Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture – 44
Experiments on DAC and it is Applications
Understanding DAC 7821 Datasheet

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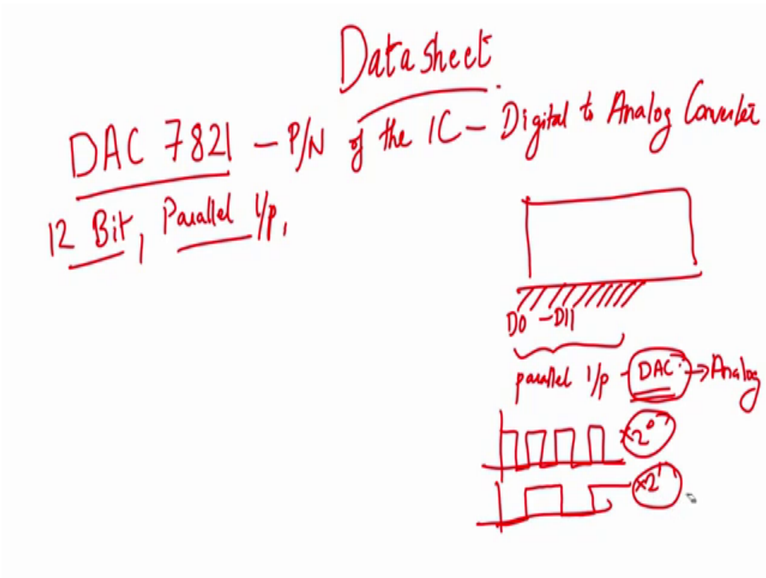

We will be seeing the datasheet as we discussed. So, what is the IC name I get ? It is DAC 7821; this is the part number of the IC, ok. That we are using, this is the digital to analog convertor IC~~. That~~ that we will be using DAC 7821.

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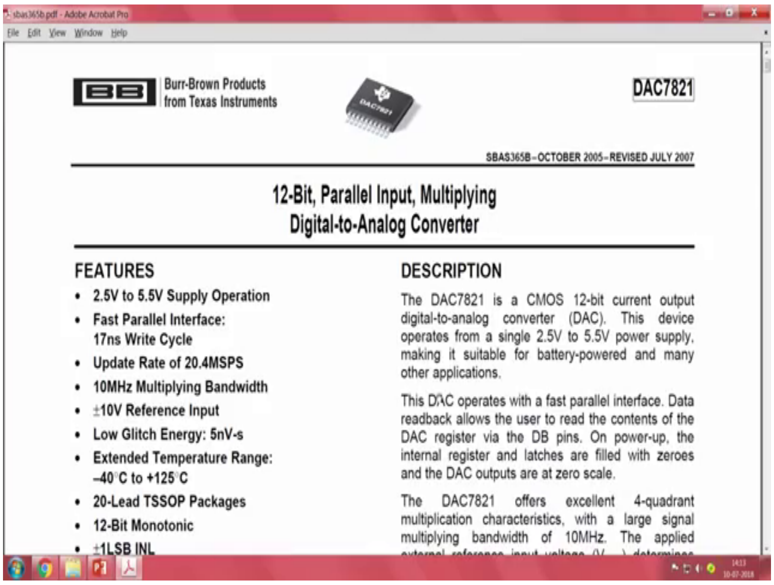

So now, let us just see the datasheet. So, this is how a normal data sheet of any company or an IC would look like. So, they ~~the~~ I think you can see my cursor. So, they have the IC image here, this is how the IC will look like. And then in one line, they will explain what actually this IC is this is 12-bit parallel input multiplying digital to analog convertor.

So, the in one line they have told us, what all what is it actually. So, this is 12 bit so, let us note it down. So, how many bits are there? 12 bits and parallel input. So, it is parallel input and multiplying type DACs. So, they are different types of DACs which ~~which~~ you have seen and you will be seeing in the course. And the so, this is a multiplying digital to analog convertor. In the datasheet also we will see how what how they have explained it. So, this a 12 bit parallel input multiplied digital to analog convertor. So, what does parallel input mean?

So, suppose this is the IC and if it is 12 bit. So, there will be D 0 to D 11, there will be dedicated pins for this, like this. So, this will be parallelly inputted. Parallelly input to the convertor, digital to analog convertor. And at the same time in one shot, it will be converted to the analog value, ok. That is 12 bit parallel input.

Now, that we have seen, this is the core description of the IC. So, let us see the features so, when you open the datasheet as I told, we will cover first the, this datasheet things quite detail. And then, come back again and see quickly when you are seeing the datasheet what all things we should look at when you are seeing a new datasheet. That is the whole idea.

So, this featuresthese features will give you a quick view about what is the whole thing.

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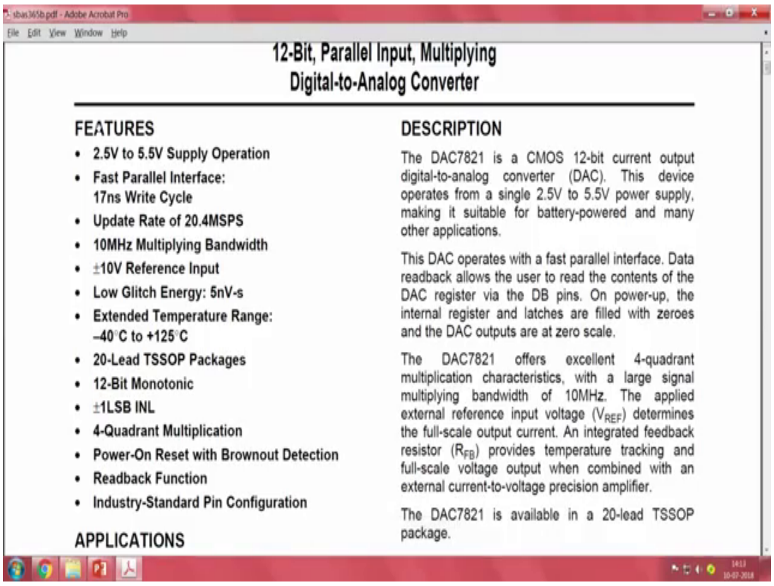

So, the features see this is the supply operation. So, this is you should always make sure, see it can operate foundly from 2.5 volt to 5.5 volt;. So, you should never give a supply more than that.

So, that is one thing so, you will let us say you apply it direct 20 volt or something and the IC will go bad. Then first parallel interface, 17 nano second right cycle, what does that mean-? It means that the when we give the input to the IC, like the data bits where the bits; which needs to be converted to analog. How much time? So, the analog value that will be converted inside the IC would be stored in some buffer or a internal small flash which should be written. That value whatever analog value is there that would be written there.

So, this is the time taken to convert the digital value some. So, it is something like that. So, that will be written on, written on to it. So, next time you want to update the analog value you have to latch on the new set of digital inputs. Still, you latch on latch it on analog value will not change. Then update rate of 20 point 20.4 msps MSPS; msps MSPS is mega Mega samples Samples per Per secondSecond.

So, this is like it can take that much update rates. So, that many samples if it comes it can keep changing it that speed-; though, 10 megahertz multiplying bandwidth. Then the multiplying bandwidth in the sense because we had seen know the digital inputs how they will look like each bit if you want to see. So, each bit if you want to see, we saw it like this one bit will be the like this, correct? One bit would be having lower freq-uency, like this correct. So, in the conversion we have to multiply it with 2 raise to 0 2 raise to one and all right. So, this is how the multiplying type DAC will work.

So, that bandwidth for taking in to account these signals the first changing signals is what they are mentioned in the datasheet;. So, that is 10 megahertz multiplying bandwidth, then plus or minus 10-volt reference input.

So, this is the input levels of the, they this is reference input. This is what so, this is what it means. So, plus or minus 10 volt would be like what are the values of the of your ranges-; like, 0 volt to 10 volt or it can even be minus 10 volt, or it can even be minus 10 volt to 10 volt.

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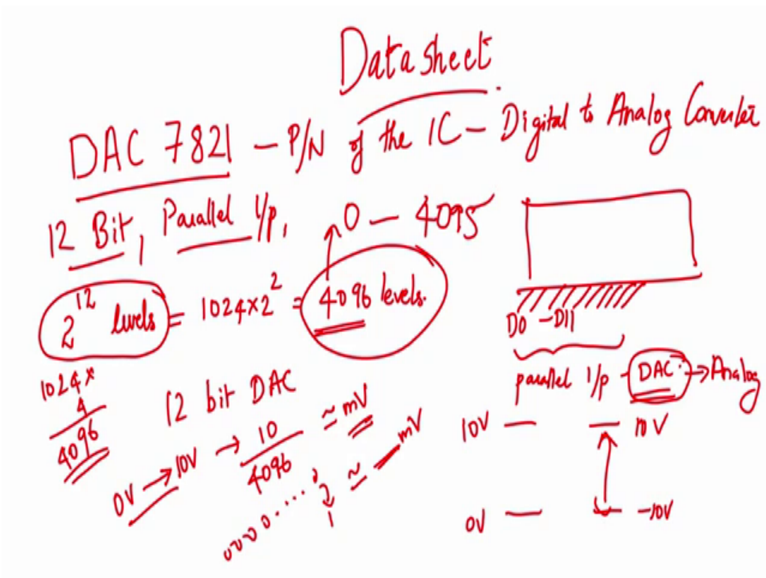

And you can have so, because this is 12 bit DAC ok, this is 12 bit DAC right so; that means, there can be up to 2 raise to 12 levels as we have learnt now. So, that is what how much 2 raise to 10 is 1024;. Soso, 1024 into 2 raise to 2.

So, this will be 1024 into 4, around 4,000, 1024 into 4, 4,016, 4096. So, 4,096 levels are possible. 4,096 levels are possible because it is a 12 bit DAC. So, that means that, there can be from 0 volt up to whatever is the reference voltage. So, here it is 10 volt, this DAC will be able to give analog voltages with precision of 10 by 4,096, this much value.

So, this will be in like if you take it will be around in some milli volts per in some milli volts per level, ok. So, that means, if 12 bit right so, 0 0 0 0 0 like that 12 bits will be there. So, for each change in bit here, it will update the voltage value by some definite millivolt. That is what this means, hope this is clear to you we have discussed this.

Now, next so, low glitch energy 5 nano volt second. So, the glitch energy is like suppose there is a delay in one of the bits getting updated to whatever value we have set. That is what is called glitch in very, very simple way. So, that the, what you call the time taken volt second is energy right. So, that energy consumed in conversion that is low glitch energy. And then extended so, we have to you can you can actually go back and check it in detail. Then extended temperature range so, this is the operating range of the IC.

So, it can operate up to 125 degree Celsius. 125 degree Celsius is usually called industrial grid temperature and it can go up to minus 40 degrees. And then it is a main thing this is 20 lead TSSOP, TSSOP is the package, and 20 lead means there are 20 pins or 20 connections.

