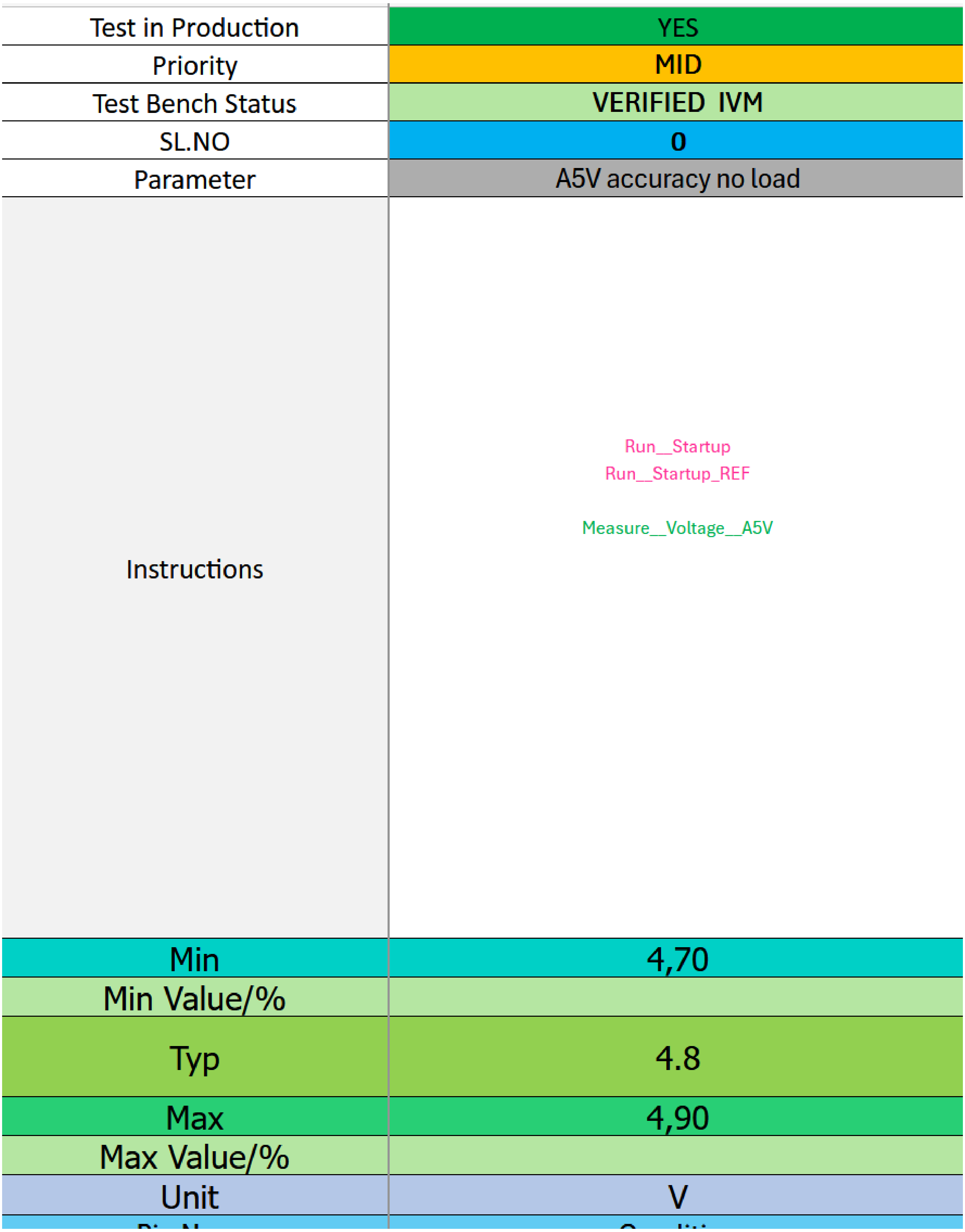
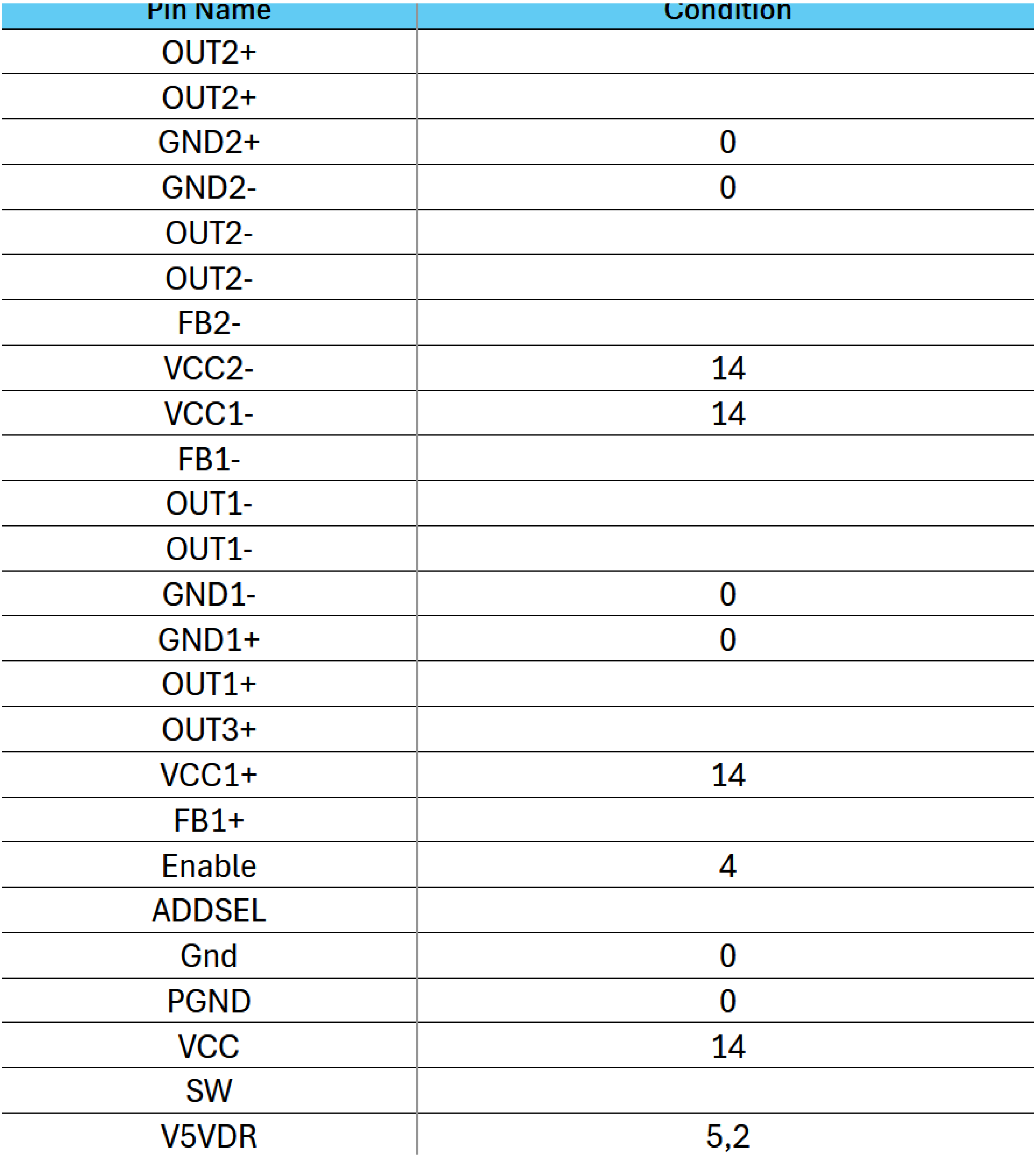
Transformation of ATE Test Form with dfttools Integration

