D1/01. Introduction into Relational Databases

School on the Database Infrastructure for the CMS Phase 2 Upgrade

Outline

- Relational model
  - Database normalization
  - Example
- Database modeling
  - Entity-Relationship diagram
  - Example
- Relational database
  - Table
  - Constraints

Quiz 01: You and DB

1. Know DB software exists…
2. Just general concepts (tables, SQL)
3. Use databases directly (SQL)
4. Have designed DB once
5. Design and maintain DB

Quiz 02: You and Oracle DB

1. Know Oracle DB exists…
2. Used indirectly via 3rd party software
3. Use or have used Oracle DB directly (SQL)
4. Develop or have developed software on top of Oracle DB
5. Develop and/or maintain Oracle DB

Types of Database Models

- A database model shows the logical structure of a database
  - relationships and constraints that determine how data can be stored and accessed
  - database models are designed based on the rules and concepts of broader data model
  - most data models can be represented by an accompanying database diagram
- Types of Database Models
  - Hierarchical
  - Network
  - Relational
  - Graph
  - Object-oriented
  - Star schema
  - Document model

E.F.Codd: author of Relational *

- Edgar Frank Codd (1923 – 2003)
  - English computer scientist
  - RAF Coastal Command during the WW2, flying Sunderlands
- Formalized everything relational (algebra, model, databases)
  - While working for IBM, invented the relational model for database management
  - The theoretical basis for relational databases and relational database management systems
  - F. Codd, E. (1970). "A Relational Model of Data for Large Shared Data Banks". Commun. ACM. 13. 377-387. https://www.doi.org/10.1007/978-3-642-48354-7_4
- Not easy relationship with IBM, others
  - Codd's 12 Rules for an RDBMS
    - 1985 a two-part article published in *Computerworld* magazine
    - "Is Your DBMS Really Relational?" in October 14, 1985
    - "Does Your DBMS Run By the Rules?" in October 21, 1985

Relational Database

- Relational model elements
  - <u>Structures</u> - well-defined objects store or access the data of a database
  - <u>Operations</u> - clearly defined actions enable applications to manipulate the data and structures
  - <u>Integrity rules</u> - govern operations on the data and structures of a database
- Relational database
  - stores data in a set of simple <u>relations</u>
  - relation is a <u>set of tuples</u>
  - tuple is an unordered <u>set of attribute</u> values
- Table
  - two-dimensional representation of a relation
    - Rows = tuples
    - Columns = attributes
  - each row in a table has the same set of columns

Database normalization

- Structuring Data into Relational Model
- Motivation
  - reduce data redundancy
  - improve data integrity
  - minimize redesign when extending the database structure
    - applications interacting with the database are minimally affected
  - mirror real-world concepts and their interrelationships
- Denormalized form → Normalization → Denormalization
- Normal Forms
  - NF1, NF2, NF3, EKNF, BCNF, ...
    - eliminate repeating groups (create a separate table for each set of related data)
    - identify each set of related data with a primary key
    - not have transitive dependencies
    - ...

Dataset: UNF

WAFER KIND	WAFER SERIAL	WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE	MEAS. DATE	VOLTS	AMPS
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	180	398.5
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	200	399.7
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	220	400.7
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	240	402.2
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	260	404.3
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	0	22.17
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	20	259.8
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	40	328.8
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	60	368.6
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	80	385.8
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	0	22.64
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	20	252.3
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	40	318.9
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	60	361.2
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	80	381.3

Dataset: Repeating Groups (1)

Sensor

WAFER KIND	WAFER SERIAL	WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE	MEAS. DATE	VOLTS	AMPS
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	180	398.5
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	200	399.7
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	220	400.7
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	240	402.2
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962	2018-08-15	260	404.3
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	0	22.17
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	20	259.8
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	40	328.8
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	60	368.6
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963	2018-08-23	80	385.8
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	0	22.64
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	20	252.3
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	40	318.9
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	60	361.2
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964	2018-08-25	80	381.3

Dataset: Sensors & IV data

Sensor

WAFER KIND	WAFER SERIAL	WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	2	Hamamatsu Sensor	HAS_01789_5965	3011220120000005965
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926	1	Hamamatsu Sensor	HAS_01789_5966	3011220120000005966
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926	2	Hamamatsu Sensor	HAS_01789_5967	3011220120000005967
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928	1	Hamamatsu Sensor	HAS_01789_5968	3011220120000005968
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928	2	Hamamatsu Sensor	HAS_01789_5969	3011220120000005969

IV data

SENSOR BARCODE	MEAS. DATE	VOLTS	AMPS
3011220120000005962	2018-08-15	180	398.5
3011220120000005962	2018-08-15	200	399.7
3011220120000005962	2018-08-15	220	400.7
3011220120000005962	2018-08-15	240	402.2
3011220120000005962	2018-08-15	260	404.3
3011220120000005963	2018-08-23	0	22.17
3011220120000005963	2018-08-23	20	259.8
3011220120000005963	2018-08-23	40	328.8

Dataset: Repeating Groups (2)

Wafer

WAFER KIND	WAFER SERIAL	WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924	2	Hamamatsu Sensor	HAS_01789_5965	3011220120000005965
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926	1	Hamamatsu Sensor	HAS_01789_5966	3011220120000005966
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926	2	Hamamatsu Sensor	HAS_01789_5967	3011220120000005967
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928	1	Hamamatsu Sensor	HAS_01789_5968	3011220120000005968
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928	2	Hamamatsu Sensor	HAS_01789_5969	3011220120000005969

Dataset

SENSOR BARCODE	MEAS. DATE	VOLTS	AMPS
3011220120000005962	2018-08-15	180	398.5
3011220120000005962	2018-08-15	200	399.7
3011220120000005962	2018-08-15	220	400.7
3011220120000005962	2018-08-15	240	402.2
3011220120000005962	2018-08-15	260	404.3
3011220120000005963	2018-08-23	0	22.17
3011220120000005963	2018-08-23	20	259.8
3011220120000005963	2018-08-23	40	328.8

Dataset: Wafer and Dataset

Wafer

WAFER KIND	WAFER SERIAL	WAFER BARCODE
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928

Sensor

WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE
3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962
3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963
3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964
3011220120000005924	2	Hamamatsu Sensor	HAS_01789_5965	3011220120000005965
3011220120000005926	1	Hamamatsu Sensor	HAS_01789_5966	3011220120000005966
3011220120000005926	2	Hamamatsu Sensor	HAS_01789_5967	3011220120000005967
3011220120000005928	1	Hamamatsu Sensor	HAS_01789_5968	3011220120000005968
3011220120000005928	2	Hamamatsu Sensor	HAS_01789_5969	3011220120000005969

Dataset

SENSOR BARCODE	MEAS. DATE
3011220120000005962	2018-08-15
3011220120000005963	2018-08-23
3011220120000005964	2018-08-25
3011220120000005965	2018-08-26
3011220120000005966	2018-08-27
3011220120000005967	2018-08-28
3011220120000005968	2018-08-29
3011220120000005969	2018-08-30

IV data

MEAS. DATE	VOLTS	AMPS
2018-08-15	180	398.5
2018-08-15	200	399.7
2018-08-15	220	400.7
2018-08-15	240	402.2
2018-08-15	260	404.3
2018-08-23	0	22.17
2018-08-23	20	259.8
2018-08-23	40	328.8

Dataset: Generalization

Wafer

WAFER KIND	WAFER SERIAL	WAFER BARCODE
Hamamatsu Sensor Wafer	HAF_123456_2036	3011220120000005922
Hamamatsu Sensor Wafer	HAF_123456_2038	3011220120000005924
Hamamatsu Sensor Wafer	HAF_123456_2040	3011220120000005926
Hamamatsu Sensor Wafer	HAF_123456_2042	3011220120000005928