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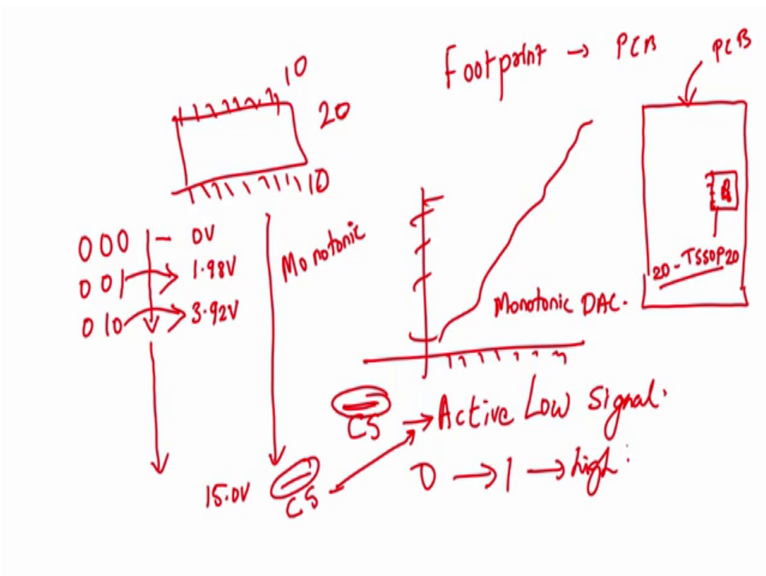

So, it will be like this and 20 leads will be there so, may be 10 on each side. 10, 10 we will see we will see the packaging information in detail.

So, this is that package so, when we are making, when you are making any design, package like while doing the board design while doing the PCB design, we need to ensure what is a package and accordingly we have to make footprints we have create foot prints. ~~what~~ What we have to create? You have to create the correct foot print on the PCB. So, let us say the we make a PCB with this DAC, correct? We will place this is the PCB. So, the IC will be placed somewhere, right.

So, for this we need to know the package. So, this is TSSOP and 20 lead it will usually called 20 TSSOP or TSSOP 20. So, 20 leads will be there, accordingly we have to create the package. So, this also we need to remember when you are making a design. So, we are always talking from your design point of view.

So, next thing is what? So, we are going through the main features right, main features as (Refer Time: 09:02) this is very important to you. So, that this is the way you should analyze the datasheet 1's, 2, 3 times. If you look at a datasheet, then quickly you can go through these things actually. Then 12 bit monotonic, what does 12-bit monotonic ~~mean ?~~ mean? What does monotonic DAC mean? So, that means, that when you go from let us say if we take a 3 bit DAC. So, 3 bit DAC means 0, 0, 0, 0, 0, because 12 bit is very difficult to represent here. That is why we are showing like this. So, 0, 1, 0, ~~correct ?~~correct?

So, this is the increasing digital word right, we have seen. So, if the corresponding analog voltage also only increases like this, keeps on increasing only up to say 15 volt whatever voltage we have ~~set ;~~set; then there is a direct correlation between the increasing digital world and word and the increasing analog voltage. Such a digital to analog convertor is called monotonic ok. Monotonic means, corresponding to your digital volt below, your analog voltage will only continuously increase. This is monotonic type; ~~This~~ this monotonic DAC.

Then plus or minus 1 LSB is least significant bit, ok 4 quadrant multiplication. So, this is the internal logic that is there in the IC. Then power on reset with brownout detection. So, this is the again the reset process a like when it. So, when it powers on the IC it will go back to it is (Refer Time: 10:38) state. It will not show any random analog voltage. It will show the analog voltage of like say the 0, 0, 0, 0 digital word. That is what that is what power on reset means ok. Then read back function, industry standard pin ~~configuration, that~~configuration that is TSSOP.

So, these are the main features. So, in the datasheet first they will show you the main features. Next what they will show you, they will show you applications.

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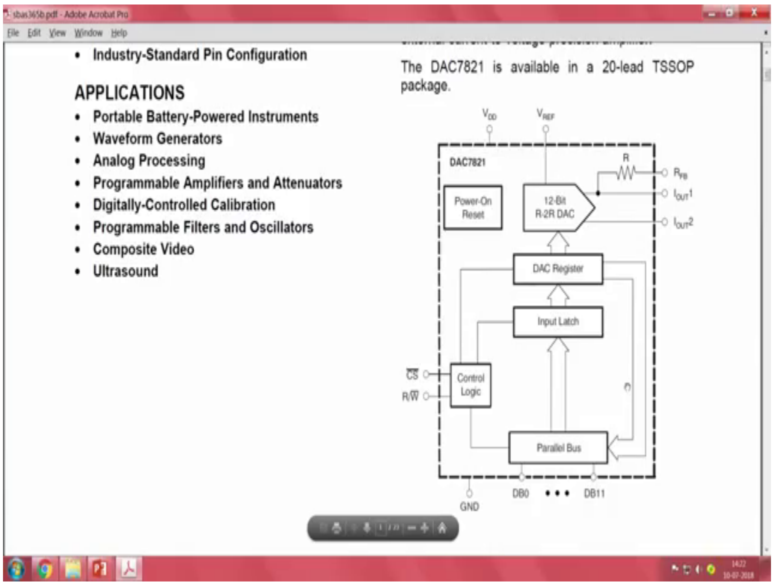

What are the applications? So, this is like for your general understanding, this is not necessarily important for you. Because when you identify an IC, it is already understood that you know the, what is your specific applications. And if you are like before you identify IC if you are looking for like candidate IC's which IC can I use for my design. At that point this section will become important to you.

Let us say some body suggest you there is an IC like this, why ~~can not~~cannot you use that for your application? You discuss you will have technical discussions with your colleagues. Then they will tell the, this company has this IC, why do not you check it out for your application. Then when you like look at it they will tell you application. So, this section is for that so, it can be used for portable battery powered instruments, way form generators analog processing, programmable amplifies and attenuators, digitally control calibration, programmable filters and oscillators, composite video ultrasound like this,.

So, then this is a description, this is I am not going to the full details of it otherwise it would be like reading the data sheet to you. So, that is fine so, these are whatever we have discussed only they have discussed here;~~.~~ ~~The~~ the reference voltage, the supply voltage all those things. So, let us look at a block diagram that they have shown. So, the DAC is available in a 20 lead TSSOP package.

So, what are the things the VD, VD is the V DD is there V ref is there, V ref we saw that V ref is ~~what ?~~ what? Is here 12 plus or minus 10-volt reference input. Then supply voltage is there, then they have a power on reset, then control logics. So, CS is what? Chip select CS is usually called chip select in most IC's. If they have a CS bar signal, it is chip select, and what does CS bar ~~integrate ?~~integrate?

So, if you look at any IC's data sheet. And if you see a bar on top of it ; that means, if you see a bar on top of it right ; that means, this is an active low signal, ok. So, if any chip pin description has a bar on top of it, it is an active low signal. What does active low ~~mean ?~~ mean? Active low means that the signal will be enabled or the functionality of the pin will be enabled, when the value of the signal is 0. So, that the complement of it which is what bar does becomes 1 and it becomes high.

So, that is active low so, what does active low ~~mean ?~~ mean? Active low means that the signal or that pin is active when it is low or 0. So, this you should understand this active low signal ok. And read write bar ok, read write bar would mean that, when if this signal is high. So, it is read so, it will reading, and when it this signal is 0, it is writing. So, with the same pin you can have both read or write depending on the value that you give ok.

Then this is your data bus which you have already discussed dB 0 to dB 11; that means, it is a 12-bit data bus, bus and that will go in as a parallel bus, there will be a latch. So, it will be it is like an latch would be like a buffer that is there, until the latch is again refreshed, this the new values of this will not go in to the latch. Then that will be written in to the register, and then the 12-bit R to R ladder R to R DAC. So, we would have we would have you could have covered R to R DACs in detail.

So, the 12-bit R to R DAC a 12-bit R to R DAC will convert it into analog voltage, and we can see it, ok. And the output can be seen here. So, output is measured in terms of current; which it is given in terms of current. So, (Refer Time: 14:36) connect a resistor on outside that pin, you can actually see it through as a voltage,. That is the main so, these are the this is the first page of the datasheet, this is how it will look like, ok.

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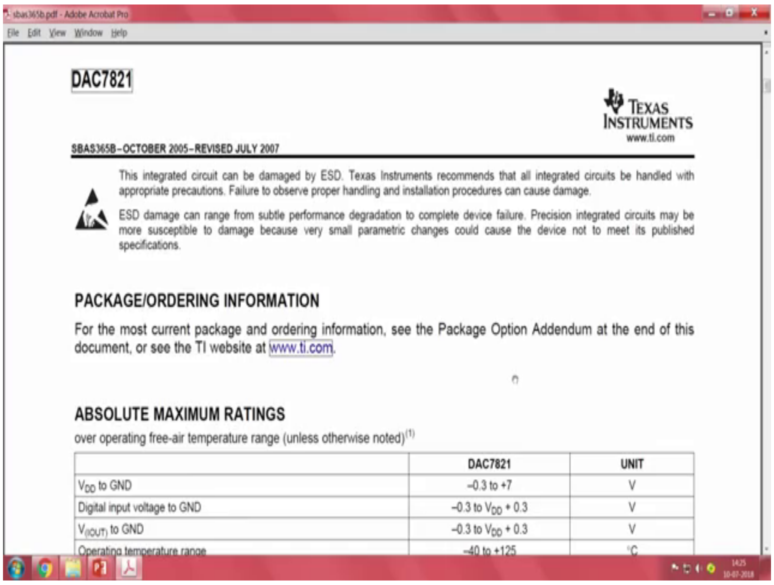
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DAC7821

TEXAS INSTRUMENTS
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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)(1)

	DAC7821	UNIT
V_{DD} to GND	–0.3 to +7	V
Digital input voltage to GND	–0.3 to V_{DD} + 0.3	V
$V_{(IOUT)}$ to GND	–0.3 to V_{DD} + 0.3	V
Operating temperature range	–40 to +125	°C

Now, next is, now. So, this is the first page, ok. Next, next is main thing, this table is this table right, this table is very important.

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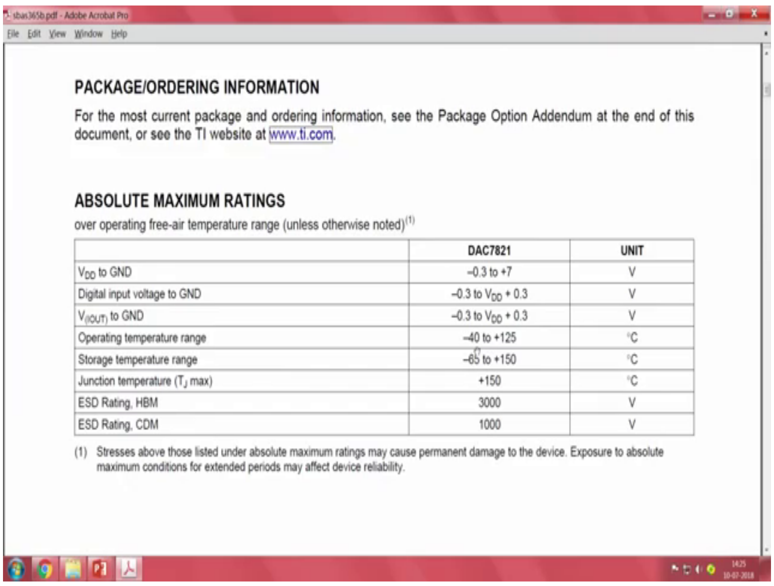
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Digital input voltage to GND	–0.3 to V_{DD} + 0.3	V
$V_{(IOUT)}$ to GND	–0.3 to V_{DD} + 0.3	V
Operating temperature range	–40 to +125	°C
Storage temperature range	–65 to +150	°C
Junction temperature (T_J max)	+150	°C
ESD Rating, HBM	3000	V
ESD Rating, CDM	1000	V

(1) Stresses above those listed under absolute maximum ratings may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

This is what you should make sure that you do not mess with these values while you are operating the IC. So, main thing is what we did it to ground voltage ok.

So, minus 0.3 to 7 volt it can go. Over operating free air temperature range. So, you provide that this free air temperature outside, what is the range, then digital input voltage to ground, it can V DD; where V DD can have a plus or minus 0.3-volt fluctuation V out to ground operating temperature range, we always saw this minus 40 to 125.