1. **Overview**

This report documents the transformation of a traditional ATE test form (illustrated by the image) into an automated, executable Python script and structured JSON format. The transformation leverages the dfttools library to enable hardware interaction, simulation, and advanced trigger capabilities.



Test in Production	YES
Priority	MID
Test Bench Status	VERIFIED IVM
SL.NO	0
Parameter	A5V accuracy no load
Instructions	Run__Startup Run__Startup_REF Measure__Voltage__A5V
Min	4,70
Min Value/%	
Typ	4.8
Max	4,90
Max Value/%	
Unit	V



Pin Name	Condition
OUT2+	
OUT2+	
GND2+	0
GND2-	0
OUT2-	
OUT2-	
FB2-	
VCC2-	14
VCC1-	14
FB1-	
OUT1-	
OUT1-	
GND1-	0
GND1+	0
OUT1+	
OUT3+	
VCC1+	14
FB1+	
Enable	4
ADDSEL	
Gnd	0
PGND	0
VCC	14
SW	
V5VDR	5,2

2. **Comparison: ATE Test Form vs. Transformed Code/JSON**

Aspect	Image/Table (Manual)	Transformed Code/JSON (Automated)
Readability	High (for humans)	High (for humans and machines)
Executable	No	Yes
Automation	Manual	Fully automatable
Traceability	Limited	Complete (all data in one place)
Simulation Support	No	Yes (via `expected_value`/callbacks)