Sensor

WAFER BARCODE	SLOT	SENSOR KIND	SENSOR SERIAL	SENSOR BARCODE
3011220120000005922	1	Hamamatsu Sensor	HAS_01789_5962	3011220120000005962
3011220120000005922	2	Hamamatsu Sensor	HAS_01789_5963	3011220120000005963
3011220120000005924	1	Hamamatsu Sensor	HAS_01789_5964	3011220120000005964
3011220120000005924	2	Hamamatsu Sensor	HAS_01789_5965	3011220120000005965
3011220120000005926	1	Hamamatsu Sensor	HAS_01789_5966	3011220120000005966
3011220120000005926	2	Hamamatsu Sensor	HAS_01789_5967	3011220120000005967
3011220120000005928	1	Hamamatsu Sensor	HAS_01789_5968	3011220120000005968
3011220120000005928	2	Hamamatsu Sensor	HAS_01789_5969	3011220120000005969

Dataset

SENSOR BARCODE	MEAS. DATE
3011220120000005962	2018-08-15
3011220120000005963	2018-08-23
3011220120000005964	2018-08-25
3011220120000005965	2018-08-26
3011220120000005966	2018-08-27
3011220120000005967	2018-08-28
3011220120000005968	2018-08-29
3011220120000005969	2018-08-30

IV data

MEAS. DATE	VOLTS	AMPS
2018-08-15	180	398.5
2018-08-15	200	399.7
2018-08-15	220	400.7
2018-08-15	240	402.2
2018-08-15	260	404.3
2018-08-23	0	22.17
2018-08-23	20	259.8
2018-08-23	40	328.8

Dataset: Parts

Part

PART BARCODE	PART KIND	PART SERIAL	PARENT BARCODE	SLOT
3011220120000005922	Hamamatsu Sensor Wafer	HAF_123456_2036		
3011220120000005924	Hamamatsu Sensor Wafer	HAF_123456_2038		
3011220120000005926	Hamamatsu Sensor Wafer	HAF_123456_2040		
3011220120000005928	Hamamatsu Sensor Wafer	HAF_123456_2042		
3011220120000005962	Hamamatsu Sensor	HAS_01789_5962	3011220120000005922	1
3011220120000005963	Hamamatsu Sensor	HAS_01789_5963	3011220120000005922	2
3011220120000005964	Hamamatsu Sensor	HAS_01789_5964	3011220120000005924	1
3011220120000005965	Hamamatsu Sensor	HAS_01789_5965	3011220120000005924	2
3011220120000005966	Hamamatsu Sensor	HAS_01789_5966	3011220120000005926	1
3011220120000005967	Hamamatsu Sensor	HAS_01789_5967	3011220120000005926	2
3011220120000005968	Hamamatsu Sensor	HAS_01789_5968	3011220120000005928	1
3011220120000005969	Hamamatsu Sensor	HAS_01789_5969	3011220120000005928	2

Dataset

PART BARCODE	MEAS. DATE
3011220120000005962	2018-08-15
3011220120000005963	2018-08-23
3011220120000005964	2018-08-25
3011220120000005965	2018-08-26
3011220120000005966	2018-08-27
3011220120000005967	2018-08-28
3011220120000005968	2018-08-29
3011220120000005969	2018-08-30

IV data

MEAS. DATE	VOLTS	AMPS
2018-08-15	180	398.5
2018-08-15	200	399.7
2018-08-15	220	400.7
2018-08-15	240	402.2
2018-08-15	260	404.3
2018-08-23	0	22.17
2018-08-23	20	259.8
2018-08-23	40	328.8

Dataset: Natural Primary Keys

Part

PART BARCODE	PART KIND	PART SERIAL	PARENT BARCODE	SLOT
30112201200000005922	Hamamatsu Sensor Wafer	HAF_123456_2036		
30112201200000005924	Hamamatsu Sensor Wafer	HAF_123456_2038		
30112201200000005926	Hamamatsu Sensor Wafer	HAF_123456_2040		
30112201200000005928	Hamamatsu Sensor Wafer	HAF_123456_2042		
30112201200000005962	Hamamatsu Sensor	HAS_01789_5962	30112201200000005922	1
30112201200000005963	Hamamatsu Sensor	HAS_01789_5963	30112201200000005922	2
30112201200000005964	Hamamatsu Sensor	HAS_01789_5964	30112201200000005924	1
30112201200000005965	Hamamatsu Sensor	HAS_01789_5965	30112201200000005924	2
30112201200000005966	Hamamatsu Sensor	HAS_01789_5966	30112201200000005926	1
30112201200000005967	Hamamatsu Sensor	HAS_01789_5967	30112201200000005926	2
30112201200000005968	Hamamatsu Sensor	HAS_01789_5968	30112201200000005928	1
30112201200000005969	Hamamatsu Sensor	HAS_01789_5969	30112201200000005928	2

Dataset

SENSOR BARCODE	MEAS. DATE
30112201200000005962	2018-08-15
30112201200000005963	2018-08-23
30112201200000005964	2018-08-25
30112201200000005965	2018-08-26
30112201200000005966	2018-08-27
30112201200000005967	2018-08-28
30112201200000005968	2018-08-29
30112201200000005969	2018-08-30

IV data

MEAS. DATE	VOLTS	AMPS
2018-08-15	180	398.5
2018-08-15	200	399.7
2018-08-15	220	400.7
2018-08-15	240	402.2
2018-08-15	260	404.3
2018-08-23	0	22.17
2018-08-23	20	259.8
2018-08-23	40	328.8

Dataset: Surrogate Primary Keys

Part

ID	PART BARCODE	PART KIND	PART SERIAL	PARENT ID
1	3011220120000005922	Hamamatsu Sensor Wafer	HAF_123456_2036	
2	3011220120000005924	Hamamatsu Sensor Wafer	HAF_123456_2038	
3	3011220120000005926	Hamamatsu Sensor Wafer	HAF_123456_2040	
4	3011220120000005928	Hamamatsu Sensor Wafer	HAF_123456_2042	
5	3011220120000005962	Hamamatsu Sensor	HAS_01789_5962	1
6	3011220120000005963	Hamamatsu Sensor	HAS_01789_5963	1
7	3011220120000005964	Hamamatsu Sensor	HAS_01789_5964	2
8	3011220120000005965	Hamamatsu Sensor	HAS_01789_5965	2
9	3011220120000005966	Hamamatsu Sensor	HAS_01789_5966	3
10	3011220120000005967	Hamamatsu Sensor	HAS_01789_5967	3
11	3011220120000005968	Hamamatsu Sensor	HAS_01789_5968	4
12	3011220120000005969	Hamamatsu Sensor	HAS_01789_5969	4

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

Dataset: Repeating Groups (3)

Part

ID	PART BARCODE	PART KIND	PART SERIAL	PARENT ID	SLOT
1	3011220120000005922	Hamamatsu Sensor Wafer	HAF_123456_2036		
2	3011220120000005924	Hamamatsu Sensor Wafer	HAF_123456_2038		
3	3011220120000005926	Hamamatsu Sensor Wafer	HAF_123456_2040		
4	3011220120000005928	Hamamatsu Sensor Wafer	HAF_123456_2042		
5	3011220120000005962	Hamamatsu Sensor	HAS_01789_5962	1	1
6	3011220120000005963	Hamamatsu Sensor	HAS_01789_5963	1	2
7	3011220120000005964	Hamamatsu Sensor	HAS_01789_5964	2	1
8	3011220120000005965	Hamamatsu Sensor	HAS_01789_5965	2	2
9	3011220120000005966	Hamamatsu Sensor	HAS_01789_5966	3	1
10	3011220120000005967	Hamamatsu Sensor	HAS_01789_5967	3	2
11	3011220120000005968	Hamamatsu Sensor	HAS_01789_5968	4	1
12	3011220120000005969	Hamamatsu Sensor	HAS_01789_5969	4	2