Storage temperature usually so, operating temperature for the IC to operate efficiently and faithfully, the operating temperature range should vary from minus 40 to 125 degree Celsius. But it can be stored at a higher temperature, and at a much lower temperature also minus 65 to 150 degree Celsius.

So, this is like always a storage temperature will be more than operating temperature.

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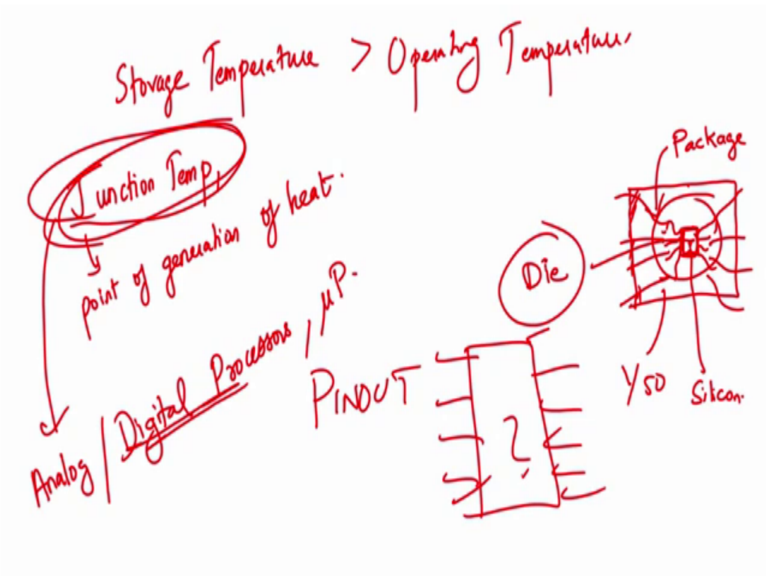

If you take any IC always storage temperature;~~.~~ ~~Storage~~ storage temperature will be greater than operating temperature,. So, most of the IC's will be designed like this you can open and check any data sheet you want it will be like this. Storage temperature will be higher than the operating temperature,.

So, that is storage temperature. So, junction temperature, that is plus 150, what is junction ~~temperature ?~~ temperature? Junction temperature is a concept from VLSI. So, your chip will have a package. I will ~~uickly~~quickly go through it, this is not actually within this scope of what we are discussing, but for sense of completeness. So, this will be the black color you would have seen any IC know it will be black color here full black. Inside that you will have a small die. This is the actual logic, this is the actual chip, this is just the package, this is package.

If you if you break it open, if it is a some IC's like damage, you have something you can break it open and inside you will see a small package. It will be very small. It will be like 1 by 50th of this area outside area. And from here you will see leads been taken out. This is the silicon wafer, in which your design is built whatever DAC design is here these leads are then finally, taken out like this as the package pins.

So, this is what you call die, ok. And junction temperature is a temperature on the die when it is under full operation. So, there are 3 temperatures, if you open any datasheet of any IC, you can see these 3. Junction temperature, operating temperature and storage temperature. Usually, junction temperature will be the highest, because that is where the heat will heat is getting generated, that is the point of generation. That is the point of generation of heat, junction temperature then operate temperature and storage temperature,.

~~Ah~~ So, this you should understand very clearly, because it is very important for any IC point of view. Especially, junction temperature is very important if you are having any design with some analog processors, or a analog digital processes. Because there if it crosses a lot of computation will be involved, and processes of micro processes, it is called mu P’s ok.

So, lot computation will be involved, and if lot of computation is involved automatically the die temperature will go up, ok. So, that time you should make sure that you are working within the limits of the junction temperature,. And then ESD rating is what electrostatic discharge rating. So, that is like what is the highest voltage, that you can use I mean so that it does not get damaged with electrostatic discharge.

So, they will always have this flag. They will tell that stresses above those listed under absolute maximum ratings may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device durability. So, what they are telling is that, if you go beyond this values, any way we do not guarantee proper working, and even we might we are telling that it might even get damaged. Also, if you keep working at ~~this limits~~these limits, almost limits though it may be it is told that it is at this limit also it is working, if you keep working at this high limits also, your performance will get degraded, or it might even damage the device over time. So, we would always work within sufficient buffered limits within the maximum ratings,.

So, ~~absolute maximum ratings is~~absolute maximum ratings are a very important thing. I will finally, once we are done with this we will enumerate which are the main sections of any datasheet that you should go through,. So, that you can keep it as pointer, you can you can keep it as pointer for yourself. And then ~~uickly~~quickly take that list of items and then check your datasheet every time you open a datasheet.

So now we have seen absolute maximum rating done, ~~cool ?~~ cool? Next is electrical characteristics so, this also we have seen.

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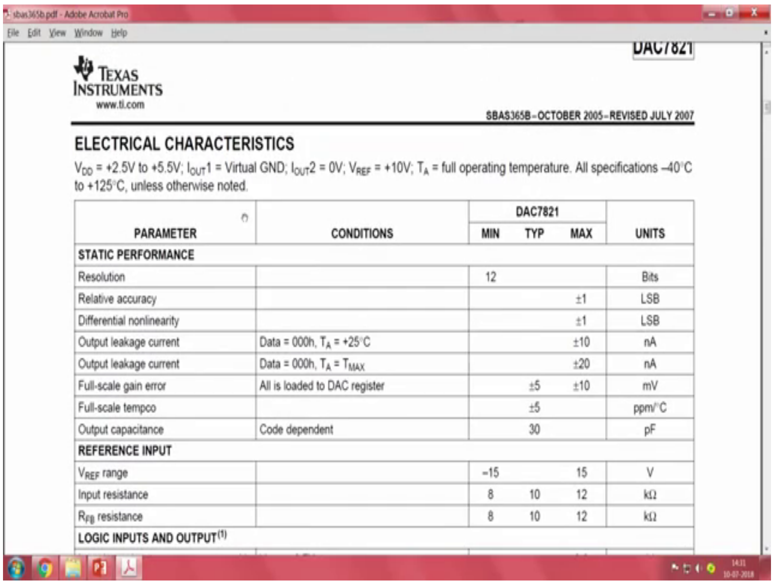
DAC7821

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ELECTRICAL CHARACTERISTICS

V_{DD} = +2.5V to +5.5V; $I_{OUT}1$ = Virtual GND; $I_{OUT}2$ = 0V; V_{REF} = +10V; T_A = full operating temperature. All specifications –40°C to +125°C, unless otherwise noted.

PARAMETER	CONDITIONS	DAC7821			UNITS
		MIN	TYP	MAX	
STATIC PERFORMANCE					
Resolution		12			Bits
Relative accuracy				±1	LSB
Differential nonlinearity				±1	LSB
Output leakage current	Data = 000h, T_A = +25°C			±10	nA
Output leakage current	Data = 000h, $T_A = T_{MAX}$			±20	nA
Full-scale gain error	All is loaded to DAC register		±5	±10	mV
Full-scale tempco			±5		ppm/°C
Output capacitance	Code dependent		30		pF
REFERENCE INPUT					
V_{REF} range		–15		15	V
Input resistance		8	10	12	kΩ
R_{FB} resistance		8	10	12	kΩ
LOGIC INPUTS AND OUTPUT[1]					

So, like what is the output leakage current. So, these are very high details we do not need actually when you are making (Refer Time: 20:35) this much detail we do not have to see. Only see main things. So, gain error leakage current and all it is fine, that is. But what is a design point of view, what is a voltage reference range? It can go up to minus 15 volt to 15 volt. This is your reference voltage. This is the maximum and minimum values that will be taken to get your step analog step voltage, whatever we saw right 15 minus 0 by 2 raise to 3 2 raise to 12 and all. That will come from here.

Then input resistance feedback resistance and all, this you just you (Refer Time: 21:02) just keep it keep this in mind. Then this is what I told, when we told right, that noise level things logic inputs what are logic inputs. V IL, V IH input high voltage input low voltage. So, these are ~~the those~~those things those voltages. Input low input high, those things input leakage current power req-uirement. So, it the V DD for the IC to operate is around 5 volt, typically operating voltage.

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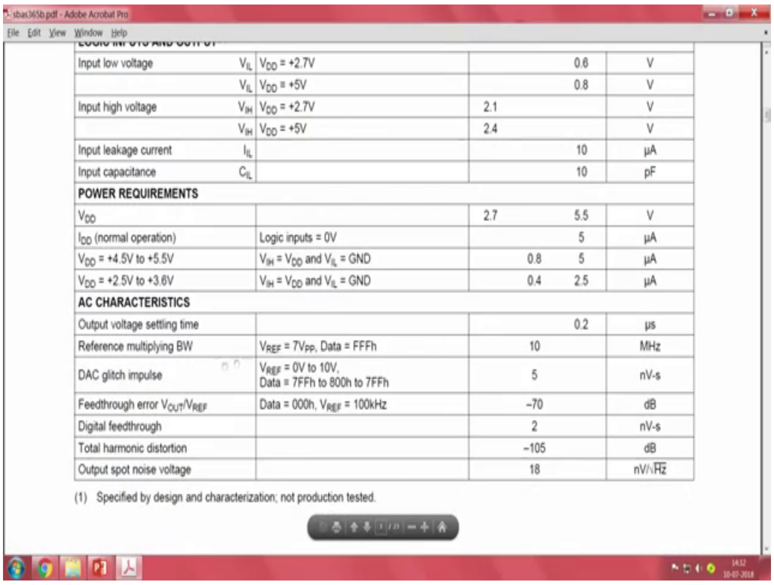

Input low voltage	V_{IL}	V_{DD} = +2.7V			0.6	V
	V_{IL}	V_{DD} = +5V			0.8	V
Input high voltage	V_{IH}	V_{DD} = +2.7V	2.1			V
	V_{IH}	V_{DD} = +5V	2.4			V
Input leakage current	I_{IL}				10	µA
Input capacitance	C_{IL}				10	pF
POWER REQUIREMENTS						
V_{DD}			2.7		5.5	V
I_{DD} (normal operation)		Logic inputs = 0V			5	µA
V_{DD} = +4.5V to +5.5V		V_{IH} = V_{DD} and V_{IL} = GND		0.8	5	µA
V_{DD} = +2.5V to +3.6V		V_{IH} = V_{DD} and V_{IL} = GND		0.4	2.5	µA
AC CHARACTERISTICS						
Output voltage settling time					0.2	µs
Reference multiplying BW		V_{REF} = $7V_{PP}$, Data = FFFh		10		MHz
DAC glitch impulse		V_{REF} = 0V to 10V, Data = 7FFh to 800h to 7FFh		5		nV-s
Feedthrough error V_{OUT}/V_{REF}		Data = 000h, V_{REF} = 100kHz		–70		dB
Digital feedthrough				2		nV-s
Total harmonic distortion				–105		dB
Output spot noise voltage				18		$nV/\sqrt{Hz}$

(1) Specified by design and characterization; not production tested.

Then AC characteristics, these are all very high technical details. Because this is, this is the results from there, characterization ok. What they will characterize? Everything because ~~they~~, they have to guarantee so many parameters in the datasheet. But many of this parameters, we might not have to look at it when we are that much in detail when we are designing it. Only few things that we need to see, what is the reference voltage, what is the V DD voltage, is there any specific resistance that should be connected. That much you can see and just leave it.

Then later if you having some issues, see basic things we need to be sure, and then start working on it may be then you might feel some issues, then you can go and check the nitigrities in the datasheet. And to see if there is any small issues, ok. Then these are those things, DAC glitch impulse total harmonic distortion output spot noise voltage. Noise also we saw right so, they even characterize the noise voltage in the AC characteristics,.