Aspect	Image/Table (Manual)	Transformed Code/JSON (Automated)
Hardware Interaction	Manual	Automated (via `dfttools`)
Error Prone	High (manual entry)	Low (scripted, repeatable)
Customer Sharing	Yes (but not executable)	Yes (executable, transparent)
Pin Mapping	Table	Structured list (easy to parse/use)
Test Types	Limited (e.g., just accuracy)	Expanded (force, measure, sweep, trigger)
I2C Support	No	Yes (Read/Write)
Reusability	Low	High

---

3. **JSON Data Structure (Example: `A5V_Accuracy_No_Load`)**

The JSON structure encodes metadata, limits, and pin mappings for the test:

```
{
  "_id": { "$oid": "" },
  "name": "A5V_Accuracy_No_Load",
  "code": "
Test_Name = 'A5V_Accuracy_No_Load'
print(f'...........{Test_Name} ........')
from dfttools import *
import random
from Procedures import Startup,Startup_REF

Typical_value = 4.8 # 4.8V
High_Limit = 4.9
Low_Limit = 4.7
error_spred = 0.15
# measure the A5V and provide some random value for similation purpose
# between -error_spred and +error_spred random biase value added or removed it is just for simulation purpose
# In lab setup VMEASURE function must return the measured value of A5V
a5v_value = VMEASURE(signal=A5V, reference=GND1-, expected_value=Typical_value + random.uniform(-error_spred,error_spred))

#]+ check the limit
if Low_Limit < a5v_value < High_Limit:
 print(f'......... {Test_Name} PASSED .......')
else:
 print(f'......... {Test_Name} FAILED .......')


print(f'Low: {Low_Limit}V, Typ: {Typical_value}V, High: {High_Limit}V')
print(f'Measured Value : {a5v_value}V')
error_percentage = abs(a5v_value - Typical_value) / abs(Typical_value) * 100
print(f'Error Percentage {error_percentage}%')",  // Python code for the test
  "engineerinfo": {
    "date": "",
    "email": "",
    "engineer": ""
  },
  "pinmapdata": [
    { "pinname": "OUT2+", "pinno": 1, "unit": "", "value": "" },
    { "pinname": "OUT2+", "pinno": 2, "unit": "", "value": "" },
    { "pinname": "GND1-", "pinno": 13, "unit": "", "value": "" },
    { "pinname": "A5V", "pinno": 60, "unit": "", "value": "" },
    // ... other pins
    { "pinname": "VCC2+", "pinno": 64, "unit": "V", "value": "14" }
  ],
  "priority": "High",
  "stage": "Compiled"
}
```

4. **Transformed Python Script (Example: `A5V_Accuracy_No_Load.py`)**

1. Procedures Pins Parsing fron Json Data (Example : `from Procedures import Startup` & `Startup.py`)

Symbols in the Code (Transforming symbols to Strings Vice versa, Pin name (VCC) and field names trasformed into dictionaries during script execution)

```
# import the dfttool functionalities

print(f'... Startup Procedure ......')

from dfttools import VFORCE

# force 14V on "VCC" pin wrt "GND1+"

VFORCE(signal="VCC",reference="GND1-",value=14)
```