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

Dataset: Kind of Part

Kind of Part

ID	KIND OF PART NAME
1	Hamamatsu Sensor Wafer
2	Hamamatsu Sensor

Part

ID	PART BARCODE	KOP ID	PART SERIAL	PARENT ID	SLOT
1	30112201200000005922	1	HAF_123456_2036		
2	30112201200000005924	1	HAF_123456_2038		
3	30112201200000005926	1	HAF_123456_2040		
4	30112201200000005928	1	HAF_123456_2042		
5	30112201200000005962	2	HAS_01789_5962	1	1
6	30112201200000005963	2	HAS_01789_5963	1	2
7	30112201200000005964	2	HAS_01789_5964	2	1
8	30112201200000005965	2	HAS_01789_5965	2	2
9	30112201200000005966	2	HAS_01789_5966	3	1
10	30112201200000005967	2	HAS_01789_5967	3	2
11	30112201200000005968	2	HAS_01789_5968	4	1
12	30112201200000005969	2	HAS_01789_5969	4	2

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

Example Dataset: Transitive Dependency

Kind of Part

ID	KIND OF PART NAME
1	Hamamatsu Sensor Wafer
2	Hamamatsu Sensor

Part

ID	PART BARCODE	KOP ID	PART SERIAL	PARENT ID	SLOT
1	30112201200000005922	1	HAF_123456_2036		
2	30112201200000005924	1	HAF_123456_2038		
3	30112201200000005926	1	HAF_123456_2040		
4	30112201200000005928	1	HAF_123456_2042		
5	30112201200000005962	2	HAS_01789_5962	1	1
6	30112201200000005963	2	HAS_01789_5963	1	2
7	30112201200000005964	2	HAS_01789_5964	2	1
8	30112201200000005965	2	HAS_01789_5965	2	2
9	30112201200000005966	2	HAS_01789_5966	3	1
10	30112201200000005967	2	HAS_01789_5967	3	2
11	30112201200000005968	2	HAS_01789_5968	4	1
12	30112201200000005969	2	HAS_01789_5969	4	2

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

Dataset: Part Tree

Kind of Part

ID	KIND OF PART NAME
1	Hamamatsu Sensor Wafer
2	Hamamatsu Sensor

Part

ID	PART BARCODE	KOP ID	PART SERIAL
1	30112201200000005922	1	HAF_123456_2036
2	30112201200000005924	1	HAF_123456_2038
3	30112201200000005926	1	HAF_123456_2040
4	30112201200000005928	1	HAF_123456_2042
5	30112201200000005962	2	HAS_01789_5962
6	30112201200000005963	2	HAS_01789_5963
7	30112201200000005964	2	HAS_01789_5964
8	30112201200000005965	2	HAS_01789_5965
9	30112201200000005966	2	HAS_01789_5966
10	30112201200000005967	2	HAS_01789_5967
11	30112201200000005968	2	HAS_01789_5968
12	30112201200000005969	2	HAS_01789_5969

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

Part Tree

PART ID	PARENT ID	SLOT
5	1	1
6	1	2
7	2	1
8	2	2
9	3	1
10	3	2
11	4	1
12	4	2

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

Application Design Process

- Business Modeling → Application Modeling
  - Use Case, Process, Activity, States, Function, ...
    - representing processes of an institution or group
    - with purpose of current process to be analysed, improved, and <u>automated</u>
    - structured representation of the functions (activities, actions, processes, operations)
  - Data, Classes, Static, Entity-Relationship, ...
    - graphical approach to database design
    - uses assets to represent real world objects
    - subset of model assets is directly mapped into the physical database
- Modeling tools
  - UML - Unified Modeling Language
  - Oracle CASE*Method

Entity - Relationship (ER) Modeling

Part of Oracle CASE*Method
  developed by Richard Barker, et al. working at CACI around 1981
  later R.Barker joined Oracle and published a CASE Method series of books
CASE*Method
  Process model → Process Diagram
  Functions model → Function Hierarchy
  Entity-Relationship model → ER Diagram (ERD)
  Application and Database model → Application and Database
CASE resources

  Richard Barker (1990). CASE Method: Entity Relationship Modelling. Reading, MA: Addison-Wesley Professional. ISBN 0-201-41696-4
  http://www.entitymodelling.org

ERD: Entities

- Entity
  - thing of significance
  - whether real or conceptual
  - about which the business being modeled needs to hold information
- Modeling notation
  - Rounded rectangle
  - Singular name
  - Spaces are OK
- PART example
 - Physical or Logical Component of Detector (or other Device)
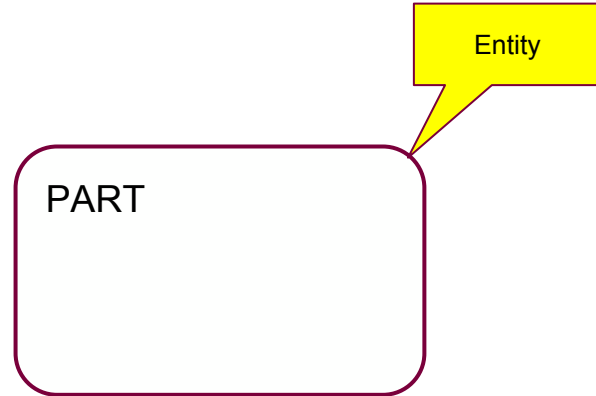
Entity

PART

ERD: Entity Attributes

- Entity Attributes
  - properties
  - data / information about entity
  - Requires data type specification
- Modeling notation
  - Singular name
  - Spaces are OK
  - # - unique identifier, PK
  - * - required
  - o - optional
- PART example
  - ID - unique identifier of the entity
  - SERIAL NUMBER - serial number of the component, required
  - KIND NAME - name of the component kind or type
  - BARCODE - component barcode, optional
  - DESCRIPTION - comments about the part, optional

PART
ID
* SERIAL NUMBER
* KIND
o BARCODE
o DESCRIPTION

Attributes
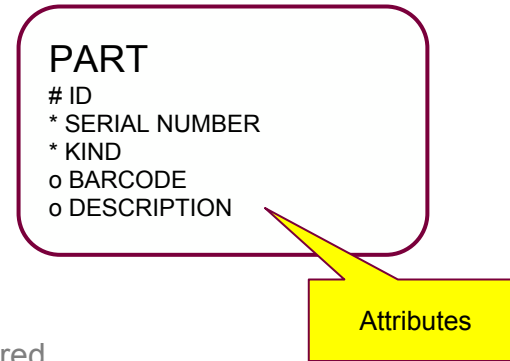
ERD: Relationships

- Relationship
  - named significant associations between two entities
  - optionality (whether a relationship is mandatory or optional)
  - cardinality (the number at each end of a relationship)
- Modeling notation
  - bi-directional expressions
  - required
  - optional
  - single cardinality
  - multiple cardinality
- KIND OF PART to PART
  - Each KIND OF PART describe one or more PART
  - Each PART must be described by one and only one KIND OF PART

