOMETRY_OFFSET, is present and a 2nd-level cell contains TEXT or figure records. Even while no figures are present in a 2nd-level cell, a TEXTSTRING record cannot be ignored while the property, P44_GEOMETRY_OFFSET, is present.

S_GDS_PROPERTY Record

According to P44-1216, a P39 record type must be ignored while present in a P44 file if the record is not used by all mask layout applications. Although the record will be ignored, its syntax and semantics must be verified as correct. There are, however, no P44-specific restrictions set for the property, S_GDS_PROPERTY, which conflicts with the specifications set for the rest of the ignored records. Because the maximum and minimum values are not specified, Yotta proposes that the OASIS® Working Group consider prohibiting its use rather than ignoring it which would be consistent with the way the records that are prohibited are defined.

Until this matter is addressed, Yotta has created test cases which test the limitations and restrictions set by the formats GDSII and OASIS® P39-0308.

Prohibited Test Cases

P44-prohibited P39 records PATH, CIRCLE, POLYGON and XNAME must not be present with a P44 file. Yotta tests a P44 reader for their presence. While present, Yotta issues a fatal error.

File Name Restrictions

The length of a file name includes all characters, including the extension of the file name. Yotta views the file name to be of two parts which are (1) the body of the file name and (2) the extension of the file name. P44 allows the use of a file name without an extension. It allows the body of the file name to be 64 characters long which can cause a problem for applications which require an extension. At least one mask writing company uses extensionless file names which, Yotta, believes is a bad practice especially with the use of a file name to track files throughout the foundry to fabless to foundry design to manufacturing flow.

If the body of an extensionless file name is 64 characters long, those applications which require an extension will need to truncate the body of the file name by, at least, two characters. If the extension required is *.oam, the body of the file name can only be 60 characters long. Having done so will have broken the integrity of the name upstream of the change. Not a good practice. Yotta is of the belief that the body of a file name must be conserved so that it remains referential, always.

Yotta provides test cases that test file name length as specified by P44-1216 but is suggesting that the restrictions for file name length be redefined so that the extension is of a fixed length. Furthermore, Yotta suggests that the name for the P44 extension be fixed to '*.oam' and the name of the corresponding text dump be '*.oam.txt.' With these allowances for an extension, the body of the file name can only be 56 characters or less. Furthermore, with the extensions always being of the same characters, the extension becomes referential. Within a library of P44-related files, today, there might be thousands of P44 files having different extensions. Querying for a list of all P44 files on a server by the name of the extension would be prone to error. Having a fixed name for an extension makes all P44 files and their corresponding text dumps referential.

Yotta suggests the following P44 language for the P44 file name length:

> There are two parts to a p44 file name. The first part is the body of the file name and the second part is the extension for the file name. The number of characters allowed for the file name extension is fixed to four. The name of the extension must be *.oam where '*' represents the body of the file name. The extension must include a period as the first character. Any corresponding extension such as the textual representation of a P44 file must be fixed to a length of eight characters. Any other application-specific extension aligned with a P44 file must include *.oam followed by one period and three more characters specific to that application. The name of the extension for a P44 file text dump must be *.oam.txt. The length of the body of the file name can be no longer than 56 characters.

This definition allows for a two-part total character length of 64 and makes, referential, the extensions for P44 files and their corresponding text dumps. Furthermore, all P44 files and their corresponding text dumps will be referential. All of Yotta's test cases adhere to this language.

P39 allows for the use of all printable ASCII characters (32-127) within the P39 file. It does not define a character set for the file name of a P39 file. P44 does not allow the use of the following printable ASCII characters in the file name of a p44 file:

> !#$%&(),;@[]^'`{}~+=/ \ < > ? *":

The following printable characters have not been tested by Yotta because they cannot be created in a Windows environment.

> / \ < >?*":

File Naming Conventions

Yotta's test case file name conventions attempt to hold closely to the restrictions and other demands imposed on the records, names, strings and values defined by both of the P39 and P44 specifications. The naming convention is supposed to accurately convey the, basic, intent of the test case without having to open the file and read the embedded documentation.

Here is an example of Yotta's file naming convention:

> bounding_box_field_reversed_a_f_k_p44_localization_area.oas

The character length of the file name is 59 which is below the maximum number of characters allowed in a P44-1216 file name. The bounding box field describes the <lower-left-x> <lower-left-y> <upper-right-x> <upper-right-y> coordinate values for a localized area's bounding box. In this case, the field values have been reversed (i.e. the upper –right values for x and y are less than the lower-left values for x and y). According to section 1.11.3.4, P44_LOCALIZATION_AREA (EXCEPTION HANDLING), such a state within a P44 file should be a fatal (f) error. An '_a_' within the file name means that the property, P44_LOCALIZATON_AREA, is 'Allowed' by the P44 specification. This distinction within the file name helps Yotta organize the test cases into the above defined categories. A 'k' is a distinction for a test case that lets Yotta know that at least some of the values present in the test case could change while running a text to OASIS® conversion. Yotta runs these test cases in a different manner from the rest of the test cases. Here is a list of the file name distinctions that need an explanation:

Table 1- Key to File Name Abbreviations

Distinction	Definition
32	At or exceeding a 32-bit processing space
64	At a double-precision floating point 64-bit limit
a	Allowed according to P44

attr	attribute
b	Requires a binary editor to update
c	CORRECT according to P44
cll	cell
clls	cells
cllnm	cellname
cllnms	cellnames
cmprssd	compressed
cntct	contact
coord_val	coordinate value
csd	character string data
emt	empty
ena	explicit reference-number assignment
evn	even
f	FATAL
ff_mix	flag field mix of strict/non-strict mode
flg	flag
horz	Horizontal trapezoid configuration
i	Ignored according to P44
ina	Implicit reference-number assignment
intrvl	interval
k	keep
lclzd	localized
lngth	length
lrg	large (1000000), xdim and ydim, value
m	Mandatory according to p44
mix	Mix of explicit and implicit reference-numbers
mu	Manual bounding box update required
nd	No embedded documentation
nfp	No floating point
ndprt	node port
nonemt	non-empty
ns	Non-strict mode
nsl	Name stored locally
offst	offset
plcmnt	placement
plcmnts	placements
propval	propvalue
prpt_val	property value
r	File name restrictions
ref_num	reference-number
rsrvd	reserved
s	Strict mode
swch	switch
sa_ref	sref and aref
toe	table-offsets stored in the END record
tos	table-offsets stored in the START record
val	value

vol	volume
vert	Vertical trapezoid configuration
w	WARNING
x	Prohibited according to P44

Yotta only, sparingly, tests P44 files having the table-offset structure in the START record. The coverage is enough to represent what is allowed by the P44 specification. Yotta issues a warning for all P44 files that have the table-offsets structure stored in the START record. Yotta only, sparingly, tests P44 files that allow a mix of strict (s) and non-strict (ns) flag-fields in the table-offsets structure. The coverage is enough to represent what is allowed by the P44 specification. Yotta issues a warning for all P44 files that have this mix. Yotta only, sparingly, tests P44 files that allow the mix of implicit (ina) and explicit (ena) reference-number referencing methods. The coverage is enough to represent what is allowed by the P44 specification. Yotta issues warnings and fatal errors for all test cases that have this mix.