2. Procedures fields parsing (Example : `from Procedures import Startup_REF` & `Startup_REF.py`)

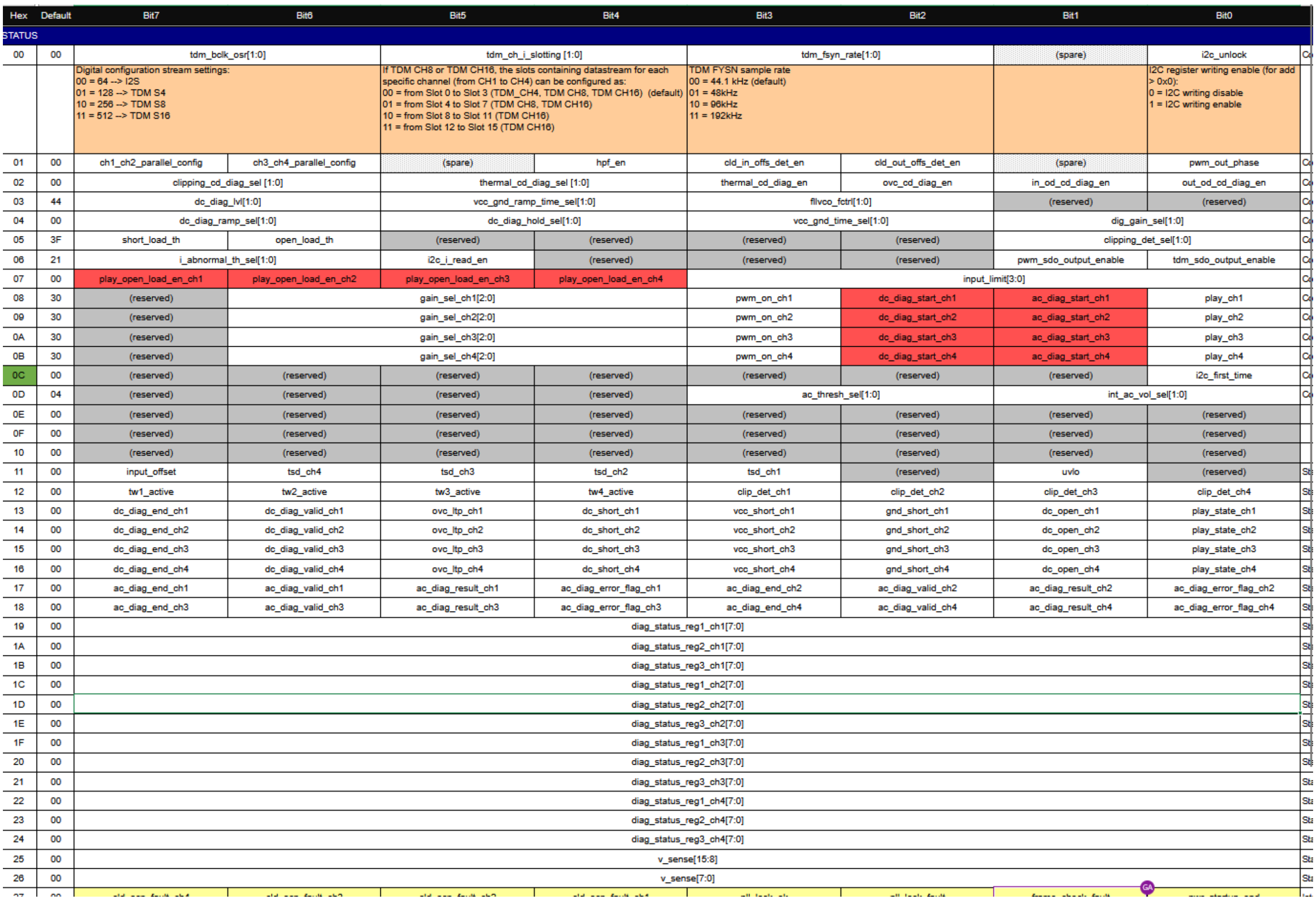
Symbols in the Code (Transforming symbols to Strings Vice versa, field names (i2c_page_sle) trasformed into dictionaries during script execution) .

```
# import all the functionalities of the dfttools library

from dfttools import *

import time

print('.......... Startup_REF .........')

# force 4V on ENABLE pin wrt "GND1+"
```

```
VFORCE(signal="Enable",reference="GND1-",value=4)

VFORCE(signal="V5VDR",reference="GND1-",value=5.2)

# VFORCE(signal=VDDIO,reference="GND1-",value=1.8)

# enable pll

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'i2c_page_sel', 'length':
2, 'registers': [{'REG': '0xFE', 'POS': 0, 'RegisterName': 'Page selection',
'RegisterLength': 8, 'Name': 'i2c_page_sel', 'Mask': '0x1', 'Length': 1,
'FieldMSB': 0, 'FieldLSB': 0, 'Attribute': '0000000N', 'Default': '00', 'User':
'000000YY', 'Clocking': 'SMB', 'Reset': 'C', 'PageName': 'PAG0'}, {'REG': '0xFE',
'POS': 0, 'RegisterName': 'Page selection', 'RegisterLength': 8, 'Name':
'i2c_page_sel', 'Mask': '0x1', 'Length': 1, 'FieldMSB': 0, 'FieldLSB': 0,
'Attribute': '0000000N', 'Default': '00', 'User': '000000YY', 'Clocking': 'SMB',
'Reset': 'C', 'PageName': 'PAG1'}]}, write_value=0x00)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'i2c_unlock', 'length':
1, 'registers': [{'REG': '0x00', 'POS': 0, 'RegisterName': 'Config REG1',
'RegisterLength': 8, 'Name': 'i2c_unlock', 'Mask': '0x1', 'Length': 1, 'FieldMSB':
0, 'FieldLSB': 0, 'Attribute': 'NNNNNNNN', 'Default': '00', 'User': '000YYYYY',
'Clocking': 'FRO', 'Reset': 'C', 'PageName': 'PAG0'}]}, write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'tdm_fsyn_rate',
'length': 2, 'registers': [{'REG': '0x00', 'POS': 2, 'RegisterName': 'Config
REG1', 'RegisterLength': 8, 'Name': 'tdm_fsyn_rate[1:0]', 'Mask': '0xC', 'Length':
2, 'FieldMSB': 1, 'FieldLSB': 0, 'Attribute': 'NNNNNNNN', 'Default': '00', 'User':
'000YYYYY', 'Clocking': 'FRO', 'Reset': 'C', 'PageName': 'PAG0'}]},
write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'unlock_tst_addr',
'length': 1, 'registers': [{'REG': '0xF7', 'POS': 0, 'RegisterName': 'Unlock
register', 'RegisterLength': 8, 'Name': 'unlock_tst_addr', 'Mask': '0x1',
'Length': 1, 'FieldMSB': 0, 'FieldLSB': 0, 'Attribute': '0000000R', 'Default':
'00', 'User': '00000000', 'Clocking': 'FRO', 'Reset': 'C', 'PageName': 'PAG0'}]},
write_value=0xAA)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'unlock_tst_addr',
'length': 1, 'registers': [{'REG': '0xF7', 'POS': 0, 'RegisterName': 'Unlock
register', 'RegisterLength': 8, 'Name': 'unlock_tst_addr', 'Mask': '0x1',