KIND OF PART
\# ID
* NAME

Relationship

describe

be described

PART
\# ID
* SERIAL NUMBER
o BARCODE
o DESCRIPTION

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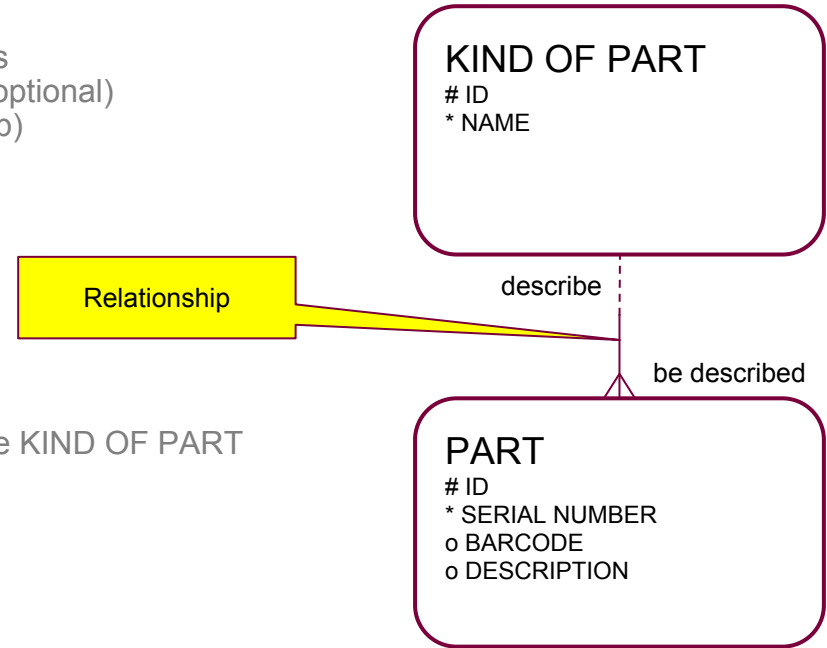
ERD: Relationship Types (1)
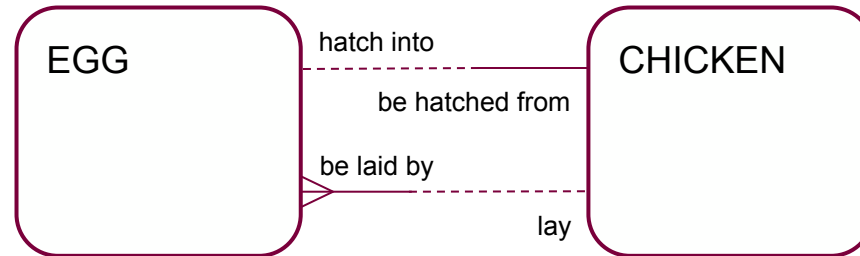
- Composition
  - → Each NUCLEUS must <u>be composed</u> of one or more PROTONs
  - ← Each PROTON must <u>belong to</u> one and only one NUCLEUS
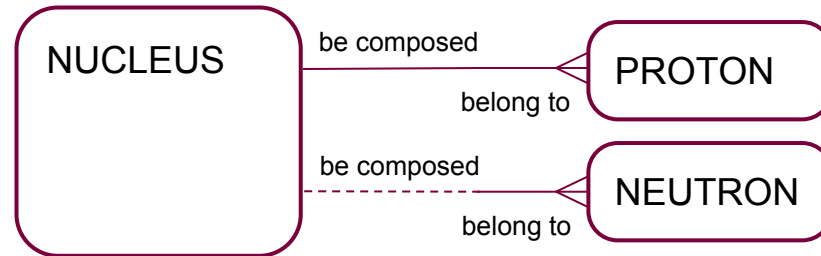
  - → Each NUCLEUS may <u>be composed</u> of one or more NEUTRONs
  - ← Each NEUTRON must <u>belong to</u> one and only one NUCLEUS

ERD: Relationship Types (2)

- Reference
  - → Each EGG may <u>hatch into</u> one and only one CHICKEN
  - ← Each CHICKEN must <u>be hatched from</u> one and only one EGG

```
┌──────────┐  hatch into        ┌──────────┐
│          │───────────────     │          │
│   EGG    │  be hatched from   │ CHICKEN  │
│          │  be laid by        │          │
│          │>───────────────    │          │
└──────────┘          lay       └──────────┘
```

  - → Each EGG must <u>be laid by</u> one and only one CHICKEN
  - ← Each CHICKEN may <u>lay</u> one or more EGGs

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ERD: Relationship Types (3)

- Recursive composition
  - → Each FOLDER may <u>contain</u> one or more FOLDERs
  - ← Each FOLDER may <u>be part of</u> one and only one FOLDER
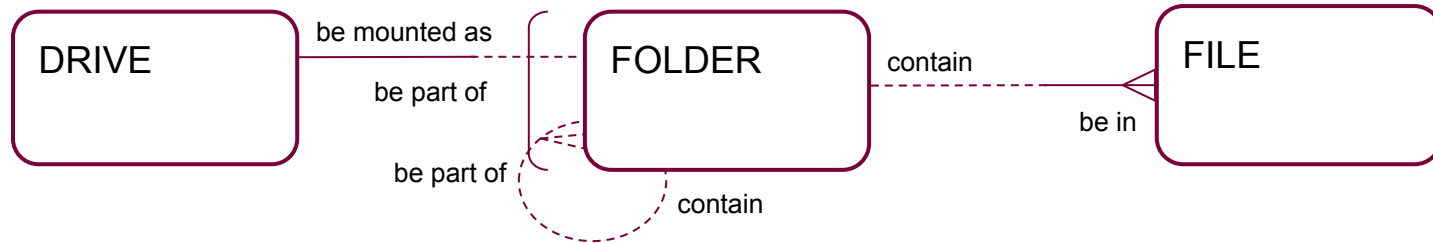
- Exclusion Arc
  - ← Each FOLDER may <u>be part of</u> one and only one FOLDER or may <u>be part of</u> one and only one DRIVE
  - Exclusive OR

Example Dataset

Kind of Part

ID	KIND OF PART NAME
1	Hamamatsu Sensor Wafer
2	Hamamatsu Sensor

Part

ID	PART BARCODE	KOP ID	PART SERIAL
1	30112201200000005922	1	HAF_123456_2036
2	30112201200000005924	1	HAF_123456_2038
3	30112201200000005926	1	HAF_123456_2040
4	30112201200000005928	1	HAF_123456_2042
5	30112201200000005962	2	HAS_01789_5962
6	30112201200000005963	2	HAS_01789_5963
7	30112201200000005964	2	HAS_01789_5964
8	30112201200000005965	2	HAS_01789_5965
9	30112201200000005966	2	HAS_01789_5966
10	30112201200000005967	2	HAS_01789_5967
11	30112201200000005968	2	HAS_01789_5968
12	30112201200000005969	2	HAS_01789_5969

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2	6	2018-08-23
3	7	2018-08-25
4	8	2018-08-26
5	9	2018-08-27
6	10	2018-08-28
7	11	2018-08-29
8	12	2018-08-30

Part Tree

PART ID	PARENT ID	SLOT
5	1	1
6	1	2
7	2	1
8	2	2
9	3	1
10	3	2
11	4	1
12	4	2

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2	1	200	399.7
3	1	220	400.7
4	1	240	402.2
5	1	260	404.3
6	2	0	22.17
7	2	20	259.8
8	2	40	328.8

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Example Dataset: Entities

Kind of Part

ID	KIND OF PART NAME
1	Hamamatsu Sensor Wafer
2	

KIND OF PART
\# ID
* NAME

Part

ID	PART BARCODE	KOP ID	PART SERIAL
1	30112201200000005922	1	HAF_123456_2036
2	30112201200000005924	1	HAF_123456_2038
3			23456_2040
4			23456_2042
5			1789_5962
6			1789_5963
7			1789_5964
8			1789_5965
9			01789_5966
10	30112201200000005967	2	HAS_01789_5967
11	30112201200000005968	2	HAS_01789_5968
12	30112201200000005969	2	HAS_01789_5969

PART
\# ID
* BARCODE
* SERIAL NUMBER
* KIND OF PART ID

Dataset

ID	PART ID	MEAS. DATE
1	5	2018-08-15
2		
3		
4		
5		
6		
7		
8		

DATASET
\# ID
* DATE CREATED
* PART ID

Part Tree

PART ID	PARENT ID	SLOT
5	1	1

PART TREE
\# ID
* PART ID
* PARENT ID
* SLOT

IV data

ID	DAT ID	VOLTS	AMPS
1	1	180	398.5
2			
3			
4			
5			
6			
7			
8			

IV MEASUREMENT
\# ID
* DATASET ID
* CURRENT AMPS
* VOLTAGE

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Example ERD (1)