All other test cases offered by Yotta have the table-offsets structure stored in the END record, strict mode for all flag fields in the table-offsets structure - including TEXTSTRING, LAYERNAME and XNAME - and implicitly references names, strings and cells. These test cases will not have the distinctions (ina, ena, toe, tos, s or ns) in the P44 test case file name.

Those that have these types of structures are located in the test case category, Mandatory. They will have a distinctive file name which has the characters 'tos' ('table-offsets structure stored in the START record')in the file name.

Two test cases have no, embedded, documentation:

> text_string_min_type_5_i_c_nd_textstring.oas

> text_string_zero_length_type_5_i_f_nd_textstring.oas

Their file names indicate no presence of documentation (nd). These two test cases test the minimum string length for a text-string within a TEXTSTRING record. Having embedded documentation interfered with the test cases' intent because the embedded test case documentation contain text-string lengths far great the tested minimum.

Test Case Documentation

Yotta embeds documentation within all but two of its P44 test cases. This was done to boost efficiency to the analysis of any test case that comes into question. Other than the two exceptions, each test case lists the following information for the User's use:

> The Start of Test Case Documentation
> P44 Documentation Version
> Test Case Designation
> P44 Section(s)
> P44 Figure(s) and Table(s)
> Test Case Description
> Contact Information

Trademark Information
Copyright Information

The Start of Test Case Documentation

Each test case declares its end and the beginning of the P44 documentation by the following embedded text in a TEXSTRING record:

End_____Test Case Documentation_____Start

P44 Documentation Version

Yotta uses the SEMI version numbering scheme (i.e. P44-MMYY). The version of the P44 document that had been used to build the test cases will be stated here. In this case, the version number in use is P44-1216.

All uses of OASIS® P39 records, data constructs and properties in these P44 test cases stem from the SEMI P39 specification, P39-0308.

Test Case Designation

Each Yotta test case has been assigned an, embedded, Test Case Designation. There are three designations:

- CORRECT
  - o A test case which a P44 reader should interpret as being correct to read and process as specified by SEMI P44-1216. An example would be a test case that contains a cellname-string that is 256 characters long which is the maximum allowed length for a cellname-string defined by SEMI P44-1216.
- WARNING
  - o A test case which a P44 reader should interpret as being correct according to SEMI P44-1216 but being worthy of a warning about the test case not being a best practice. It be, as well, that a value in the file is approaching a processing space that, if exceeded, will produce unreliable or incorrect results. An example would be Yotta issuing a warning for bounding box calculations that have integers in use that exceed 14 decimal digits of floating point precision.
- FATAL
  - o A test case which a P44 reader should interpret as being outside of a specified maximum/minimum value, a missing record that is mandatory, a missing record of pair of allowed records that must be present together, a character string that is not of a specified type, such as an a- or n-string, etc. An example would be a P44 file that does not have the mandatory property, P44_GEOMETRY_COUNT, present.

The company expects that it will be negotiating the designations chosen for some of the test cases since there is no precedence that has already been established the designations. Once agreeably set, Yotta

believes their ever-presence will stabilize P44 implementations globally, company-to-company and platform-to-platform.

P44 Section(s)

Each test case refers to the relevant section(s) within the P44-1216 specification. If Yotta had felt it imperative to include a reference to the SEMI P39 specification, it will have distinguished this inclusion here from P44 referential information by something like SEMI P39-0308 followed by the corresponding Section(s).

P44 Figure(s) and Table(s)

Where relevant, a test case will refer to the relevant figure(s)/table(s) within the P44-1216 specification. If Yotta had felt it imperative to include a reference to the SEMI P39 specification, it will have distinguished this inclusion here from P44 referential information by something like SEMI P39-0308 followed by the corresponding Figure(s)/Table(s).

Test Case Description

Each test case has an embedded description of how a P44-1216 reader should interpret what it reads. Each embedded documentation text-string within a TEXTSTRING record a can be only 256 characters long. Many of Yotta's test cases required more than one TEXTSTRING to fully embed the documentation. These multiple TEXTSTRING records are paginated by, first, the relative sequence of the page to the total number of pages (i.e. Page 1 of 5 to Page 5 of 5) required to represent the documentation.

Embedded Contact, Copyright and Trademark Information

As part of the embedded documentation for each test case, Yotta felt it necessary to include contact information should there be questions about a test case and include Copyright and Trademark information that normally follows all documentation like this.

Contact Information

Each test case shows contact information should there be a question about a test case. The best way to reach Yotta, by e-mail, is (tom@yottadatasciences.com). We are accessible 24/7. So, you should have a response or be communicating with someone at Yotta within 24 hours.

Trademark Information

Yotta is required, by law, to list the owner of its registered trademark, OASIS®. Each test case has this information.

Copyright Information

Yotta includes a copyright legend with each test case. A licensee of these test cases can embed the text herein in other applications, owned by the licensee, but must note, somewhere that the copied text belongs to Yotta Data Sciences.

Definitions

The definitions here are to help clarify/simplify some of the terms in use within the P44-1216 specification.

Bounding Box Width and Height

A cell's bounding box in a p44 file must be the axis-aligned and minimal area within which all points lie. The bounding box for any cell cannot include the coordinate space for TEXT records. This space must be ignored.

A cell's bounding box is limited to a 32-bit coordinate space while the cells are 2nd- and 3rd-levl cells. A cell's bounding box is limited to a restricted 64-bit coordinate space only while the cell is the top cell.