'Length': 1, 'FieldMSB': 0, 'FieldLSB': 0, 'Attribute': '0000000R', 'Default':
'00', 'User': '00000000', 'Clocking': 'FRO', 'Reset': 'C', 'PageName': 'PAG0'}]},
write_value=0xBB)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'i2c_page_sel', 'length':
2, 'registers': [{'REG': '0xFE', 'POS': 0, 'RegisterName': 'Page selection',
'RegisterLength': 8, 'Name': 'i2c_page_sel', 'Mask': '0x1', 'Length': 1,
'FieldMSB': 0, 'FieldLSB': 0, 'Attribute': '0000000N', 'Default': '00', 'User':
'000000YY', 'Clocking': 'SMB', 'Reset': 'C', 'PageName': 'PAG0'}, {'REG': '0xFE',
'POS': 0, 'RegisterName': 'Page selection', 'RegisterLength': 8, 'Name':
'i2c_page_sel', 'Mask': '0x1', 'Length': 1, 'FieldMSB': 0, 'FieldLSB': 0,
'Attribute': '0000000N', 'Default': '00', 'User': '000000YY', 'Clocking': 'SMB',
'Reset': 'C', 'PageName': 'PAG1'}]}, write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'force_pll_en', 'length':
1, 'registers': [{'REG': '0x20', 'POS': 5, 'RegisterName': 'Analog test 3',
'RegisterLength': 8, 'Name': 'force_pll_en', 'Mask': '0x20', 'Length': 1,
'FieldMSB': 5, 'FieldLSB': 5, 'Attribute': 'NNNNNNNN', 'Default': '00', 'User':
'0000YYYY', 'Clocking': 'SMB', 'Reset': 'C', 'PageName': 'PAG1'}]},
write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'pll_en_m', 'length': 1,
'registers': [{'REG': '0x20', 'POS': 6, 'RegisterName': 'Analog test 3',
'RegisterLength': 8, 'Name': 'pll_en_m', 'Mask': '0x40', 'Length': 1, 'FieldMSB':
6, 'FieldLSB': 6, 'Attribute': 'NNNNNNNN', 'Default': '00', 'User': '0000YYYY',
'Clocking': 'SMB', 'Reset': 'C', 'PageName': 'PAG1'}]}, write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'otp_burn', 'length': 1,
'registers': [{'REG': '0x3E', 'POS': 1, 'RegisterName': 'OTP control reg 1',
'RegisterLength': 8, 'Name': 'otp_burn', 'Mask': '0x2', 'Length': 1, 'FieldMSB':
1, 'FieldLSB': 1, 'Attribute': 'RR0NNNNN', 'Default': '00', 'User': '00000000',
'Clocking': 'FRO', 'Reset': 'C', 'PageName': 'PAG1'}]}, write_value=0x01)

I2C_WRITE( device_address=0x68, field_info={'fieldname': 'i2c_page_sel', 'length':
2, 'registers': [{'REG': '0xFE', 'POS': 0, 'RegisterName': 'Page selection',
'RegisterLength': 8, 'Name': 'i2c_page_sel', 'Mask': '0x1', 'Length': 1,
'FieldMSB': 0, 'FieldLSB': 0, 'Attribute': '0000000N', 'Default': '00', 'User':
'000000YY', 'Clocking': 'SMB', 'Reset': 'C', 'PageName': 'PAG0'}, {'REG': '0xFE',
'POS': 0, 'RegisterName': 'Page selection', 'RegisterLength': 8, 'Name':
'i2c_page_sel', 'Mask': '0x1', 'Length': 1, 'FieldMSB': 0, 'FieldLSB': 0,
'Attribute': '0000000N', 'Default': '00', 'User': '000000YY', 'Clocking': 'SMB',
'Reset': 'C', 'PageName': 'PAG1'}]}, write_value=0x01)
```