KIND OF PART
ID
* NAME

PART
ID
* SERIAL NUMBER
* BARCODE
* KIND OF PART ID
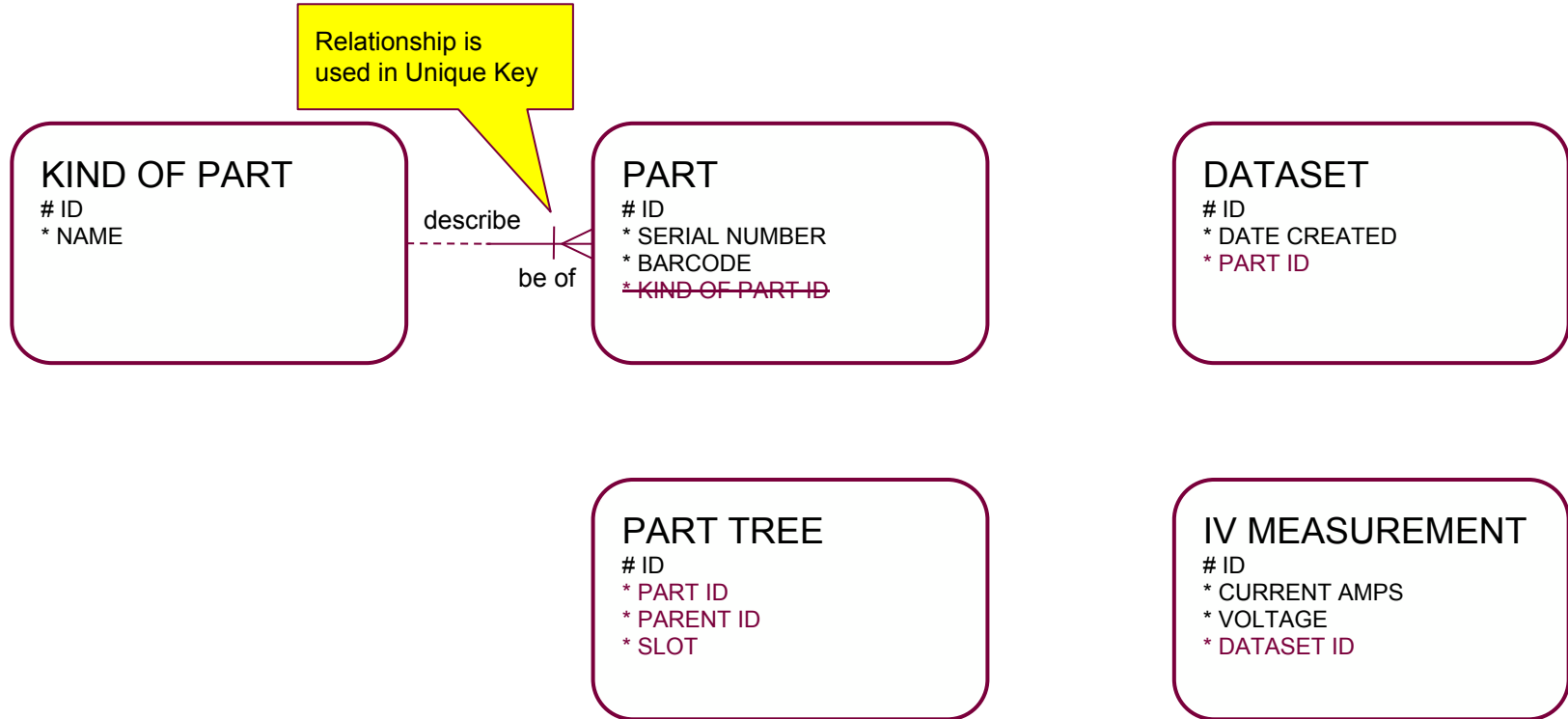
DATASET
ID
* DATE CREATED
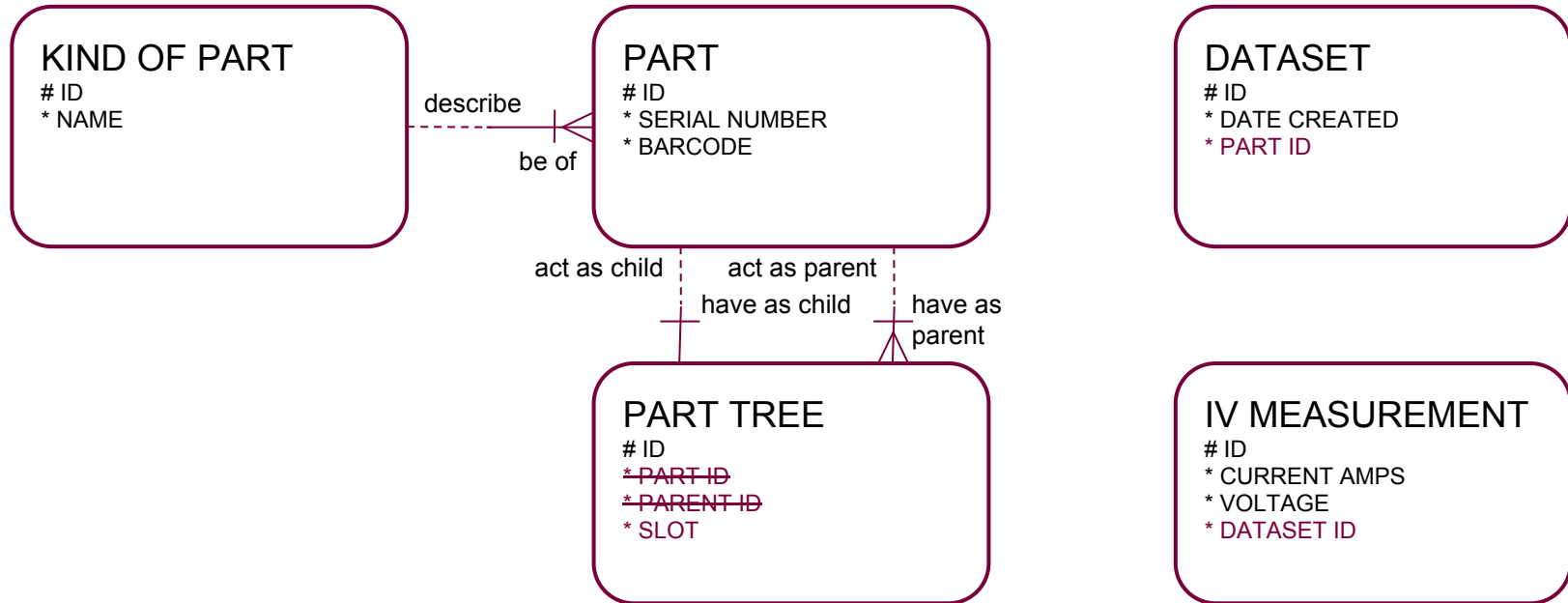* PART ID