A bounding box w/h can only be less than or equal to 1/1 mm for 2nd- and 3rd-level cells. The top cell can have a bounding box w/h having values that exceed 1/1 mm but equal to or less than the maximum restricted 64-bit values allowed by the specification P44-1216.

A bounding box can be undefined only while an empty top cell is present. An empty top cell has no definable area and no coordinate system even while non-zero bounding box values for the empty top cell are present in it CELLNAME record. All other undefined bounding boxes for 2nd- and 3rd-lrevel cells are prohibited.

Cells and Cell Hierarchy

There can only be three levels of hierarchy.

- 3rd-level cells
- 2nd-level cells
- top cell

A 3rd-level cell must contain at least one of the three figures allowed by P44. If a figure is present, then PAD and TEXT records can be present, as well. A cell that does not contain at least one figure or PLACEMENT record is prohibited P44. The only allowed empty cell possible in P44 is an empty top cell. A 3rd-level cell cannot contain PLACEMENT records. The cell cannot reference a cell in another P44 file. 3rd-level cells can be placed by the top cell. It need not be placed by the top cell if placed by a 2nd-level cell. A 3rd-level cell cannot be absent from the top cell. Figure, PAD and TEXT records present within a 3rd-level cell do not need to be gathered contiguously in any particular order whether localized. As long as there is at least one 3rd-level cell, a P44 file need not contain a 2nd-level cell. Such P44 files - files having only two levels of cell hierarchy - can be localized. A non-empty localized top cell must contain at least one 3rd-level cell. A 3rd-level cell must be a common cell if it appears in more than one localized area within a P44 file.

A 2nd-level cell must place at least one non-empty 3rd-level cell. If at least one PLACEMENT record is present, then PAD, TEXT and additional figure records can be present, as well. A 2nd-level cell cannot place an external cell present in another P44 file. A 2nd-level cell must be placed at least once by the top cell. If the property, P44_GEOMETRY_OFFSET, is present in a P44 file, all placement records must be gathered and follow a CELL record before any figure or TEXT records present within the same 2nd-level cell. The

order of TEXT and figures following all gathered cell placements does not matter. A geometry record offset value cannot point to a PAD record preceding the first TEXT or figure record in the cell whether compressed. If the property, P44_GEOMETRY_OFFSET, is not present, any PLACEMENT, figure, PAD or TEXT records present do not need to be gathered in any order whether compressed. A 2nd-level cell that is present in more than two localized areas within a P44 file must be a common cell. For there to be 2nd-level cells present in a P44, there must be three levels of cell hierarchy.

A top cell can be empty. An empty top cell is one where there are no 2nd- and 3rd-levell cells present in a P44 file. An empty top cell cannot contain any PLACEMENT records, including any PLACEMENT records that refer to a cell in another P44 file. An empty top cell has only one level of cell hierarchy. According to P44, an empty top cell can be localized, its <placement-offset> set to zero. According to P44, the bounding values <width> and <height> for the property, P44_BOUNDING_BOX_MAX, must be set to zero. To Yotta, having this requirement appears to conflict with its intended use which declares the upper limit of the cell bounding box permitted in any cell except the top cell. Currently, that upper limit is fixed to 1 mm for both values. A non-empty top cell must place at least one 2nd- or 3rd-level cell. A localized, non-empty, top cell must have at least one localized area present that contains a 2nd- or 3rd-level cell. If localized, the value, <placement-offset>, cannot point to a PAD or TEXT record preceding a localized area whether the localized area compressed. A P44 reader/writer must re-initialize the top cell's modal variables as they move from one localized area to the next. In other words, a second and third localized area must be re-initialized as a P39 file would re-initialize all modal variables for a new cell. A P44 reader/writer must not re-initialize all modal variables within a localized area without explicit, record-by-record, instructions to do so., if possible. <cell-offset> and <cellname-offset> values for the property, P44_LOCALIZATION_AREA, cannot point to a PAD record present and preceding the first CELL or CELLNAME record of a localized area, whether compressed.

Chip Window

Chip Window
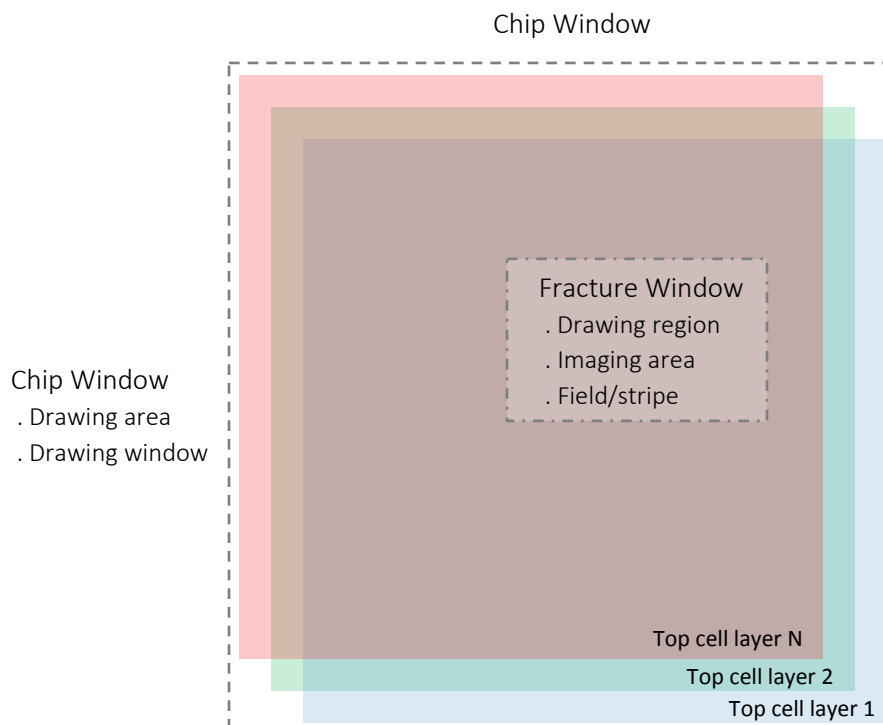
Many, many terms are used within P44 that are not defined. When asking others what these terms mean, we've gotten responses which have added new terms. For testing purposes, Yotta felt it important to define each so that the user can grasp a P44 property's meaning and context relative to the other P44 and P39 properties introduced and allowed within the specification P44-1216.