fields are parsed from regmap json data, which is the json conversion of excel sheet regmap.

3. Register Map in Excel



Hex	Default	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
STATUS										
00	00	tdm_bclk_osr[1:0]		tdm_ch_i_slotting [1:0]		tdm_fsyn_rate[1:0]		(spare)	i2c_unlock	Co
		Digital configuration stream settings: 00 = 64 --> I2S 01 = 128 --> TDM S4 10 = 256 --> TDM S8 11 = 512 --> TDM S16		If TDM CH8 or TDM CH16, the slots containing datastream for each specific channel (from CH1 to CH4) can be configured as: 00 = from Slot 0 to Slot 3 (TDM_CH4, TDM CH8, TDM CH16) (default) 01 = from Slot 4 to Slot 7 (TDM CH8, TDM CH16) 10 = from Slot 8 to Slot 11 (TDM CH16) 11 = from Slot 12 to Slot 15 (TDM CH16)		TDM FYSN sample rate 00 = 44.1 kHz (default) 01 = 48kHz 10 = 96kHz 11 = 192kHz			I2C register writing enable (for add > 0x0): 0 = I2C writing disable 1 = I2C writing enable	
01	00	ch1_ch2_parallel_config	ch3_ch4_parallel_config	(spare)	hpf_en	cld_in_offs_det_en	cld_out_offs_det_en	(spare)	pwm_out_phase	Co
02	00	clipping_cd_diag_sel [1:0]		thermal_cd_diag_sel [1:0]		thermal_cd_diag_en	ovc_cd_diag_en	in_od_cd_diag_en	out_od_cd_diag_en	Co
03	44	dc_diag_lvl[1:0]		vcc_gnd_ramp_time_sel[1:0]		fllvco_fctrl[1:0]		(reserved)	(reserved)	Co
04	00	dc_diag_ramp_sel[1:0]		dc_diag_hold_sel[1:0]		vcc_gnd_time_sel[1:0]		dig_gain_sel[1:0]		Co
05	3F	short_load_th	open_load_th	(reserved)	(reserved)	(reserved)	(reserved)	clipping_det_sel[1:0]		Co
06	21	i_abnormal_th_sel[1:0]		i2c_i_read_en	(reserved)	(reserved)	(reserved)	pwm_sdo_output_enable	tdm_sdo_output_enable	Co
07	00	play_open_load_en_ch1	play_open_load_en_ch2	play_open_load_en_ch3	play_open_load_en_ch4	input_limit[3:0]				Co
08	30	(reserved)	gain_sel_ch1[2:0]			pwm_on_ch1	dc_diag_start_ch1	ac_diag_start_ch1	play_ch1	Co
09	30	(reserved)	gain_sel_ch2[2:0]			pwm_on_ch2	dc_diag_start_ch2	ac_diag_start_ch2	play_ch2	Co
0A	30	(reserved)	gain_sel_ch3[2:0]			pwm_on_ch3	dc_diag_start_ch3	ac_diag_start_ch3	play_ch3	Co
0B	30	(reserved)	gain_sel_ch4[2:0]			pwm_on_ch4	dc_diag_start_ch4	ac_diag_start_ch4	play_ch4	Co
0C	00	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	i2c_first_time	Co
0D	04	(reserved)	(reserved)	(reserved)	(reserved)	ac_thresh_sel[1:0]		int_ac_vol_sel[1:0]		Co
0E	00	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	
0F	00	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	
10	00	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	(reserved)	
11	00	input_offset	tsd_ch4	tsd_ch3	tsd_ch2	tsd_ch1	(reserved)	uvlo	(reserved)	St
12	00	tw1_active	tw2_active	tw3_active	tw4_active	clip_det_ch1	clip_det_ch2	clip_det_ch3	clip_det_ch4	St
13	00	dc_diag_end_ch1	dc_diag_valid_ch1	ovc_ltp_ch1	dc_short_ch1	vcc_short_ch1	gnd_short_ch1	dc_open_ch1	play_state_ch1	St
14	00	dc_diag_end_ch2	dc_diag_valid_ch2	ovc_ltp_ch2	dc_short_ch2	vcc_short_ch2	gnd_short_ch2	dc_open_ch2	play_state_ch2	St
15	00	dc_diag_end_ch3	dc_diag_valid_ch3	ovc_ltp_ch3	dc_short_ch3	vcc_short_ch3	gnd_short_ch3	dc_open_ch3	play_state_ch3	St
16	00	dc_diag_end_ch4	dc_diag_valid_ch4	ovc_ltp_ch4	dc_short_ch4	vcc_short_ch4	gnd_short_ch4	dc_open_ch4	play_state_ch4	St
17	00	ac_diag_end_ch1	ac_diag_valid_ch1	ac_diag_result_ch1	ac_diag_error_flag_ch1	ac_diag_end_ch2	ac_diag_valid_ch2	ac_diag_result_ch2	ac_diag_error_flag_ch2	St
18	00	ac_diag_end_ch3	ac_diag_valid_ch3	ac_diag_result_ch3	ac_diag_error_flag_ch3	ac_diag_end_ch4	ac_diag_valid_ch4	ac_diag_result_ch4	ac_diag_error_flag_ch4	St
19	00	diag_status_reg1_ch1[7:0]								St
1A	00	diag_status_reg2_ch1[7:0]								St
1B	00	diag_status_reg3_ch1[7:0]								St
1C	00	diag_status_reg1_ch2[7:0]								St
1D	00	diag_status_reg2_ch2[7:0]								St
1E	00	diag_status_reg3_ch2[7:0]								St
1F	00	diag_status_reg1_ch3[7:0]								St
20	00	diag_status_reg2_ch3[7:0]								St
21	00	diag_status_reg3_ch3[7:0]								Sta
22	00	diag_status_reg1_ch4[7:0]								Sta
23	00	diag_status_reg2_ch4[7:0]								Sta
24	00	diag_status_reg3_ch4[7:0]								Sta
25	00	v_sense[15:8]								Sta
26	00	v_sense[7:0]								Sta