PART TREE
ID
* PART ID
* PARENT ID
* SLOT
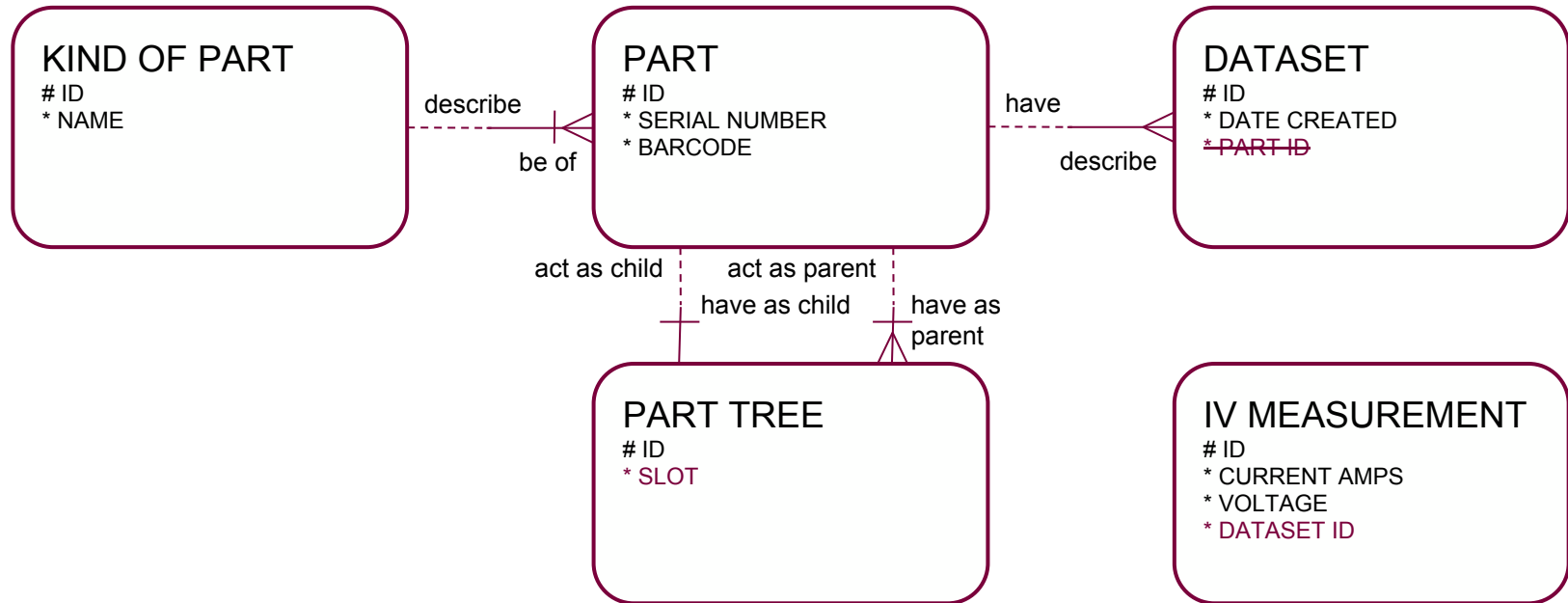
IV MEASUREMENT
ID
* CURRENT AMPS
* VOLTAGE
* DATASET ID

Example ERD (2)

KIND OF PART
ID
* NAME
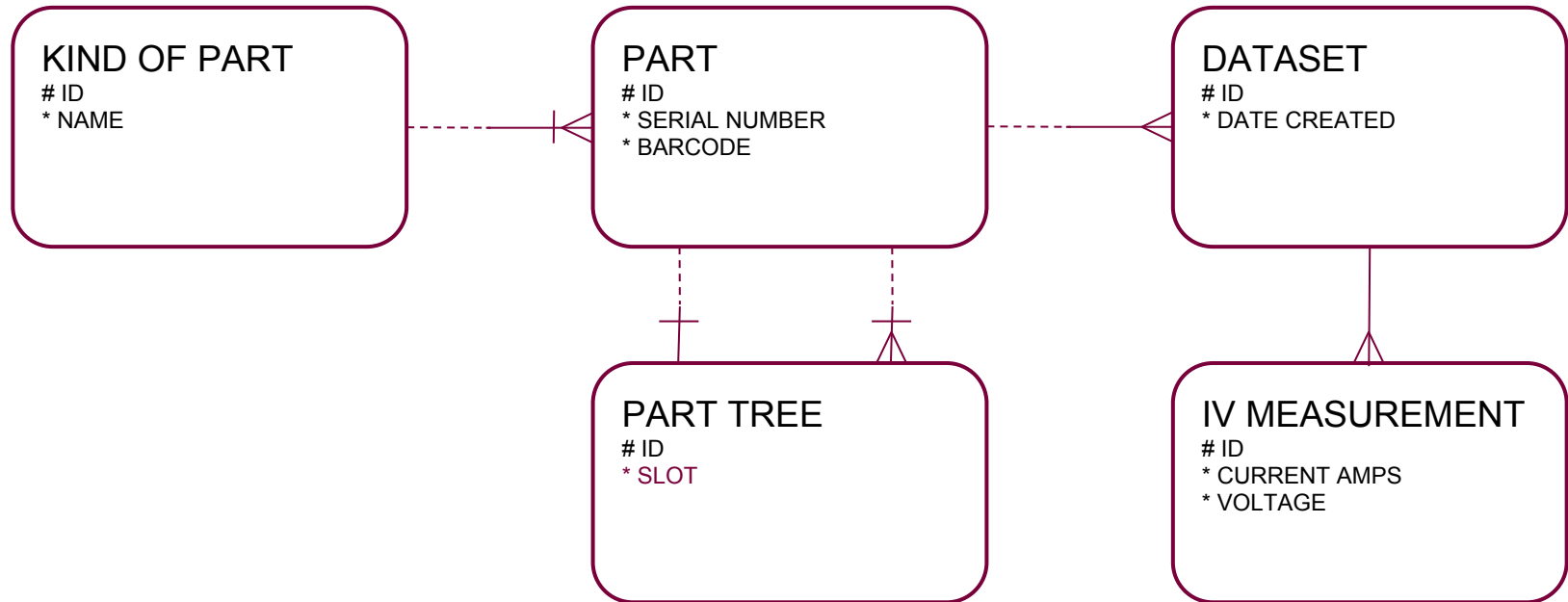
Relationship is used in Unique Key

describe

be of

PART
ID
* SERIAL NUMBER
* BARCODE
* KIND OF PART ID

DATASET
ID
* DATE CREATED
* PART ID

PART TREE
ID
* PART ID
* PARENT ID
* SLOT

IV MEASUREMENT
ID
* CURRENT AMPS
* VOLTAGE
* DATASET ID

Example ERD (3)

KIND OF PART
\# ID
* NAME

describe

be of

PART
\# ID
* SERIAL NUMBER
* BARCODE

DATASET
\# ID
* DATE CREATED
* PART ID

act as child

have as child

act as parent

have as parent

PART TREE
\# ID
* PART ID
* PARENT ID
* SLOT

IV MEASUREMENT
\# ID
* CURRENT AMPS
* VOLTAGE
* DATASET ID

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Example ERD (4)

KIND OF PART
\# ID
* NAME

PART
\# ID
* SERIAL NUMBER
* BARCODE

DATASET
\# ID
* DATE CREATED
* PART ID

PART TREE
\# ID
* SLOT

IV MEASUREMENT
\# ID
* CURRENT AMPS
* VOLTAGE
* DATASET ID

describe
be of
have
describe
act as child
have as child
act as parent
have as parent

Example ERD (5)

KIND OF PART
\# ID
* NAME

PART
\# ID
* SERIAL NUMBER
* BARCODE

DATASET
\# ID
* DATE CREATED

describe

be of

have

describe

act as child

act as parent

have as child

have as parent

have

belong to

PART TREE
\# ID
* SLOT

IV MEASUREMENT
\# ID
* CURRENT AMPS
* VOLTAGE
* DATASET ID

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Example ERD (6)