Yotta has set the largest window possible within P44 to be the chip window. Largest is to mean the extent of the coordinate space consumed by this window. The company attempts to associate and place in context with this window all other terms used within P44. All of the above terms have been defined within this document's "Definitions" section. Yotta believes that there remains some honing to do here and will be relying on feedback from the Users of the test cases. It is, nonetheless, important to drive a stake in the ground and work from there.

A chip window is the extent of the geometric layout of a chip design, all layers, excluding the coordinate space for all gathered text records. This window is the same as a drawing window or drawing area created by the figure operation windows extraction process noted in, Item 1 Table 1, P44-1216.

This window can be equal to or larger than the extent of the coordinate space of the chip design, all layers. No figures for the chip design can be present in a corresponding P44 file that are outside of this window in P44. The chip window coordinate space represents the property-values for the P44 property, P44_CHIP_WINDOW. The values for this property do not represent the coordinate space for any one layer of the chip design.

This window is not a fracture window. A fracture window is, always, a portion of a chip window. The reason being that figures that reside outside of its coordinate space can be discarded; any figures crossing the perimeter of this window, clipped. Comparatively, a chip window cannot include any figures whose coordinate space falls outside of the extent of this window.

A chip window is not an imaging area, a field/stripe nor is it a single localized area whose extent is the coordinate space of the entire top cell. A region can be, however, a the extent of a chip design, all layers.

Common Cell

A common cell is a grouping of 2nd- and/or 3rd-level cells that is present in more than one localized area. A single, localized, area cannot be the only localized area having more than one grouping of such cells. If a localized area contains only common cells, the values <cell-offset>, <cell-volume>, <cellname-offset> and <cellname-volume> from the corresponding property, P44_LOCALIZATION_AREA, must be set to zero. If this grouping of cells has been placed in more than one localized area, those cells must be defined by this property, only. They cannot be included in the values defined by the property, P44_LOCALIZATION_AREA except for the values <placement-offset> and <placement-count>. The values <cell-offset> and <cellname-offset> cannot point to an immediately preceding PAD record whether compressed with the common CELL and CELLNAME records.

P44's Compatibility with P39

The stipulation was that P44 always remain a formalized subset of its parent specification, P39. This meant that a reader should be able to read a P44 with a P39 reader and the interpretation be the same. P44 has evolved with the introduction of localization so that the coordinate space of a chip layout will not be interpreted in the same way. If a P44 file is localized, the top cell's modal variables must be re-initialized at the beginning of each localized area. Simply adding an XYABSOLUTE at the beginning of each localized area will not be sufficient to make the two specifications cross-compatible. As an example the modal variable <placement-cell> will not reinitialize by such a placed XYABSOLUTE record.

Coordinate Values

P44 defines maximum and minimum coordinate values for all figures, TEXT, cell placements and the following P39 and P44 properties:

- S_BOUNDING_BOX
- P44_CHIP_WINDOW
- P44_LOCALIZATION_AREA

2nd- and 3rd-level cell coordinate lower-left-most and upper-right-most values cannot exceed a 32-bit coordinate space. 2nd- and 3rd-level cells that have been placed by the top cell can exceed this 32-bit space but cannot exceed a restricted 64-bit coordinate space. The P39 property, S_BOUNDING_BOX, cannot exceed a 32-bit space for all 2nd- and 3rd-level cells. The same property can report values for the top cell that exceed the 32-bit coordinate space but not exceed the restricted 64-bit coordinate space. The above P44 properties that deal with the top cell only cannot exceed the 64-bit coordinate space.

Although P44 allows for the full use of the 64-bit processing space (2^{64}) for the top cell, the largest integer representable as a floating point number is 9,007,199,254,740,992 (2^{53}). Beyond this, such an integer cannot be represented as a floating-point number.[1] Any integer value larger than this will be rounded off until the integer is equal to or less than this value. If the processing of the P44 file involves three to four floating point arithmetic calculations before writing the integers out again, the upper limit of the accuracy of the integers written out will drop to integers having values less than 2^{50}.

Yotta is not certain whether all operations reading and writing P44 files will use integer arithmetic only. Processing of the file would normally use integer arithmetic, only, except for non-orthogonal geometry processing. There would, generally, be no round-off errors until a number must be printed to a screen or a physical machine must be controlled (e.g. a stepper head). It is, then, the responsibility of this software to generate meaningful numbers. An (x,y) pair that is (105,205) would be stored as integers during processing, then scaled by some floating-point number when it is needed to control a machine.

To be actively conservative by its first warning, Yotta has set the safe, upper, value for a P44 integer to $9.99999999999999 \times 10^{14}$. This value was chosen, as well, because Yotta can easily demonstrate a one grid-unit change to a bounding box (e.g. a demonstrated bounding box w/h change from 999999999999999 (safe) to 1000000000000000 (not safe)).

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[1] http://stackoverflow.com/questions/3793838/which-is-the-first-integer-that-an-ieee-754-float-is-incapable-of-representing-e

If Yotta users feel that this value can be higher as a test case, Yotta will make the adjustment to its test cases. If Yotta's users agree that all processing of a P44 file will involve integer arithmetic only, Yotta can rebuild these test cases so that they reflect the use of integer arithmetic only.

Drawing Area

A drawing area is a chip window. The drawing area is extracted from a hierarchical layout of an entire chip, all layers. The extent of its coordinate space represents the property-values for the P44 property, P44_CHIP_WINDOW.

Drawing Region

A drawing region is a region within a P44 file extracted from hierarchical chip design layout. It is the extent of a region that can be written to a photomask. Its extent is writer- and application-dependent. Its definition is the same as an imaging area or a field/strip region.

Drawing Window

A drawing window is a chip window. The drawing window is extracted from a hierarchical layout of an entire chip, all layers. The extent of its coordinate space represents the property-values for the P44 property, P44_CHIP_WINDOW.

It is not a fracture window, drawing region or a field/stripe as defined in this document. It is not a region cell.

Empty Cell

An empty cell can only be the definition of the top cell while no other cells are present in the P44 file. An empty cell cannot be a 3rd-level cell that does not have a figure present. Such a cell, according to P44, is not empty but, instead, prohibited from being present in the file. An empty cell cannot be a 2nd-level cell because it cannot refer to a prohibited 3rd-level cell having no figures present.

An empty top cell's bounding box can only be characterized as being 'undefined.'

An empty top cell can contain TEXT and PAD records but both are to be ignored after their records properly interpreted by a P44 reader according to the restrictions offered by the P44 specification P44-1216.