Then what we will do~~.~~?

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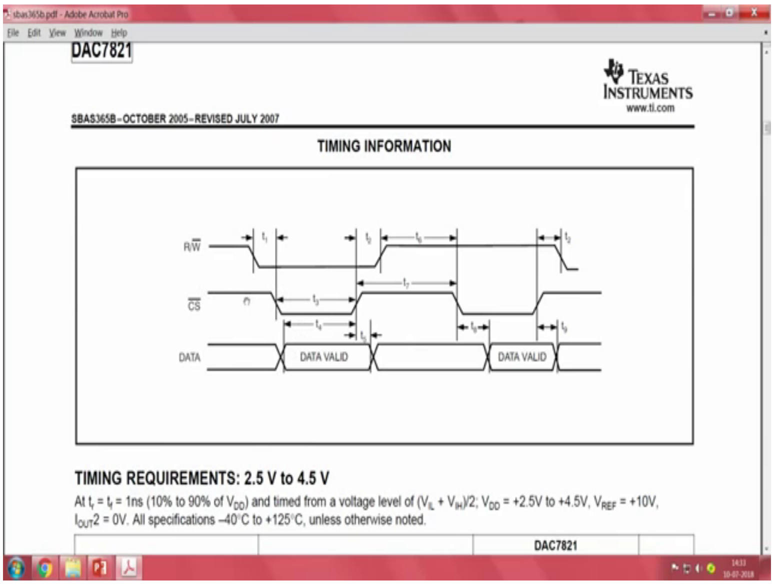

Then they will also tell you timing information, what will be the once chip. So, I told you right, this is that thing. Let us take a snapshot of this.

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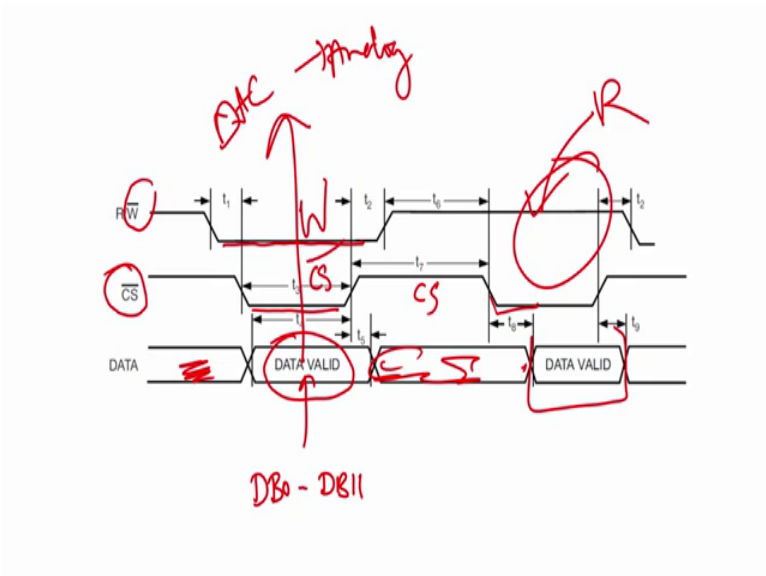

So, I just took a snapshot of that. So, that I can annotate it and show it to you here.

So, we saw that chip select is an active low signal, correct ? So, that is why when it is going low the data is valid. So, that means, data has been latched, till then the data will not be taken as a valid data. Then what ~~happens ?~~ happens? Right is this signal is low, when this signal is low; that means it is a right. So, this data, which is the dB 0 to dB ~~11 ;~~ 11; which we saw, correct.

So, that will be latched on to the DAC, and analog voltage will be taken, correct ? And then that will happen, and then chip select will go high invalid, then whatever data even if it is changes know it will not take it. Only next time when this becomes low, that time it will take it as the valid data. And then, but that time it is read. So, these things you should see. When it is read, when it is right this is high. So, this is read, this is right, this is chip select is enabled, this is chip select is high.

So, these things you should see, next.

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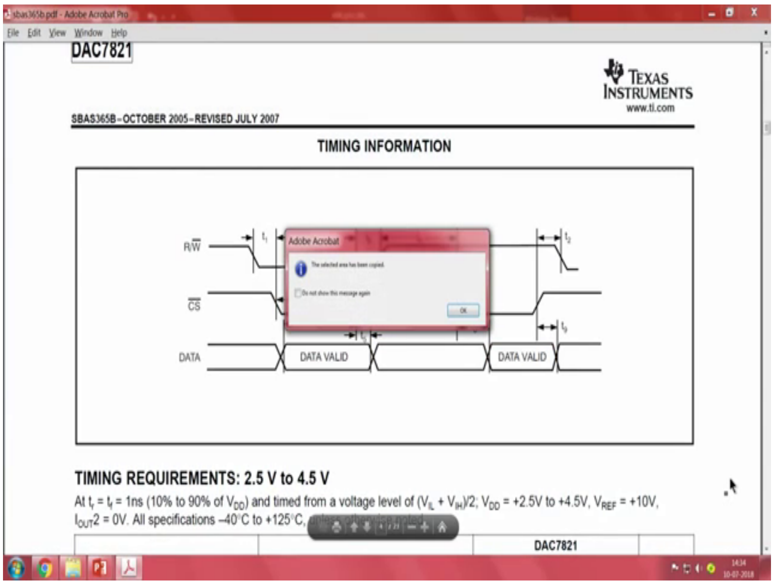

So, that is the timing re uirement. Now next.

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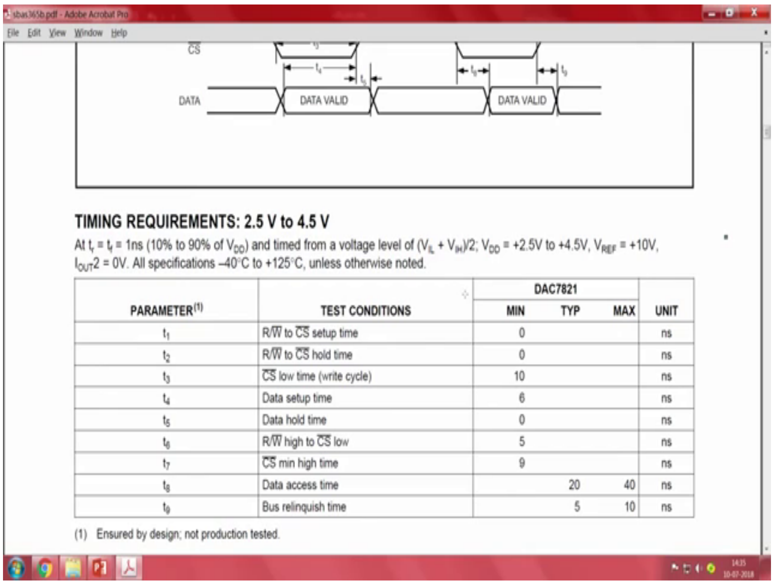

TIMING REQUIREMENTS: 2.5 V to 4.5 V

At $t_r = t_f$ = 1ns (10% to 90% of V_{DD}) and timed from a voltage level of $(V_{IL} + V_{IH})/2$; V_{DD} = +2.5V to +4.5V, V_{REF} = +10V, $I_{OUT}2$ = 0V. All specifications –40°C to +125°C, unless otherwise noted.

PARAMETER[1]	TEST CONDITIONS	DAC7821 MIN	DAC7821 TYP	DAC7821 MAX	UNIT
t_1	R/W to CS setup time	0			ns
t_2	R/W to CS hold time	0			ns
t_3	CS low time (write cycle)	10			ns
t_4	Data setup time	6			ns
t_5	Data hold time	0			ns
t_6	R/W high to CS low	5			ns
t_7	CS min high time	9			ns
t_8	Data access time		20	40	ns
t_9	Bus relinquish time		5	10	ns

(1) Ensured by design; not production tested.

Then there are lot of things like (Refer Time: 24:26) later this digital things like set up time hold time and all. We need not go into that exact details of that, then set up time load hold time and all those things are there timing req-uirements. So, the for specific voltage ranges then have timing req-uirements.

So, they have characterized everything and that they have put,. Let us keep that.

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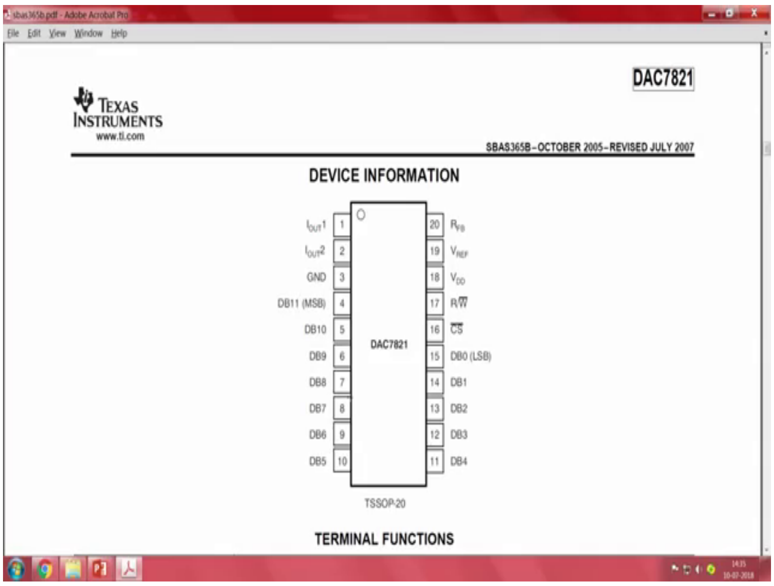

So, this is another main thing ok, this is the main thing package information. Pin out it is called pin out. This is another thing that you should look at, pin out you should look at pin out.

So, that will show you what is the package, how many pins are there ? there? And what are each pins used for. There is a main thing you need for and your design. So, we have seen so, this is the pin out. So, there is data bus, dB is data bus. So, we will have from dB 0 which is LSB, up to dB 11 which would be MSB dB 10 and dB 11, MSB correct this is the data. Then we have chip select, read, write, then V DD whatever is your V ref voltage and then R fb which is the feedback resistor. And output is given in current. So, if we connect resistor to it, you will see the e task, then ground very simple connections.

Major thing are the data bus which is a data lines the read or write the read, or write here and then chip select, I think you can see my cursor and then the data bus. So, I will tell me go out from snapshot view, yeah. So, and then that is it. This much, this is the pin out description,. So, this is the pin out description, it is clear to you right. Then I want pin out to shown, then they will show you description what are each things for.