KIND OF PART
ID
* NAME

PART
ID
* SERIAL NUMBER
* BARCODE

DATASET
ID
* DATE CREATED

PART TREE
ID
* SLOT

IV MEASUREMENT
ID
* CURRENT AMPS
* VOLTAGE

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Data Modeler: Logical Model (1)
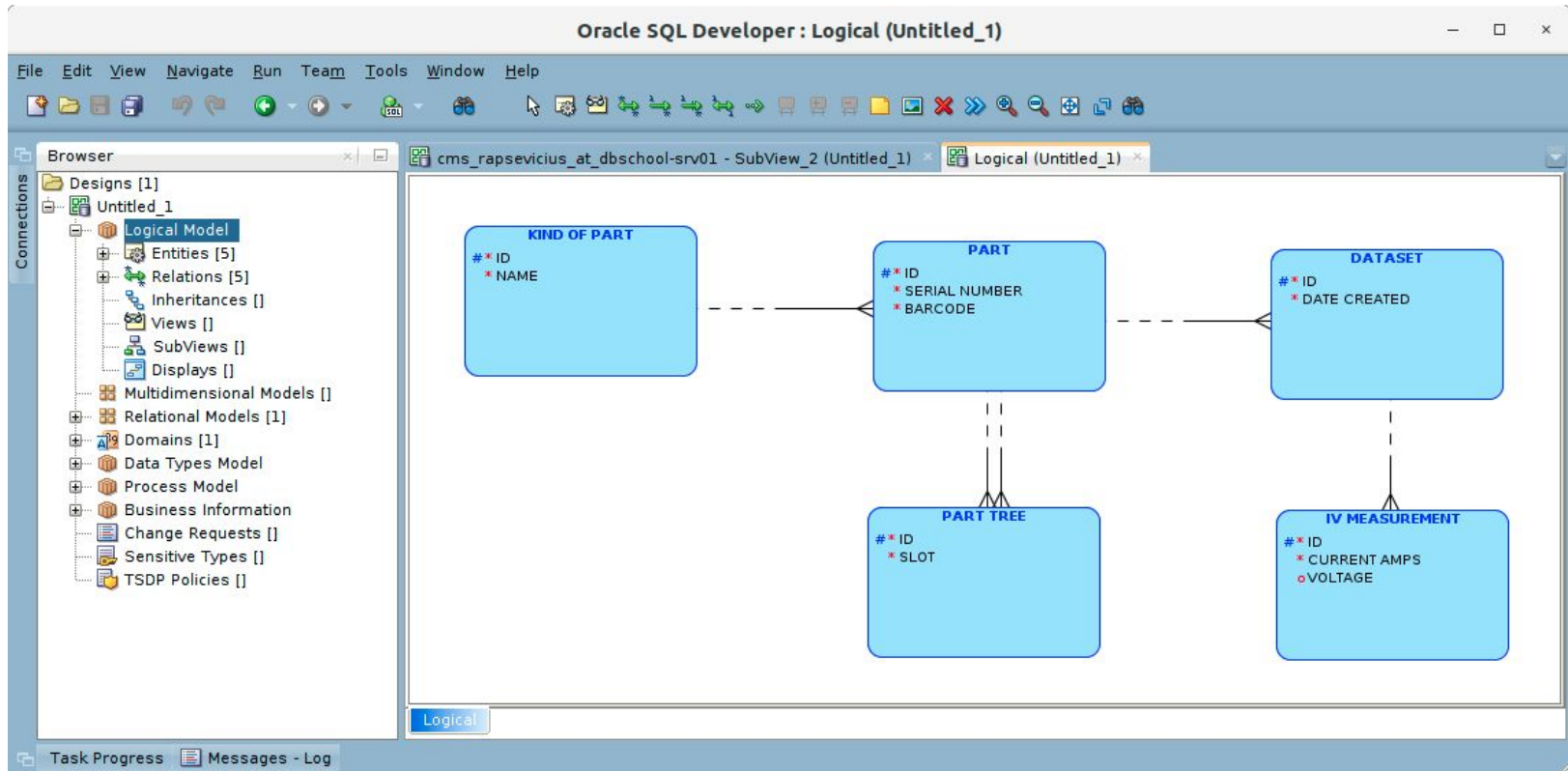
Relational Database: Table

- Data stored in <u>Table</u> (or Relation)
  - → Business Entity
  - Each Table composed of Columns and Rows
- Table <u>Column</u>
  - → Entity attribute (property, feature)
  - Has a strictly defined Type
  - Not NULL constraint
- Table <u>Row</u>
  - → Entity Instance (object, tuple)
  - Must be uniquely identified by Primary Key

Table

Column

Persons

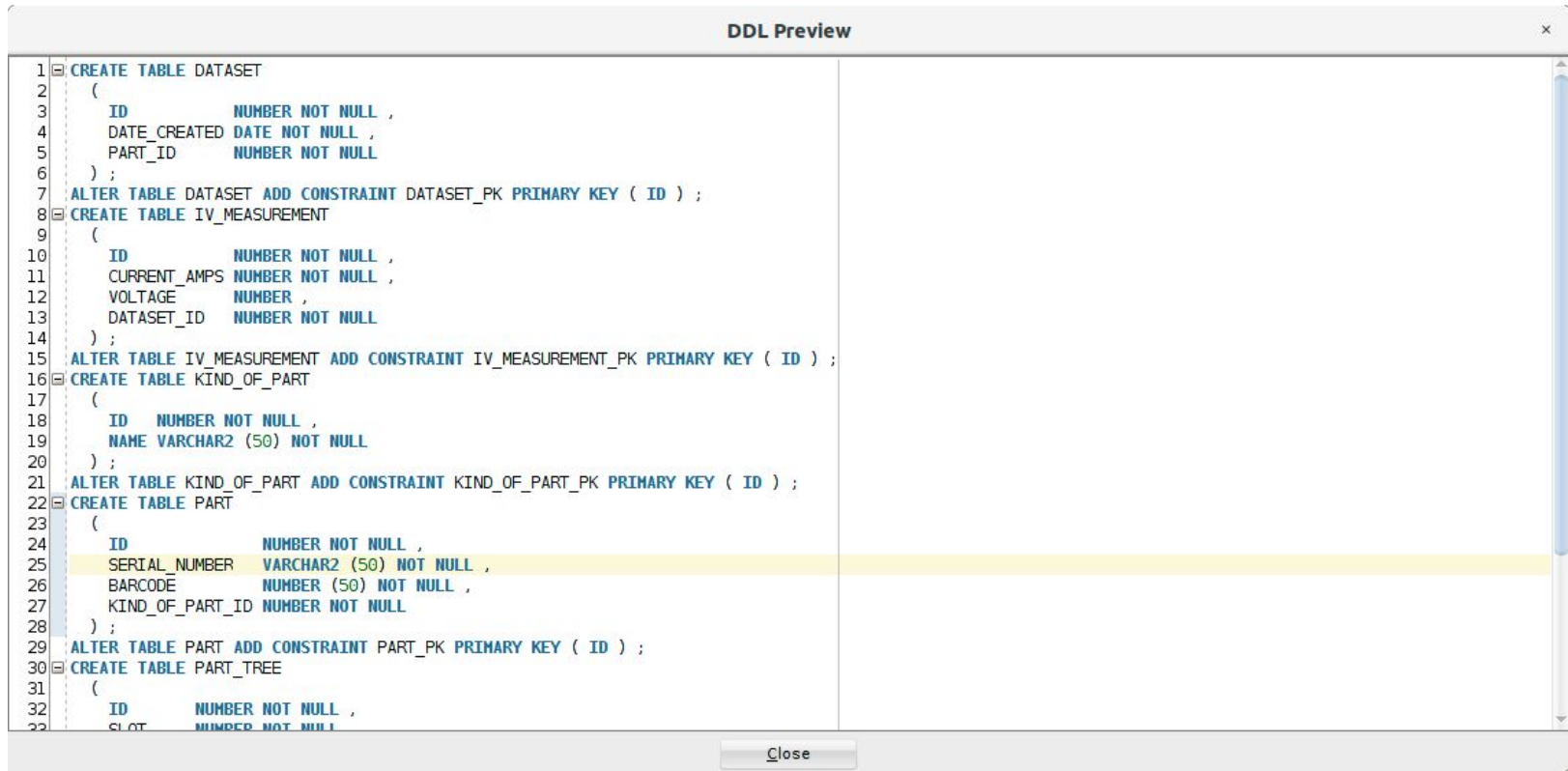| <u>ID</u>	Name	Age	Group
1	John	50	PPD
2	Jane	26	RC
3	Jonas	32	RC

Row

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Relational Database: Constraints

- Primary Key (PK)
  - → Unique Instance Identifier
  - Mostly used for referential integrity
  - Natural or surrogate (automatically generated)
  - Table can have only one PK, cannot contain NULLs
- Unique Key (UK)
  - → candidate PK
  - Values of which uniquely identify each row of a table
- Foreign key (FK)
  - → Relationship (referential integrity constraint)
  - Combination of columns with values based on the primary key values from another table
- Check Constraint (CK)
  - → Expression condition