A TEXT record's bounding box is to be ignored while present in an empty top cell.

Field/Stripe Region

Field and/or stripe refers to terminology used in the mask writer pattern file format documentation. MEBES/CORE/ALTA writers use "stripe" as the fundamental imaging area supported by the tool. A stripe has a fixed aspect ratio (32768:1024, in units of the pattern file's address unit, or the address unit imposed by the job deck). The various VSB machines use imaging "fields" expressed in integer coordinates; these are often square.

A field/stripe is the same as a drawing region, imaging area or a fracture window.

Figures

A figure is a geometric shape that is defined, as record types, by the SEMI P39-0308 specification.

- CTRAPEZOID
- TRAPEZOID
- RECTANGLE
- POLYGON
- PATH
- CIRCLE

A P44 file can only contain CTRAPEZOID, RECTANGLE and TRAPEZOID P39 record types. The records CIIRCLE, PATH and POLYGON cannot be present in a P44 file.

Fracture Window

A fracture window is a drawing region, a field/stripe region or an imaging area as defined in this document. It is not the window extracted during the figure operation noted in Table 1. This window comprises the extent of the coordinate space for the entire chip, all layers.

The fracture window is not the extent of the coordinate space occupied by all layers of a chip's top cell. It is not the chip window specified by the P44 property, P44_CHIP_WINDOW.

A fracture window defines a rectangular region within the top cell. It encompasses an arbitrarily defined coordinate space there that will be extracted from the hierarchical layout. It'll be imaged in one or more places on the photomask. Any layout information outside this window is discarded; any figures crossing the perimeter of this window are clipped.

The fracture window is not the coordinate space for the chip window because a chip window cannot have any figures outside or crossing its perimeter.

Imaging Area

An imaging area is a fracture window, a field/stripe or drawing region. It is not the chip window noted in the P44 specification, P44-1216. It is an arbitrarily defined coordinate space that has been extracted from the hierarchical layout of a chip design that'll be imaged on a photomask. Any layout information outside this window is discarded; any figures crossing the perimeter of this window are clipped.

Implicit Versus Explicit Referencing Methods

P44 restricts the CELLNAME record to reference numbers that are to be defined implicitly. Yotta tests for a mix of implicit and explicit referencing methods since P44 allows for a mix. Yotta, however, uses a mix only to test the reader's interpretation of such a P44 file. All other test cases by Yotta use an implicit referencing system, only, for all CELLNAME, PROPNAME, PROPSTRING and TEXTSTRING records present within a p44 file.

Yotta issues a fatal error for a mix of implicit and explicit referencing methods while present in the same P44 file.

Localized Cell

A localized cell is a cell that has been placed by the top cell and that has been gathered with other placed cells which is known as a localized area. There can be one or more localized 2nd- and 3rd-level cells within a single localized area. There can be one or more localized areas within the top cell. A localized cell cannot be a common cell while copies of the same cell are present in just one localized area.

An empty cell placed in the top cell cannot be localized because such an empty cell is prohibited in p44 file. Only an empty top cell, having a single level of hierarchy, can be localized.

Localized Area

A localized area consists of one or more 2nd- or 3rd-level cells. A localized area is defined by the byte-offsets of the placed CELL and CELLNAME records and the CELL and CELLNAME byte volumes that include all of the data for those localized cells. It does not include offset and volume data for any common cells within the localized area. A localized area at the top cell level is defined by the byte-offset of the first PLACEMENT record for each localized area and the count of the number of placements of localized and common cells that are to be part of the localized area.

The value <placement-offset> cannot point to a PAD or TEXT record immediately preceding the start of a localized area whether the area is compressed. If a localized area contains only common cells, the values for <cell-offset>, <cell-volume>, <cellname-offset> and <cellname-volume> of the property, P44_LOCALIZATION_AREA, must be set to zero.

Two, or more, localized areas cannot be compressed in the same CBLOCK record. A localized area can have a <placement-offset> of zero only while the top cell is empty. The property-values for the P44 property, P44_LOCALIZATION, must be set to zero in this case except for the property-value <top-cell-cellname-offset> which must state the location of the CELLNAMR record for the empty top cell. The values <width> and <height> for the P44 property, P44_LOCALIZATION must be '0.'

A localized empty top cell cannot have any other cells present in the file.

Overlap

The edges of figures cannot overlap. The edges of two cells can overlap as long as their corresponding figures do not overlap.

Name Strings and Implied Name Strings

P44 allows the use of CELLNAME, PROPNAME and PROPSTRING records while in strict mode only. All corresponding names, strings and cells must not be stored locally. They must be pointed to by a reference number.

A property-value for a PROPERTY record cannot store a string locally. It must be implicitly referenced by a reference number that points to a PROPSTRING record which is storing the string. P39 defines this reference to a PROPSTRING record as an implied a-, b- or n-string.

Non-localized P44 File

A non-localized P44 file does not restrict the ordering and the gathering of cell placement figure and textual data into any type of order whether compressed. The content of a cell can be in any order unless the P44 property, P44_GEOMETRY_OFFSET, is present for non-localized, 2nd-level, cells. In this case, all PLACEMENT records, there, must be gathered and placed before any TEXT and figure records. In this case, PLACEMENT records cannot be present with TEXT and figure records within the same CBLOCK record. TEXT and figure records do not need to be gathered and placed by a specific ordering scheme. Following all PLACEMENT records in a cell, the TEXT and figure records can be present in any order. Each does not need to be gathered into a group of contiguous TEXT and figure records. Whichever comes first is the record pointed to by the geometry offset record value declared by the P44 property, P44_GEOMETRY_OFFSET. PLACEMENT records within a non-localized top cell do not need to be gathered into any specific order defined by P44. All PLACEMENT, PAD and TEXT records present within the top cell can be compressed by a single CBLOCK record and be present within the compressed CBLOCK record in any order.

Rectangular Region

A rectangular region can be a chip window, fracture window, image area, drawing window, drawing area, drawing region or a field/stripe. Its extent is a coordinate space chosen for a region query.

Region

The term, region, is used in multiple ways within the P44 specification.

(1) A region can be an extracted grouping of randomized to adjacent/coincident 2nd- and 3rd-level cells that have been gathered and localized within the top cell.
(2) A region can be an extracted fracture window, a drawing region, a field/stripe or an imaging area.
(3) A region can be a single 2nd-level cell containing figures and placed 3rd-level cells. This region can be defined as a region cell.