4. JSON Format of the Regmap

```
{
    "fieldname": "tdm_bclk_osr",
    "length": 2,
    "registers": [
      {
        "REG": "0x00",
        "POS": 6,
        "RegisterName": "Config REG1",
        "RegisterLength": 8,
        "Name": "tdm_bclk_osr[1:0]",
        "Mask": "0xC0",
        "Length": 2,
        "FieldMSB": 1,
        "FieldLSB": 0,
        "Attribute": "NNNNNNNN",
        "Default": "00",
        "User": "000YYYYY",
        "Clocking": "FRO",
        "Reset": "C",
        "PageName": "PAG0"
      }
    ]
  },
  {
    "fieldname": "tdm_ch_i_slotting",
    "length": 2,
    "registers": [
      {
        "REG": "0x00",
        "POS": 4,
        "RegisterName": "Config REG1",
        "RegisterLength": 8,
        "Name": "tdm_ch_i_slotting [1:0]",
        "Mask": "0x30",
        "Length": 2,
        "FieldMSB": 1,
        "FieldLSB": 0,
        "Attribute": "NNNNNNNN",
        "Default": "00",
        "User": "000YYYYY",
        "Clocking": "FRO",
        "Reset": "C",
        "PageName": "PAG0"
      }
    ]
  },
  {
    "fieldname": "tdm_fsyn_rate",
    "length": 2,
    "registers": [
      {
        "REG": "0x00",
        "POS": 2,
        "RegisterName": "Config REG1",
        "RegisterLength": 8,
        "Name": "tdm_fsyn_rate[1:0]",
        "Mask": "0xC",
        "Length": 2,
        "FieldMSB": 1,
        "FieldLSB": 0,
        "Attribute": "NNNNNNNN",
        "Default": "00",
        "User": "000YYYYY",
        "Clocking": "FRO",
        "Reset": "C",
        "PageName": "PAG0"
      }
    ]
  }
```

The code in the json data **chpater 3** transformed to Python script which uses dfttools to perform measurements, Forcing,I2C_READ, I2C_WRITE **(dfttools library needs call back functions which are hadware specific)** enforce limits, and report results:

```
Test_Name = 'A5V_Accuracy_No_Load'
print(f'............{Test_Name} ........')
```

```
from dfttools import *
import random
from Procedures import Startup,Startup_REF
'''
Run__Startup
Run__Startup_REF
Measure__Voltage__A5V
'''
Typical_value = 4.8 # 4.8V
High_Limit = 4.9
Low_Limit = 4.7
error_spred = 0.15
# measure the A5V and provide some random value for similation purpose
# between -error_spred and +error_spred random biase value added or removed it is just for simulation purpose
# In lab setup VMEASURE function must return the measured value of A5V
a5v_value = VMEASURE(signal=A5V, reference=GND1-, expected_value=Typical_value + random.uniform(-error_spred,error_spred))

#]+ check the limit
if Low_Limit < a5v_value < High_Limit:
 print(f'......... {Test_Name} PASSED .......')
else:
 print(f'......... {Test_Name} FAILED .......')


print(f'Low: {Low_Limit}V, Typ: {Typical_value}V, High: {High_Limit}V')
print(f'Measured Value : {a5v_value}V')
error_percentage = abs(a5v_value - Typical_value) / abs(Typical_value) * 100
print(f'Error Percentage {error_percentage}%')
```