Persons

ID	Name	Age	Group
1	John	50	PPD
2	Jane	26	RC
3	Jonas	32	RC

PK | CK (Age > 0) | FK

Groups

ID	Name
PPD	Physics Performance and Dataset
RC	Run Coordination
MN	Muon

PK | UK

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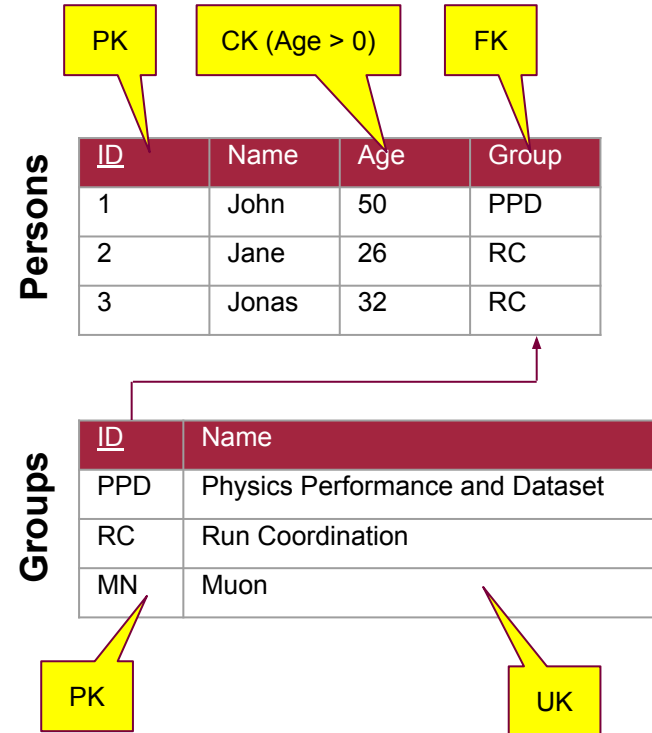
Data Modeler: Relational Model (2)
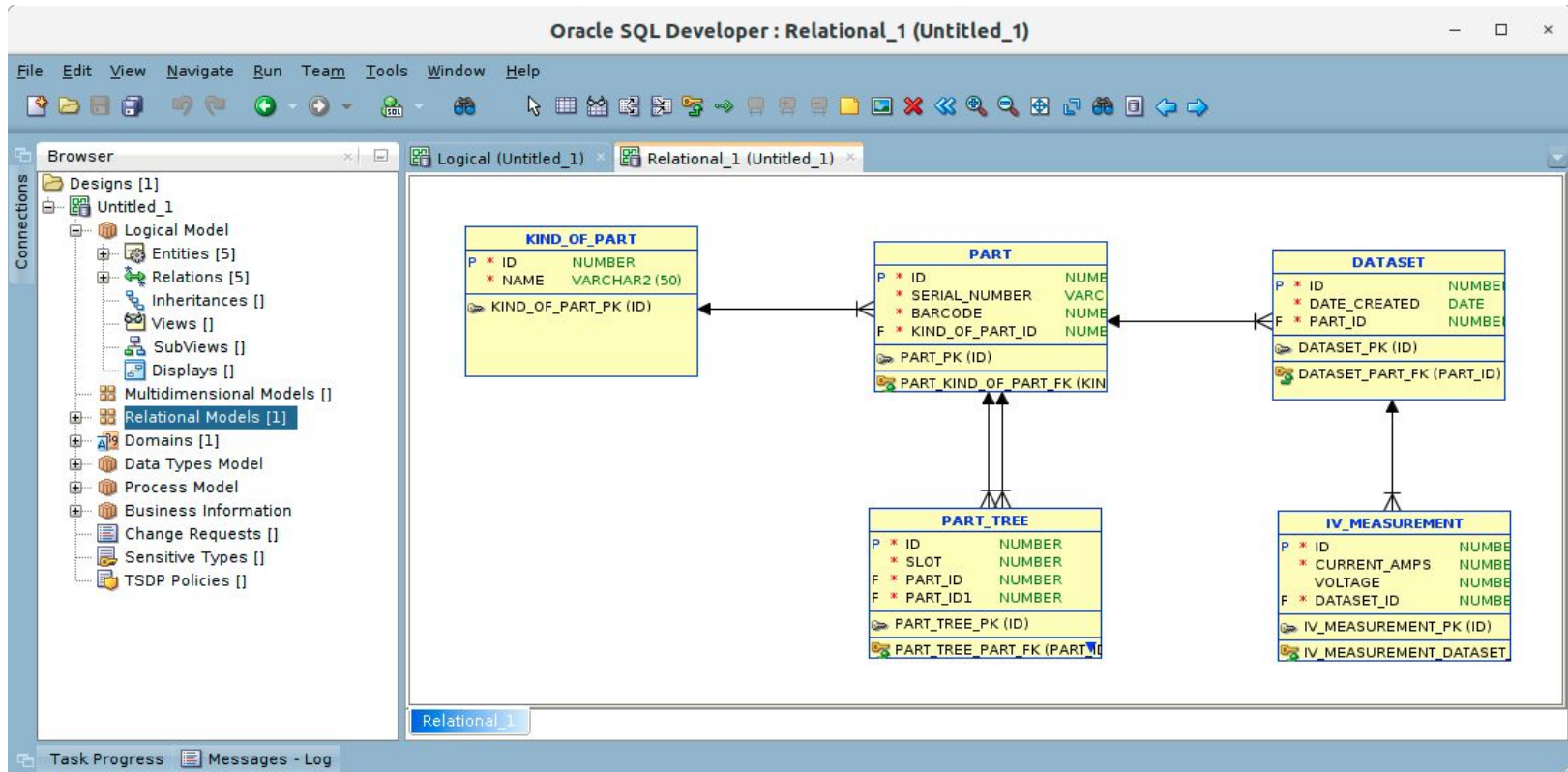
Data Modeler: DDL (3)

```
1  CREATE TABLE DATASET
2    (
3      ID             NUMBER NOT NULL ,
4      DATE_CREATED DATE NOT NULL ,
5      PART_ID       NUMBER NOT NULL
6    ) ;
7  ALTER TABLE DATASET ADD CONSTRAINT DATASET_PK PRIMARY KEY ( ID ) ;
8  CREATE TABLE IV_MEASUREMENT
9    (
10     ID             NUMBER NOT NULL ,
11     CURRENT_AMPS NUMBER NOT NULL ,
12     VOLTAGE       NUMBER ,
13     DATASET_ID   NUMBER NOT NULL
14   ) ;
15 ALTER TABLE IV_MEASUREMENT ADD CONSTRAINT IV_MEASUREMENT_PK PRIMARY KEY ( ID ) ;
16 CREATE TABLE KIND_OF_PART
17   (
18     ID   NUMBER NOT NULL ,
19     NAME VARCHAR2 (50) NOT NULL
20   ) ;
21 ALTER TABLE KIND_OF_PART ADD CONSTRAINT KIND_OF_PART_PK PRIMARY KEY ( ID ) ;
22 CREATE TABLE PART
23   (
24     ID             NUMBER NOT NULL ,
25     SERIAL_NUMBER   VARCHAR2 (50) NOT NULL ,
26     BARCODE         NUMBER (50) NOT NULL ,
27     KIND_OF_PART_ID NUMBER NOT NULL
28   ) ;
29 ALTER TABLE PART ADD CONSTRAINT PART_PK PRIMARY KEY ( ID ) ;
30 CREATE TABLE PART_TREE
31   (
32     ID       NUMBER NOT NULL ,
33     SLOT     NUMBER NOT NULL
```

DDL Preview

Close

Summary

- Relational model
    - Most popular database model after E.F.Codd
    - Database normalization (UNF, NF1, NF2, NF3, …)
- Database modeling
    - Entity-Relationship diagrams from Oracle CASE*Method
- Relational database
    - Tables
    - Constraints (PK + UK + FK + CK)
    - Views - named stored queries
- Database Design process
    - Business Data Model → Database Model → Scripts
    - ERD → Relational Model → DDL