Region Cell

A region cell is a 2nd-level cell containing placed 3rd-level cells and, optionally, additional, native, figures.

Region Cells

Region cells refers to a grouping of 2nd- and 3rd-level cells that may be localized according to P44-1216.

Region Cell Grouping

A region cell grouping is a collection of randomized and/or adjacent 2nd- and/or 3rd-level cells. It can have the same meaning as a localized area.

Region Query

A region query seeks and extracts figures within a given rectangular region. It can extract what is called a chip window, image area, fracture window, filed/stripe, drawing region, drawing window or drawing area. The extent of the rectangular region is one that is arbitrarily chosen.

Repetitions

SEMI P39 defines 11 repetition types. P44 only allows repetition types 0-3 to be present in a P44 file for all figure and PLACEMENT records.

P44 allows the use of all P39 repetition types for TEXT records. Yotta believes that this allowance contradicts the restrictions set by P44 for figure and PLACEMENT records. Yotta issues a fatal error for all TEXT records having used repetition types 4-11 in a P44 file.

The maximum value for x- and y-space for 2nd- and 3rd-level cells has been set to 1mm. The maximum integer value for the top cell has been set to 999999999999999 at a unit-declaration of 1000.

Repetition Cell

If there are repetitive patterns of figures within a region that can be abstracted into a cell and expressed as a repeated placement of that cell, then those figures can be pushed into a "repetition cell" (i.e. a 3rd-level cell), simply to make the file more compact. Essentially, a repetition cell is a 3rd-level cell.

Restricted 64-bit Coordinate Space

Yotta has assumed that all mask layout applications will convert integers to and from double-precision floating point numbers. The company has assumed, as well, that 3-4 calculations will take place while using floating point numbers; each dropping the accuracy of the rounding off of the floating-point data by a factor of '2.' Therefore, Yotta has assumed that, to maintain integers that remain accurate/reliable throughout these calculations, the largest integer should be no larger than 2^{50}.

To ease the analysis of Yotta's test cases, the company has set this value to (+/-) $9.99999999999999 \times 10^{14}$. In other words, Yotta has restricted the minimum/maximum coordinate space to these signed integer values for the top cell.

Text Records Present in P44 Files

P44 allows the presence of TEXT records within a P44 file. Its syntax and semantics must be read in and interpreted according to the limits set for the record by the P44 specification. A TEXT record's bounding box, however, must not be included in any cell bounding box calculation.

Although TEXT records must be ignored in this way, if present in a 2nd-level cell and the P44 property, P44_GEOMETRY_OFFSET, is present a TEXT record that is the first record following the gathered PLACEMENT records must be the byte-offset pointed to by this property.

A TEXT record must not have its text-string stored locally.

TEXT records cannot be the first record present in a compressed localized CBLOCK record.

A TEXT record's byte volume cannot be excluded from a <cell-volume> computation.

Undefined Bounding Box

An undefined bounding box can only be associated with an empty top cell. An empty top cell's bounding box can only be characterized as 'undefined' and its flags filed is fixed to '010.'

Window Extraction

The window extraction figure operation describes any region query where there is a need to gather geometric shapes within a given two-dimensional, rectangular, coordinate space. The window extraction process can be a region query which extracts the extent of a chip window, fracture window, imaging area, a field/stripe a drawing window or drawing area. The window extraction process can gather the extent of all figures within the top cell of a chip design, all layers. This extent can be used as the chip window for the property, P44_CHIP_WINDOW.

The window extraction operation that is noted in Table 1, Item 1 of the specification, P44-1216, that defines the chip window must have ignored the coordinate space for all TEXT records present, all layers. In other words, the written out P44 file cannot express a chip window that includes the coordinate space for all TEXT records, all layers.

Value List

A value list is a set of P39-defined, property-values that are part of a P39 PROPRTY record. The list can contain one or more property-values.

P44 Value List Definitions

Yotta felt it important to define the property-value lists for each P44 PROPERTY record. Rather than listing alphabetically, they are gathered and defined by the P44 property.

P44_FORMAT

<format>

The property-value, <format>, from the property, P44_FORMAT, represents a restriction level - currently fixed to '1' - for Table 1, of P44-1216. A property-value of '1' means that all figure operations noted in Table 1 of the P44-1216 specification must be implemented, satisfactorily, prior to the writing of a P44 file.

There is no plan to change this property-value. If it is changed, so too must the P44 property, P44_VERSION.

P44_CHIP_WINDOW

<x1>, <y1>, <x2>, and <y2>

The property-values, <x1>, <y1>, <x2>, and <y2>., from the property, P44_CHIP_WINDOW, represent the extent of the lower-left and upper-right coordinate occupied by a chip, all layers. Its property-values can cover a space equal to or greater than the bounding box coordinate space of a P44 file's top cell. It cannot include the coordinate space of any TEXT records. The chip window size can occupy the 64-bit processing space up to the signed-integer value of (+/-) 999999999999999. The property-values for this property are associated with a drawing window or drawing area derived from the window extraction figure operation noted in Table 1 of the specification P44-1216.

P44_VERSION

<oasis-mask-version>

The property-value, <oasis-mask-version>, from the property, P44_VERSION, is an implied a-string. The string must be stored in a PROPSTRING record. The value cannot be stored, locally, within the PROPERTY record. It defines the current version of the SEMI P44 standard which is P44-1216.

P44_FILE_SIZE

<file-size>

The property-value, <file-size>, from the property, P44_FILE_SIZE, reports the number of bytes required to represent all of the data present within the P44 file. Its value is an unsigned integer.

P44_TOP_CELL_NUMBER

<top-cell-number>

The property-value, <top-cell-number>, from the property, P44_TOP_CELL_NUMBER, represents the reference number for the top cell. Its value is an unsigned integer.

P44_CONVERSION_TOOL

<name>

The property-value, <name>, from the property, P44_CONVERSION_TOOL, represents the name of the tool that had written out the P44 file. Its property-value is an implied a-string. This value must not be stored locally with the PROPERTY record. It must be stored with a PROPSTRING record.

<version>

The property-value, <version>, from the property P44_CONVERSION_TOOL., represents the version number of the tool which had written out the P44 file. Its property-value is an implied a-string. This value must not be stored locally with the PROPERTY record. It must be stored with a PROPSTRING record.