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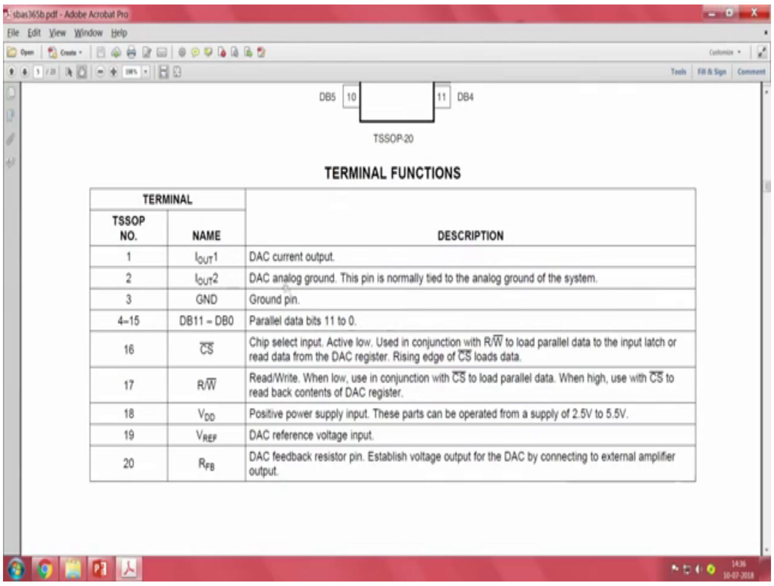

TERMINAL FUNCTIONS

TERMINAL		DESCRIPTION
TSSOP NO.	NAME	
1	$I_{OUT}1$	DAC current output.
2	$I_{OUT}2$	DAC analog ground. This pin is normally tied to the analog ground of the system.
3	GND	Ground pin.
4–15	DB11 – DB0	Parallel data bits 11 to 0.
16	$\overline{CS}$	Chip select input. Active low. Used in conjunction with R/$\overline{W}$ to load parallel data to the input latch or read data from the DAC register. Rising edge of $\overline{CS}$ loads data.
17	R/$\overline{W}$	Read/Write. When low, use in conjunction with $\overline{CS}$ to load parallel data. When high, use with $\overline{CS}$ to read back contents of DAC register.
18	V_{DD}	Positive power supply input. These parts can be operated from a supply of 2.5V to 5.5V.
19	V_{REF}	DAC reference voltage input.
20	R_{FB}	DAC feedback resistor pin. Establish voltage output for the DAC by connecting to external amplifier output.

So, this is I out is DAC current output, then I out 2 is DAC analog ground. Ground is there then dB 11 to dB 0 is your data bus. Then CS as I have told is chip select input active low. And then R w bar read and write V DD V ref, DAC reference voltage, then DAC feedback resistor establish voltage output for the DAC by connecting to external amplifier output. So, this will give you the output voltage of the DAC, ok. This is one main thing.

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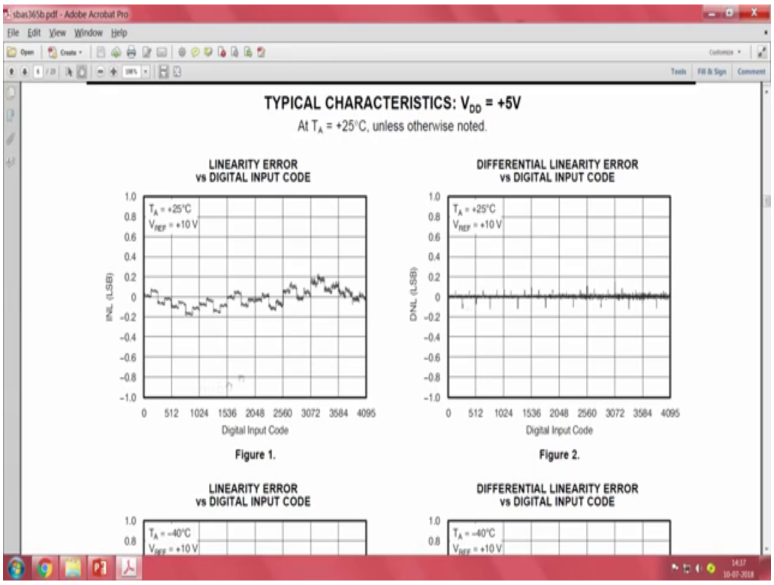

Then they will show then another thing that they will show in that the datasheet is typical characteristics, ok. It is typical characteristics this, you can just glance over it.

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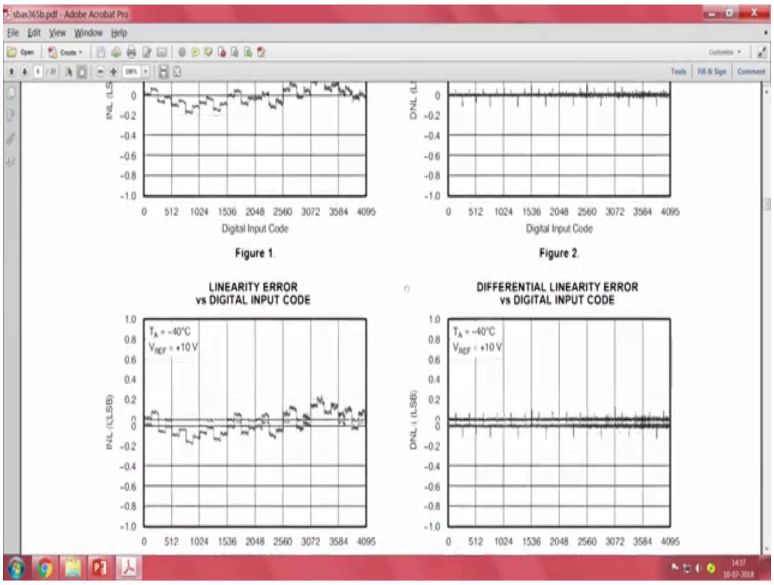

When you are trying to make only when you are having some issues you can come back and see it actually like you try to see the output of the IC, and then I want to know whether this is actually correct. Or is it expected then usually the datasheet will have typical characteristics, which they got well they were characterizing the IC. So, you can just go through it. So, that is also ok, fine. This is not that very important.

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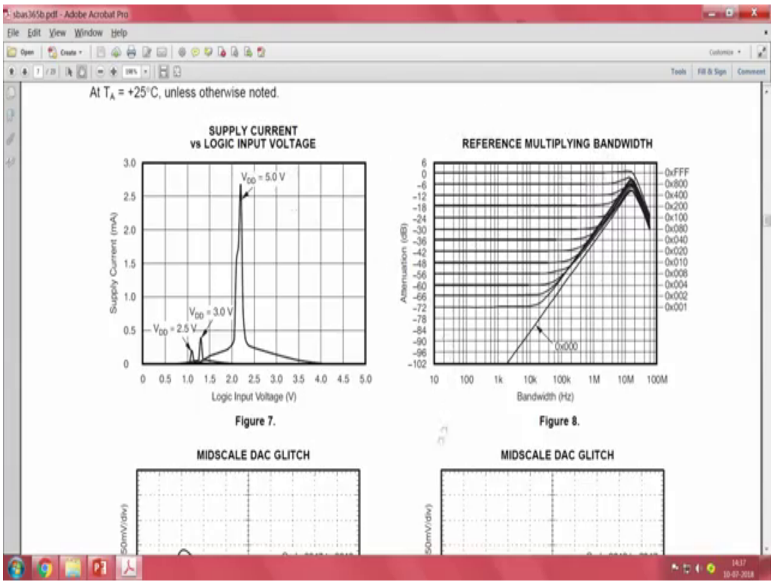
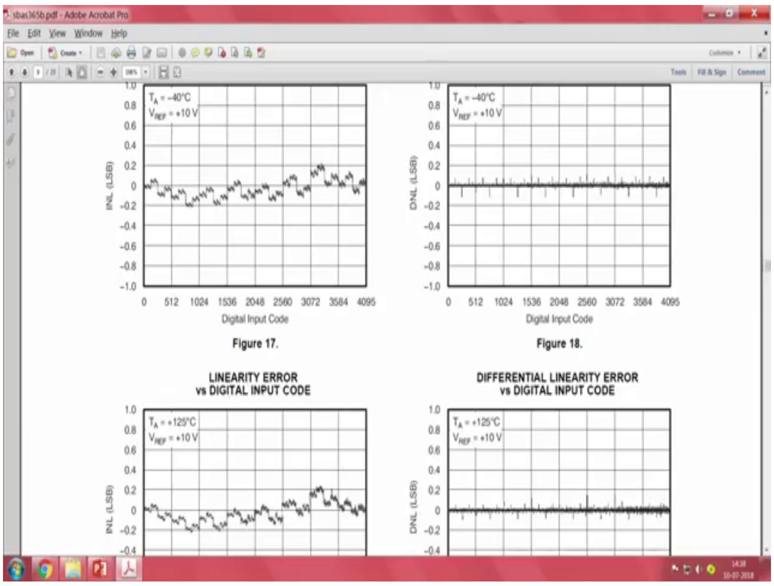


Then reference multiplying (Refer Time: 27:21) it is supply current versus logic input means scale DAC glitch, this things we can avoid. Typical characteristics, then that is done.

(Refer Slide Time: 27:34)



So, linearity error what is linearity error versus digital input code ?

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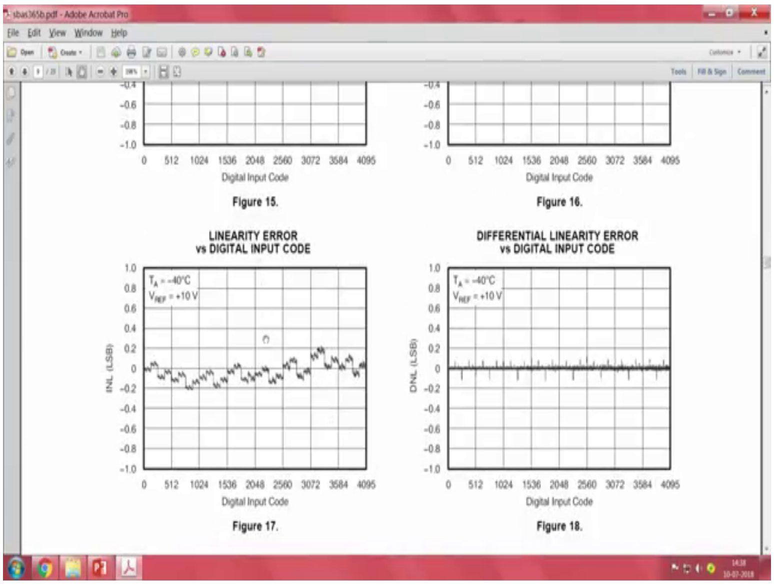

Linearity error is what I told before same thing. So, we have covered monotonicity write here. This is monotonicity ~~correct ?~~ correct? So, in monotonicity also, it can be monotonic in 2 ways. How? Let us see.

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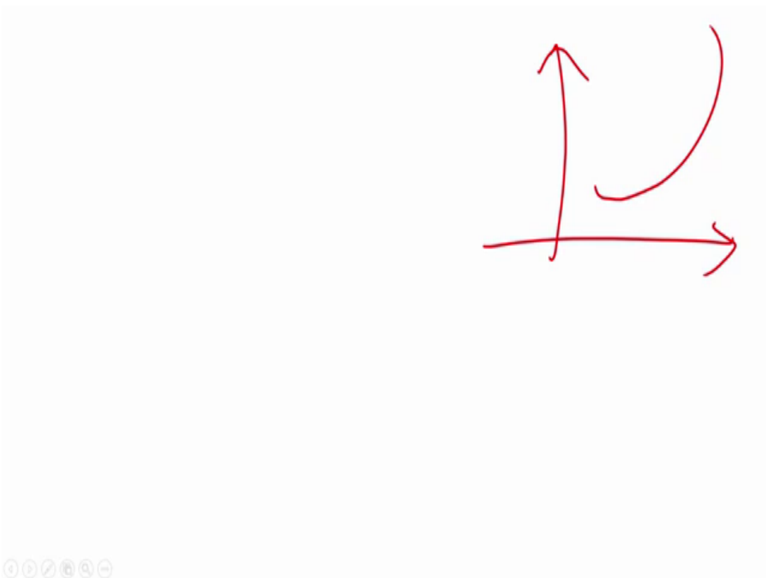

So, I told you that, digital input will be there and analog output will be there. And it if it is monotonic it will like this. But then it may still be monotonic, but it may be like this. Or it may not be a linear relation, what is the linear relation, linear relation is like this. If the curve between the digital input and the analog output not might not be a linear curve;. It it might be something like this.