5. Role of dfttools and Callbacks

- **dfttools**: Central library for hardware functions (measurements, forcing, triggers, I2C)
- **Global Context (g)**: Manages hardware availability and callback functions.
- **Callbacks**: Implement hardware-specific logic.
- **Inline Example**:

```
from dfttools import *

# Define callback functions (example)
def voltage_force_callback(g, signal, reference, value):
    force_hardware_available = True  # Set hardware availability dynamically
    measured_value = 3.295  # Example dynamic measurement

    return force_hardware_available, measured_value

# Register callbacks in global context (example)
g.hardware_callbacks = {
    'voltage_force': voltage_force_callback, # must return hardware availability and value
    'current_force': current_force_callback,
    'resistance_force': resistance_force_callback,
    'frequency_force': frequency_force_callback,
}

# Example usage: VFORCE
result_voltage = VFORCE(signal='VCC',value=1.1) # This will execute the call back and perform hardware force
print(f"Voltage Force Result: {result_voltage}") # If hardware available will print the measured value else the forced value
```

6. dfttools Functionality and Integration

- **Measurements:**
  - `VMEASURE`, `AMEASURE`, `RESMEASURE`, `FREQMEASURE`
  - Read voltage, current, resistance, frequency from signals/pins.
  - `expected_value` handles simulation scenarios.
- **Forcing:**
  - `VFORCE`, `AFORCE`, `RESFORCE`, `FREQFORCE`
  - Force voltage, current, resistance, frequency on signals/pins.
  - Callbacks handle hardware control.
- **Sweeps:**
  - `VFORCESWEEP`, `AFORCESWEEP`, `RESFORCESWEEP`, `FREQFORCESWEEP`
  - Perform sweeps of voltage, current, resistance, frequency.
  - Set `initial_value`, `end_value`, `step`, `step_time`.
  - Store results in `g.output`.
- **Triggers:**
  - `VTRIG_HL`, `VTRIG_LH`, `VTRIG_LG`, `ATRIG_HL`, `ATRIG_LH`, `ATRIG_LG`
  - Trigger based on voltage/current levels.
  - `threshold` (HL/LH), `expected_value` (for simulation).
  - Code Example:

```
# Trigger__HL__I2SDATA2
HL_Th = 3  # 3V
LH_Th = 3.3  # 3.3V

# Force voltage, then wait for trigger (HL)
VFORCE(signal=A5V, reference=GND1-, value=4.8)
trigger = VTRIG_HL(signal=A5V, reference=GND1-, threshold=HL_Th, expected_value=a5v_forced_voltage) # Added reference

if trigger:
  print("Triggered successfully")
```

- **I2C Operations:**
  - `I2C_READ`, `I2C_WRITE`
  - Read/write data to I2C devices using specified device address and field info.

  - Used for configuration, control, or diagnostics.
- **Inline Example for I2C usage and defination**

```
# Register callbacks in global context
g.hardware_callbacks = {
    'i2c_read': i2c_read_callback,
    'i2c_write': i2c_write_callback
}
# Test I2C operations
print("I2C Read Results:", I2C_READ( device_address=0x12, field_info=field_info1, expected_value=0x3))
print("I2C Write Results:", I2C_WRITE( device_address=0x12, field_info=field_info1, write_value=0x3))
# Test I2C operations
print("I2C Read Results:", I2C_READ( device_address=0x12, field_info=field_info2, expected_value=0x3))
print("I2C Write Results:", I2C_WRITE( device_address=0x12, field_info=field_info2, write_value=0x3))
```

---

7. Benefits of Automated Transformation

- **Automation:**
  - Scripts can be executed automatically as part of a production test flow.
  - Triggers can be used for automated fault detection or calibration.
- **Traceability:**
  - All information is encoded in a machine-readable format.
  - Easy to audit tests, limits, and results.
- **Simulation Support:**
  - `expected_value` and hardware callbacks enable testing without physical hardware.
  - Random variations in simulation help validate tests.
- **Hardware Abstraction:**
  - dfttools provides a common interface regardless of the underlying ATE hardware.
  - Hardware-specific details handled by callbacks.
- **Customer Communication:**
  - JSON and Python scripts can be shared with customers for collaboration.

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8. Best Practices

- **Keep JSON and Python scripts synchronized.**
- **Use version control.**
- **Document all functions.**
- **Add unit tests for callbacks and trigger functions.**
- **Use hardware availability flags to control behavior.**