P44_CONVERSION_DATE

<date>

The property-value, <date>, from the property, P44_CONVERSION_DATE, represents the date the file had been written to a P44 file. It is an implied a-string. The value must not be stored locally within its PROPERTY record. It must be stored within a PROPSTRING record.

<time>

The property-value, <time>, from the property, P44_CONVERSION_DATE, represents the time the file had been written to a P44 file. It is an implied a-string. The value must not be stored locally within its PROPERTY record. It must be stored within a PROPSTRING record.

<zone>

The property-value, <zone>, from the property, P44_CONVERSUION_DATE, represents the time differential from Coordinated Universal Time (UTC). Its value can be a positive or negative real number in quarter-hour increments.

Yotta believes that this property-value should be limited to a real type 6 or 7 as defined by SEMI P39-0308. Yotta, sparingly, tests all possible real number types, both positive and negative <zone> property-values, but has fixed the property-value for the rest of its test cases as a positive, real type 0, number.

P44_BOUNDING_BOX_MAX

<width>

The property-value, <width>, is the largest bounding box width allowed for 2nd- and 3rd-level cells. It is a static value set by the P44 specification which is 1 mm, at this time.

Its value is zero only while an empty top cell is present in the P44 file.

<height>

The property-value, <height>, from the property, P44_BOUNDING_BOX_MAX, is the largest bounding box width allowed for 2nd- and 3rd-level cells. It is a static value set by the P44 specification which is 1 mm for this version of the P44-1216 specification.

Its value is zero only while an empty top cell is present in the P44 file.

P44_LOCALIZATION

<largest-localization-width>

The property-value, <largest-localization-width>, from the property, P44_LOCALIZATION, represents the largest bounding box width found while comparing the widths of all localized areas present within the top cell that are defined by the property, P44_LOCALIZATION_AREA.

This width of a localized area that contains only commons cells must have value of zero.

<largest-localization-height>

The property-value, <largest-localization-height>, from the property, P44_LOCALIZATION, represents the largest bounding box height found while comparing the heights of all localized areas present within the top cell that are defined by the property, P44_LOCALIZATION_AREA.

This height of a localized area that contains only commons cells must have value of zero.

<largest-localized-area-cell-volume>

The property, <largest-localized-area-cell-volume>, from the property, P44_LOCALIZATION, represents the largest <cell-volume> property-value found while comparing all localized areas defined by the property, P44_LOCALIZATION_AREA. If a localized area contains only common cells, this value will be zero.

This cell volume for a localized area that contains only commons cells must have value of zero.

The byte volume for this property-value cannot have excluded the byte volume of TEXT and PAD records.

<common-cell-volume>

The property-value, <common-cell-volume>, from the property, P44_LOCALIZATION, represents the volume, in bytes, of CELL record data present within a P44 file that, only, includes the file's common cells. This property-value is the same value present within the property, P44_COMMON_CELL, called <cell-volume>.

The byte volume for this property-value cannot have excluded the byte volume of TEXT and PAD records.

<localization-area-count>

The property-value, <localization-area-count>, from the property, P44_LOCALIZATION, is the summation of all P44_LOCALIZATION_AREA property records that define the localized areas within the top cell.

<top-cell-cellname-offset>

The property-value, <top-cell-cellname-offset>, >, from the property, P44_LOCALIZATION, is the byte-offset from the top of the P44 file to the top cell CELLNAME record or to the CBLOCK record that has compressed the top cell CELLNAME record.

A PAD record cannot be the first record in a compressed top cell CELLNAME record.

P44_GEOMETRY_OFFSET_AVAILABLE

<flag>

The property-value, <flag>, from the property, P44_GEOMETRY_OFFSET_AVAILABLE, represents whether the property, P44_GEOMETRY_OFFSET, is present for all 2nd-level cells in the P44 file. A <flag> of '0' means that that this property is not present. A value of '1' means the property is present.

Yotta treats the absence of the property-value, P44_GEOMETRY_OFFSET, a fatal error while the property-value for P44_GEOMETRY_OFFSET_AVAILABLE is set to '1.'

P44_GEOMETRY_COUNT

<geometry-record-count>

The property-value, <geometry-record-count>, from the property, P44_GEOMETRY_COUNT, represents the number of figures present within each CELL record. The top cell must not contain any figure records. Its value must be fixed to zero.

P44_GEOMETRY_OFFSET

<geometry-record-offset>

The property-value, <geometry-record-offset>, from the property, P44_GEOMTRY_OFFSET, represents the byte-offset to the first TEXT or figure record within a 2nd-level cell after all PLACEMENT records have been gathered and placed first within that cell. This property need not be present for 3rd-level cells and the top cell.

There is no order required for figure and text records while this property is present.

This property-value cannot point to a compressed PAD record that precedes the first compressed TEXT or figure present within the same CBLOCK record.

P44_LOCALIZATION_AREA

<lower-left-x>, lower-left-y>, <upper-right-x> and <upper-right-y>

The property-values, <lower-left-x>, lower-left-y>, <upper-right-x> and <upper-right-y>, from the property, P44_LOCALIZATION_AREA, represent the lower-left and upper-right coordinate space defined for a single localized area within the top cell. It cannot include the coordinate space of any TEXT records.

The field values, here, can be less than or equal to the field values for the property, P44_CHIP_WINDOW.

<cell-offset>

The property-value, <cell-offset>, from the property, P44_LOCALIZATION_AREA, is the byte-offset of the first CELL record gathered as part of a localized area.

This property-value cannot point to a compressed localized CELL record area that has a PAD record as its first record. It cannot point to a compressed cell-offset that shares more than one localized area within the same CBLOCK record.

<cell-volume>

The property-value, <cell-volume>, from the property, P44_LOCALIZATION_AREA, is the number of bytes that cover the localized area starting with the first CELL record byte-offset minus the byte-offset of the last CELL record of that localized area.

TEXT and PAD record byte volumes cannot be excluded from this property-value.

<cellname-offset>

The property-value, <cellname-offset>, from the property, P44_LOCALIZATION_AREA, is the byte-offset of the first CELLNAME record gathered as part of a localized area.

This property-value cannot point to a compressed localized CELLNAME area that has a PAD record as its first record. It cannot point to a compressed cellname-offset that shares more than one localized area within the same CBLOCK record.