So, not exactly like an exponential or something like that. So, that is not linear. So, we should make sure that preferably it should be linear, but design errors will be there. So, this is what they have characterize, ideally it should be 0. Ideally it should be 0, but then there will be linearity errors while converting. So, this is the digital input code, so, they have converted into like 2 raise to 12 right 2 raise to 12 bit know. So, 4,000 up to 4,096 it can go, we have seen it.

So, we have seen it here, that it is a 12 bit DAC correct. So, it can go up to 4,096 levels or the values can go from 0 to 4,095. So, these are small things that you shouldn't look at from the data sheet. So, see the thatthat the code is going from 0 to 4,095.

So, that is what they have done.

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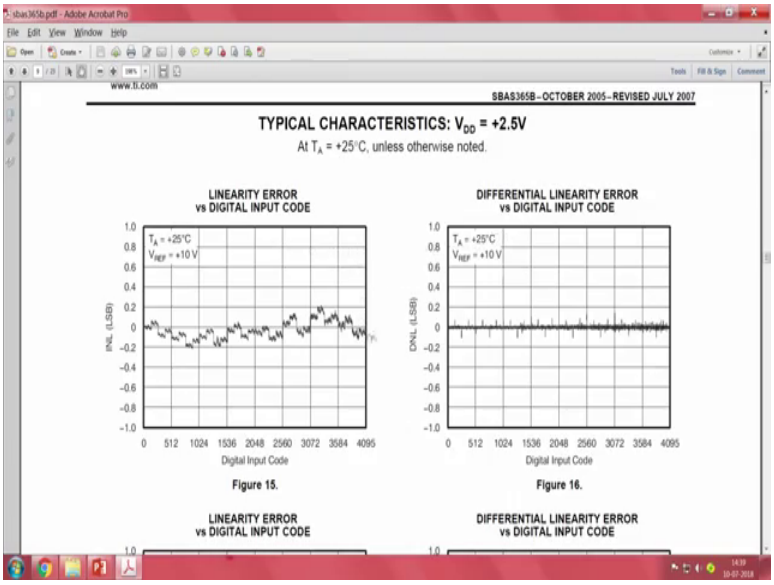

They have characterized linearity error, and these differential linearity errorthese differential linearity errors. So, I hope that is clear to you. Then typical characteristics that midscale glitch gain error what is a gain error ideally the gain error.

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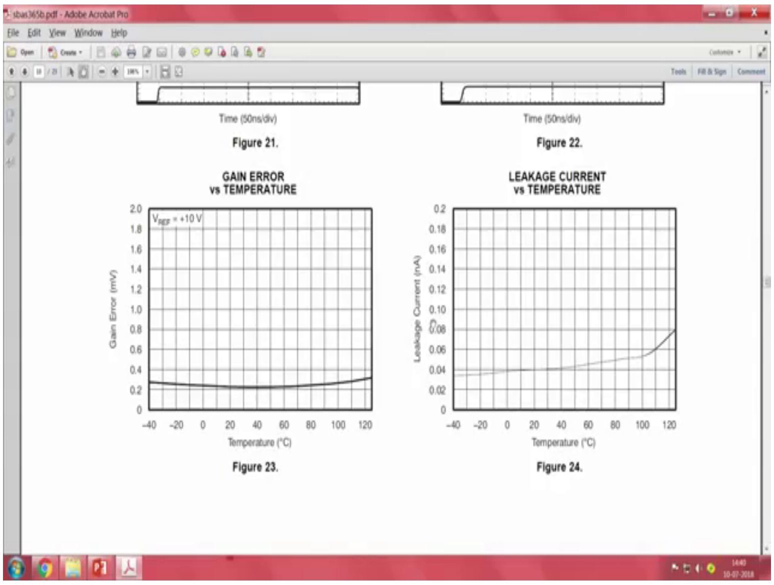

The gain should not should not be differing across the temperature. So, that you get same operation for different temperature. So, they have to they have characterized it with respect to temperature.

So, you need to know these things these are like technical documentation perspectives actually. So, for sense of completeness, you should be you should get fascinated when you see the datasheet.

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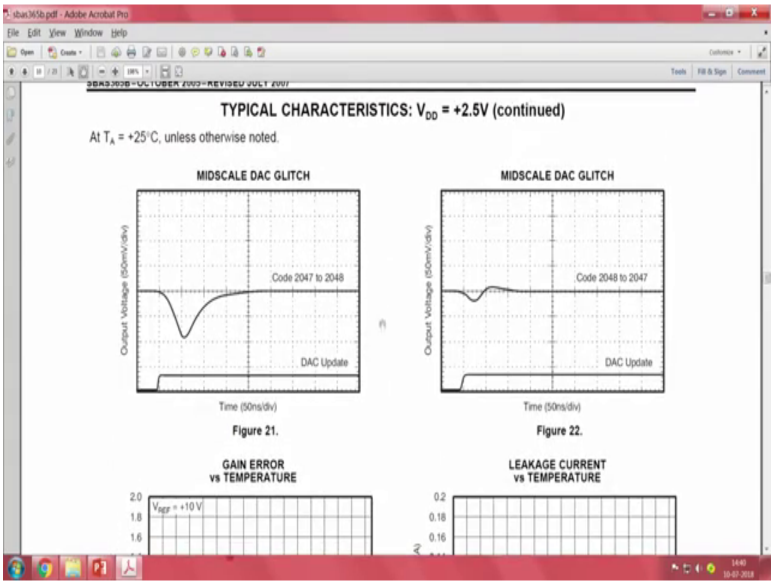


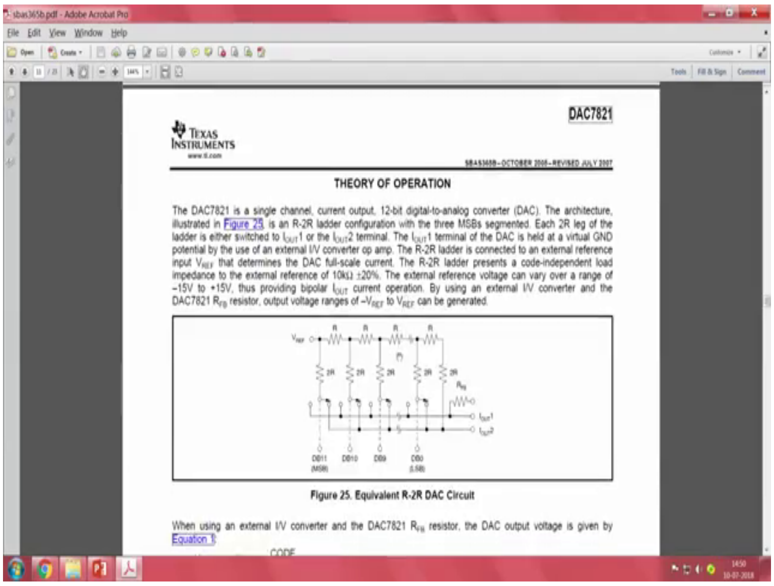
It may not be fully relevant to your circuit design re uirements, but then you can see how much detailed they have gone into preparation of any technical document.

So, because at later point if some issue comes up they should always have data to back whatever they are claiming. If you are, let us say you are you are studying now you will later join a tech company, that makes IC's or makes PCB's. So, and finally, those PCBs or those products you will be offering to customers. When the so, ~~the~~ you are actually a product seller finally.

So, you are offering it to a customer. So, customer while deployment in their field. Finally, they will face some ~~issues,~~issues; they will come back to you. At that point you should always have data to support you as much as possible. May be there might be some situations when that that scenario that particular scenario was never encountered.

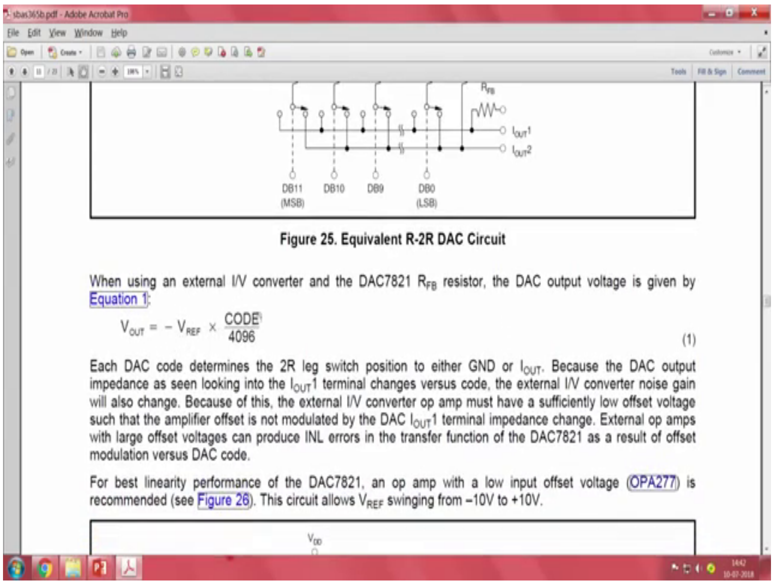
Then it is ok, but then if it is typical scenario. You are characterization of that IC or your product within your premises of your company or your organization should be such that it is very, very exhaustive and rigorous. It is the word to be used is rigorous. We have to do rigorous characterization so that you can give confidence to your customers, if you are a product seller, or if you are even if you are in a research and development institution, your work should be of that ~~uality~~quality, ok. That is why they have done all these things.

(Refer Slide Time: 31:13)



Then they have told R 2 R ladder DAC how it operates. So, I will not get in to the details of this, this is this has been covered in the theory portion. So, R 2 R ladder DAC how it will work, and how the digital inputs are given like this from here. And then the analog voltage is generated.

(Refer Slide Time: 31:33)



Then they have given so, what is a code? What is the value of the code and what will be the V out. So, value of the code can go from here we have seen right, it is a 12 bit DAC. So, from 0 to 4,096 it can go 4,095 it can go. And as we have seen before when we initially we saw right how do we convert the 3 bit binary value, we have to multiply it with the reference step know. So, that voltage is there and then you get the voltage, cool.

So, that is what happens.

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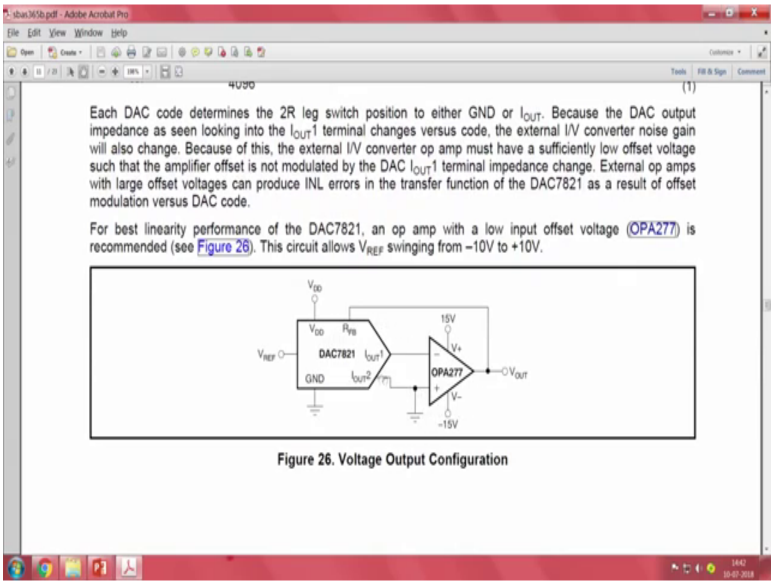

And then you can always amplify your output voltage to get the output signal, to the necessary ranges.

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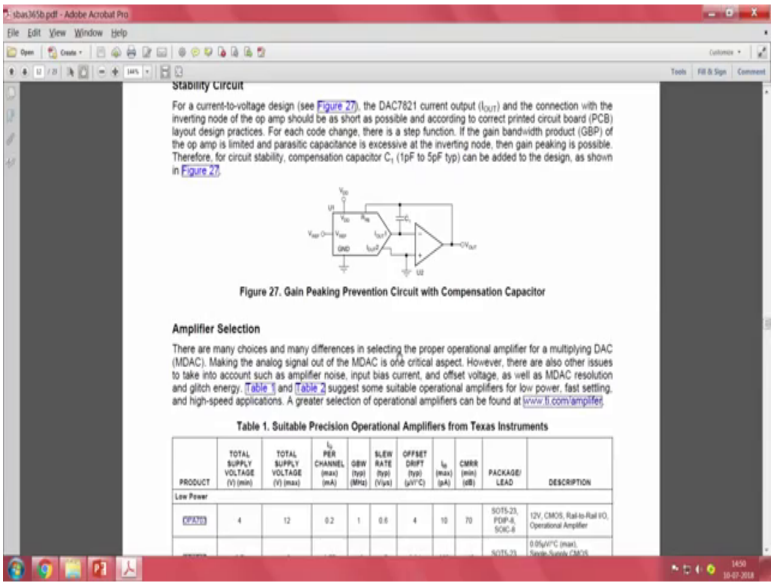

Then after that on major section of the data sheet will be application information. So, here what they will do is, they will identify certain typical applications. Typical application of the IC, and they will give you sample circuits which you can use which you can use sample circuits which you can use to see how you can implement that circuit.

So, they have to like stability circuit for current voltage design current output and the connections. So, they have gain peaking prevention circuit with compensation capacitor. So, they will prevent the peaking of the gain. And then amplifiers selection. So, these are all peripheral things actually, look at for your output amplifier.

Let us not go into the details of this.

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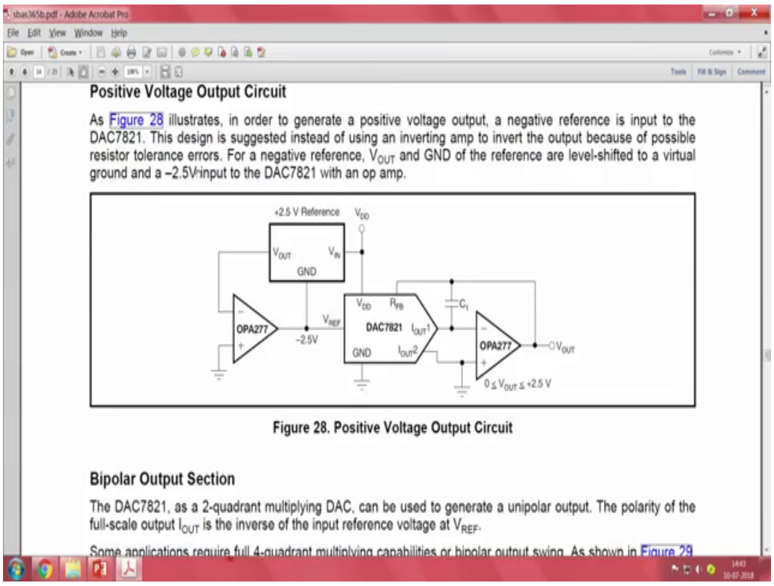

Positive Voltage Output Circuit

As Figure 28 illustrates, in order to generate a positive voltage output, a negative reference is input to the DAC7821. This design is suggested instead of using an inverting amp to invert the output because of possible resistor tolerance errors. For a negative reference, V_{OUT} and GND of the reference are level-shifted to a virtual ground and a −2.5V input to the DAC7821 with an op amp.

Figure 28. Positive Voltage Output Circuit

Bipolar Output Section

The DAC7821, as a 2-quadrant multiplying DAC, can be used to generate a unipolar output. The polarity of the full-scale output I_{OUT} is the inverse of the input reference voltage at V_{REF}.

Some applications require full 4-quadrant multiplying capabilities or bipolar output swing. As shown in Figure 29

Then positive voltage output; so, as we have seen the output of by design the output of it is negative. So, what do if you want to make the output as positive, what you should do that circuit they have given. We can always go through it in detail, then by polar output selection.

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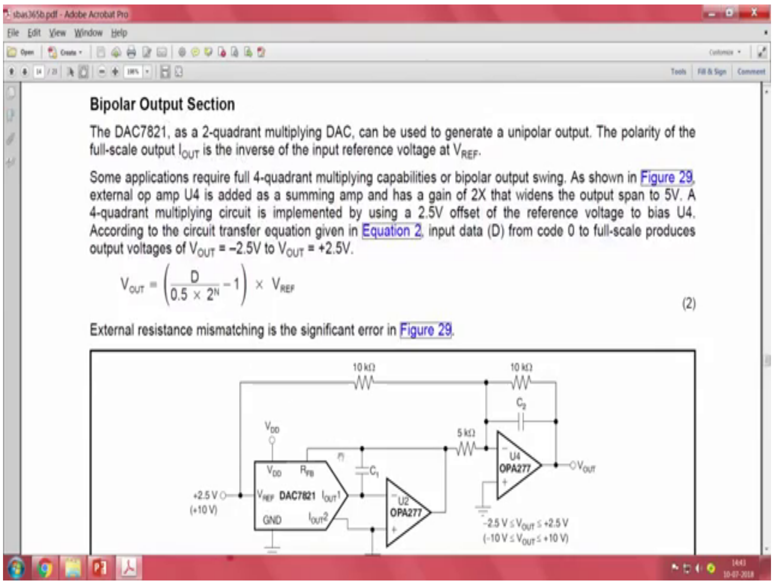

That is like you want you want to have bi polar output ; like, plus or minus so, output voltage will. So, see here, the full scale produces output voltages of V out e ual to minus 2.5 volt to plus 2.5 volt.

Ideally we were we would see by default we would see only voltage from 0 to 5 volt, or 0 to 15 volt. But now if you want to have a bipolar output that also we can do with this circuit that they have shown. If you implement this circuit along with the IC, this is the IC, and then you have to add peripheral other Op-Amp into that IC. Make a circuit like this, and then you can have bipolar output operation, that is what they have told.

So, if you take any data sheet, you take any datasheet.~~;~~ ~~they~~ They will give you ~~this typical applications~~these typical applications. So, this is what you have to see. This will help you a lot in 2 things. One is if you are confused or stuck as to what exact circuit you use for your typical application, most of the time that typical application will be there in the data ~~sheet,~~sheet and you can borrow from it and then make minor modifications as you want. Another one is, you will be able to see applications which you never even thought of with that IC.

So, this it forms a part of your learning curve also. So, you can you can learn it. So, you can learn new circuits. This is an analog circuits course, that too with a very high practical design aspect to it. So, that is why we are covering ~~these thing~~this thing so, this is one place. One part is us teaching you what all circuits that you can go through and what all circuits you can read. Another part is us empowering you and pointing you to how to enrich yourself better cover more things ac uire more knowledge and where to look for it. That is even more important actually which not many people will tell you.

So, you can always open any data sheet in your board just open datasheets, go to typical applications, you can always find new circuit applications for the same IC. So, this is a very important value addition.

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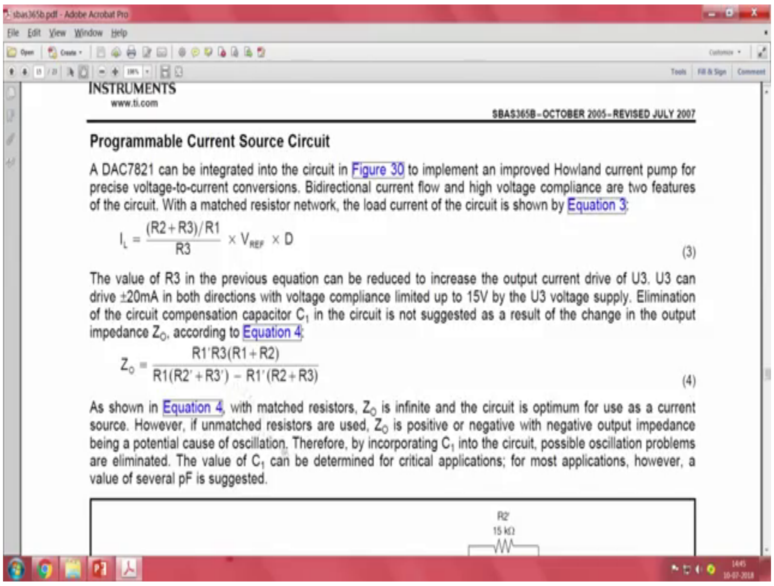
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Programmable Current Source Circuit

A DAC7821 can be integrated into the circuit in Figure 30 to implement an improved Howland current pump for precise voltage-to-current conversions. Bidirectional current flow and high voltage compliance are two features of the circuit. With a matched resistor network, the load current of the circuit is shown by Equation 3:

$$I_L = \frac{(R2+R3)/R1}{R3} \times V_{REF} \times D \qquad (3)$$

The value of R3 in the previous equation can be reduced to increase the output current drive of U3. U3 can drive ±20mA in both directions with voltage compliance limited up to 15V by the U3 voltage supply. Elimination of the circuit compensation capacitor C_1 in the circuit is not suggested as a result of the change in the output impedance Z_O, according to Equation 4:

$$Z_O = \frac{R1'R3(R1+R2)}{R1(R2'+R3') - R1'(R2+R3)} \qquad (4)$$

As shown in Equation 4, with matched resistors, Z_O is infinite and the circuit is optimum for use as a current source. However, if unmatched resistors are used, Z_O is positive or negative with negative output impedance being a potential cause of oscillation. Therefore, by incorporating C_1 into the circuit, possible oscillation problems are eliminated. The value of C_1 can be determined for critical applications; for most applications, however, a value of several pF is suggested.

See another one there is a programmable current source circuit. So, if time permits in the course we might even go through one of these circuits with the board, ok, then parallel interface.

So, that is all, with this the datasheet almost gets over. Then once if you want to buy the IC you will have package information.