<cellname-volume>

The property-value, <cellname-volume>, from the property, P44_LOCALIZATION_AREA, is the number of bytes that cover the localized area starting with the first CELLNAME record byte-offset minus the byte-offset of the CELLNAME record of the next localized area.

PAD record byte volumes cannot be excluded from this property-value.

This property-value cannot point to a compressed localized CELLNAME record volume whose first record is a PAD record.

<placement-offset>

The property, <placement-offset>, from the property, P44_LOCALIZATION_AREA, represents the offset starting with the byte-offset of the top cell, CELL record, to the first PLACEMENT record of a gathered set of PLACEMENT records that define a localized area.

This property-value cannot point to TEXT and PAD records that precede a localized area. It cannot point to a compressed localized area whose first record is a PAD or TEXT record.

<placement-count>

The property-value, <placement-count>, from the property, P44_LOCALIZATION_AREA, represents the number of placement records that define a localized area.

If the top cell is both empty and localized, the property-value for this field is fixed to '0.'

P44_COMMON_CELL

<cell-offset>

The property-value, <cell-offset>, from the property, P44_COMMON_CELL, is the byte-offset of the first CELL record gathered as part of a common cell area.

This property-value cannot point to a compressed localized CELL record area that has a PAD record as its first record. It cannot point to a compressed cell-offset that shares a localized area within the same CBLOCK record.

<cell-volume>

The property-value, <cell-volume>, from the property, P44_COMMON_CELL, is the number of bytes that cover the common cell area starting with the first CELL record byte-offset minus the byte-offset of the record immediately following the last common cell, CELL record

TEXT and PAD record byte volumes cannot be excluded from this property-value.

<cellname-offset>

The property-value, <cellname-offset>, from the property, P44_COMMON_CELL, is the byte-offset of the first CELLNAME record gathered as part of the common cell area.

This property-value cannot point to a compressed localized CELLNAME area that has a PAD record as its first record. It cannot point to a compressed cellname-offset that shares a localized area within the same CBLOCK record.

<cellname-volume>

The property-value, <cellname-volume>, from the property, P44_COMMON_CELL, is the number of bytes that cover the common cell area starting with the first CELLNAME record byte-offset minus the byte-offset of the record following immediately after the last common cell CELLNAME record.

PAD record byte volumes cannot be excluded from this property-value.

This property-value cannot point to a compressed localized CELLNAME record volume whose first record is a PAD record.

Inconsistencies with the definitions of the P44 PROPERTY record property-value fields are what had led Yotta to define them in this documentation. It will be important to ensure that these fields are used by all P44 implementations.

P44-1216 BNF Syntax

Table 2 – Modified BNF Notation from P39-0308, Table 16

Symbol	Term	Meaning
ABCD	Bold Uppercase	Denote an OASIS.MASK record name
abcd	Bold Lowercase	Denotes a fundamental datatype defined in SEMI P39-0308, Section 7
< >	Angle Brackets	Enclose and element name which is further defined elsewhere in the BNF
->	Arrow	Means "is composed of"
[ ]	Square Brackets	Enclose element(s) which are optional and, if present, occur only once
{ }	Braces	Enclose element(s) which are required

|	Vertical Bar	Indicates a choice between mutually exclusive elements within { } braces
*	Asterisk	An asterisk following an element means the element may occur zero or more times
…	Ellipsis	Appears between elements to indicate a variable-length list of like type
' '	Single Quotes	Enclose a decimal number denoting an OASIS® unsigned-integer
" "	Double Quotes	Enclose a literal character string
"<CR>"	Control Character	Angle brackets enclose the name of an ASCII Control Character within a string
//	Double Virgule	Indicates all characters to its right are comments – not part of syntax,

The BNF syntax for all OASIS® records can be accessed through the SEMI specification P39-0308. The BNF syntax for all P44-1216 properties is:

P44_FORMAT -> <format>
P44_CHIP_WINDOW-> <x1>, <y1>, <x2>, <y2>
P44_VERSION -> <oasis-mask-version>
P44_FILE_SIZE -> <file-size>
P44_TOP_CELL_NUMBER -> <top-cell-number>
P44_CONVERSION_TOOL -> <name>, <version>
P44_CONVERSION_DATE -> <date>, <time>, <zone>
P44_BOUNDING_BOX_MAX -> <width>, <height>
P44_LOCALIZATION -> <largest-localization-width>, <largest-localization-height>, <largest-localized-area-cell-volume>, <common-cell-volume>, <localization-area-count>, <top-cell-cellname-offset>
P44_GEOMETRY_OFFSET_AVAILABLE -> <flag>
P44_GEOMETRY_COUNT -> <geometry-record-count>
P44_GEOMETRY_OFFSET -> <geometry-record-offset>
P44_LOCALIZATION_AREA -> <lower-left-x>, <lower-left-y>, <upper-right-x>, <upper-right-y>, <cell-offset>, <cell-volume>, <cellname-offset>, <cellname-volume>, <placement-offset>, <placement-count>
P44_COMMON_CELL -> <cell-offset>, <cell-volume>, <cellname-offset>, <cellname-volume>

Field Values Not Tested by Yotta

Yotta makes nearly exclusive use of the P39 implicit reference-number system. Because each reference number must occur in one unit increments, it is practically, impossible to build a test case which uses 64-bit reference numbers without the file being very, very, large; too large for a regressions test case. The field values not tested are:

(1) Maximum 32-bit reference numbers for all PROPERTY, PLACEMENT, CELL, CELLNAME, PROPNAME, PROPSTRING, TEXT and TEXTSTRING records.
(2) 32-bit maximums for repetition xdim and ydim for all figure, TEXT and PLACEMENT records

(3) 64-bit maximum for the P39 property, S_CELL_OFFSET
(4) 64-bit maximum value for P44_FILE_SIZE.
(5) 32-bit maximum for P44_TOP_CELL_NUMBER
(6) 32- and 64-bit maximum values for <largest-localized-area-cell-volume>, <common-cell-volume>, <localization area count>, <top-cell-cellname-offset> for the P44 property, P44_LOCALIZATION
(7) 32-bit maximum value for the P44 property, P44_GEOMETRY_COUNT
(8) 64-bit maximum value for the P44 property, P44_GEOMETRY_OFFSET
(9) 32- and 64-bit maximums for <cell-offset>, <cell-volume>, <cellname-offset>, <cellname-volume>, <placement-offset> and <localization-area-count> for the P44 properties, P44_LOCALIZATION_AREA and P44_COMMON_CELL

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