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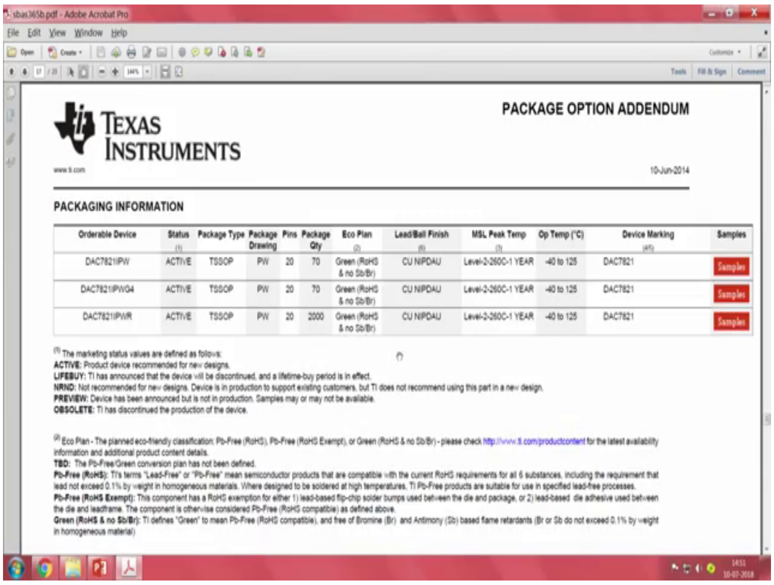
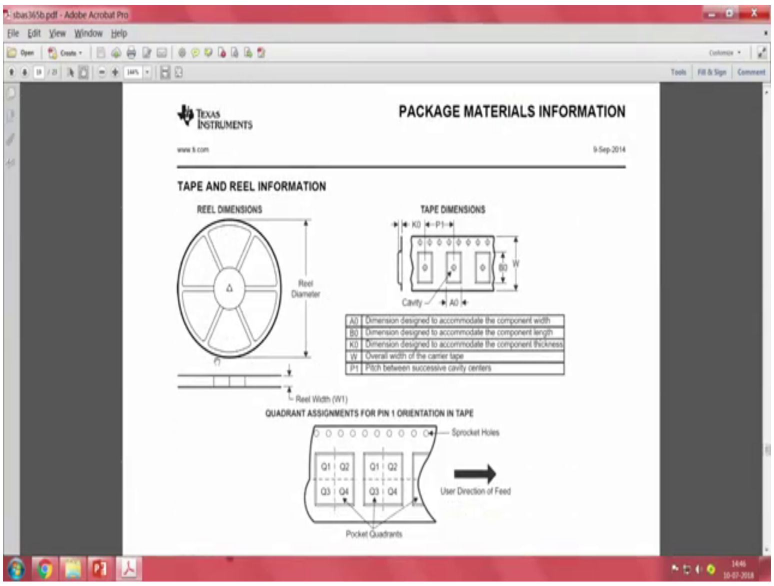


So, they will have the orderable, part number for the device, what is a package, what is a this thing environment plan is it ROHS complaint. ROHS is like it should not produce any radioactive hazardous substances, that is ROHS.

So, it is green and what are the things so, that they will show. And then once and the last part of the datasheet usually is the package information.

(Refer Slide Time: 35:46)



This is mainly for people who want to make the PCB with the IC, footprint if they want to create, that that like that I have shown. They will give all the engineering drawings of the packaging. That is what this is about.

So, you will see all the engineering drawing.

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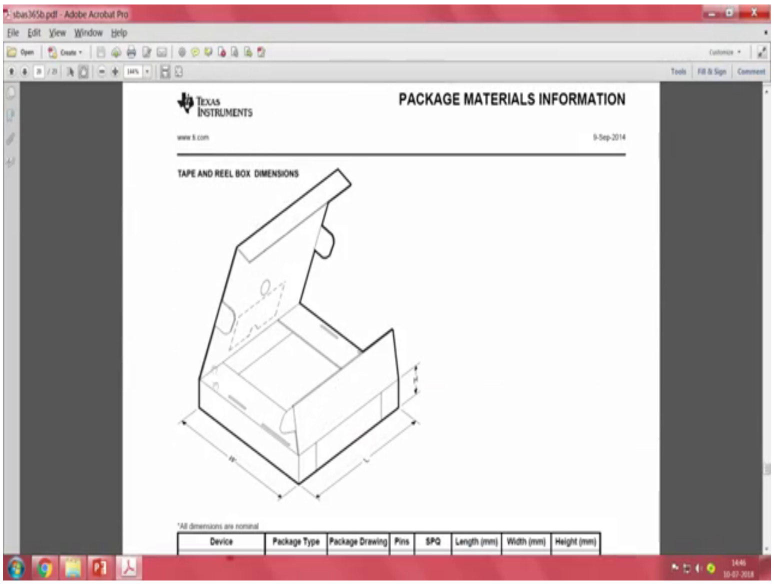

How the package is, how it will come packaged it, is it tape and reel or it is a roll, those things.

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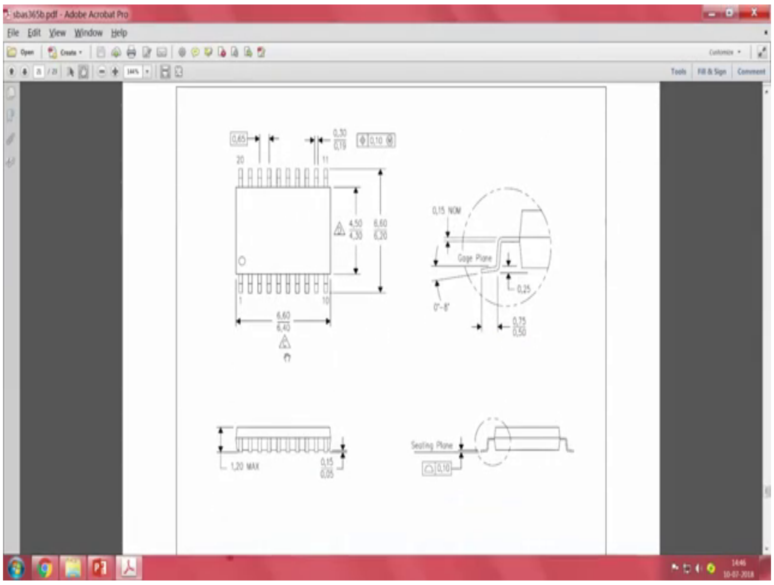

So, these are the pins, what is the pitch distance between the pins, what is the overall package dimension. What is the angle of the pins, how does a pin sit on the PCB, all these things they will show?

So, these are more important when you are finally, making the PCB. But if you already have a board you need not look at these things, you can just directly go head and test it, taking in to account the functional characteristics that are mentioned in the data sheet. But this is important if you are making foot prints and or may and or making a PCB on your ~~own ;~~own; which you will be doing at some point in your career if you are interested in analog circuits. PCB design in analog circuits is a separate course in itself. And so, this is this comes under that.

So, those all this all the engineering drawings will be given at the end of the datasheet, fine. So, that is it we have finished covering the datasheet in like very short time. So, these are the main things I think you got a very wholesome idea about how a datasheet looks like. Now let us ~~uickly~~quickly write down what in your mind. So, I am also not I will also not go back to the datasheet, but we will ~~uickly~~quickly write down, what is the, what are the main things that where that we will that we have to look for in a datasheet. Like, I told like I told before.

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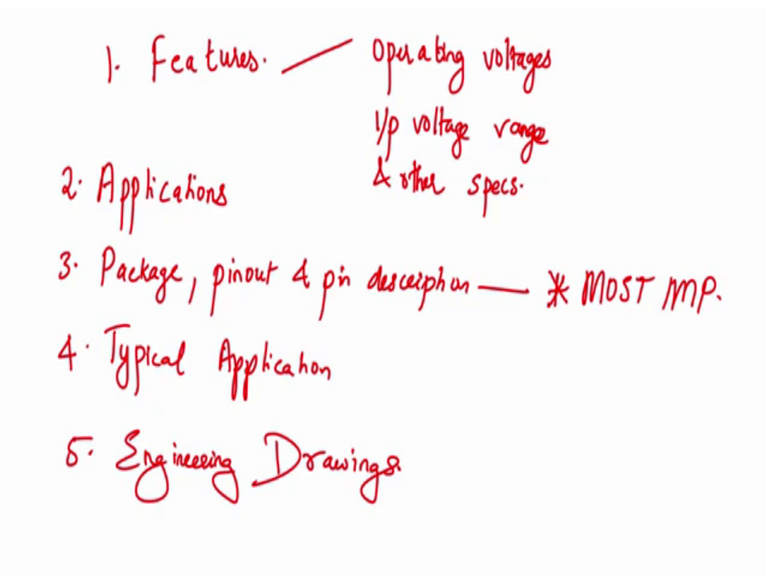

So, first ~~thing ;~~thing; features what are the main features.

So, that will be the first section. So, you will see what are the operating voltages, what are the how operating voltages, what are the operating voltages, what are the input voltage range, and other specifications. Like, we saw right 12 bit it is total bit DAC, all those other specifications,. Then features, then what did we see? Then what will be ~~there ?~~ there? Another thing that will be there is applications, what are the broad areas where this IC can be applied, this is also very useful~~,~~.

Then what we have to look at is package pin out and pin description. This is a most important. I will put an asterisk, this is most important. When you are opening a datasheet~~,~~. ~~Then~~ then is typical application, which is very useful for your circuit design. And 5th one is engineering drawings. Only these 5 things you need to look when you open a datasheet. Just you can note this down, open any datasheet you just need to go through these things, and then you can immediately do either debug the circuit that you have in your hand, or start going ahead and making a PCB on your own.

So, let us with this in mind, let these 5 things in mind, let us just go ~~uickly~~ quickly ~~go~~ through the datasheet again, in like under 2 minutes, ok. So, what all what all are ~~there ?~~ there? So, we go to the first page ok, features are there what is the main description, features we will see the features. Yes, these things are there, fine. What are the applications what are the main applications that you should look at ? Fine, then you can uickly go to the package ok, this is how internally it will look like.

You will already be having some idea about how the circuit works, when you goead to explore IC's that you need. So, just you will roughly get an idea of what it, it is using R 2 R ladder to convert back, fine. Then you come down, then you have to see the maximum ratings, this also comes in the features ok, ok. I should not go beyond these voltages, fine. I should not store at this temperature, and I should not operate beyond this temperature cool.

Then immediately you go to these things, only look at important things like reference voltage operating V DD and all. Then that will be done, then ~~uickly~~quickly go to the after that main thing is ~~what ?~~ what? After that main thing is the package, and the pin out. What all pins are there? What other functionalities or what you should connect to what. That is it.

Then pin not will be done, correct? Then you can glance through these curves, if it all something you find interesting, correct? Then you need not spend much time in these curves. You can just ~~uickly~~quickly go through it, then you can look at the typical applications, theory of operation ; which also you would already be knowing, but application information will be smoothing new to you. You can see typical applications and see if they have already given, some typical application that you can barrow for your design. And then go through the typical applications. And then finally, what is the part number you want, and then what is that the engineering drawing you have to see, what is the dimensions if at all you want to make a foot print on the PCB.

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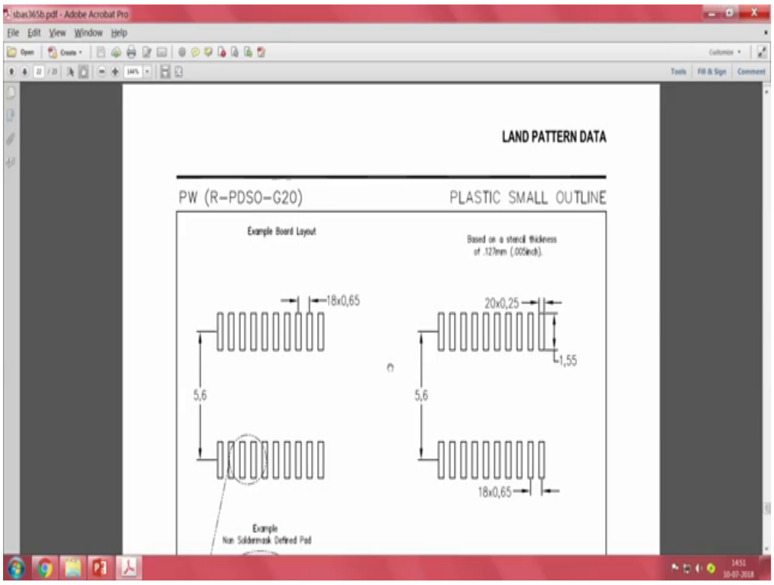

So, this is the datasheet of so, we cover it in a general point of view, to see how you can cover a datasheet, ok. So, see it in under 1 minute we have seen ~~uickly~~quickly. After we spent some time, you understood we understood what is what to be looked for in a datasheet and what is to be just glance through. And then this way you can cover any datasheet you want in a very ~~uick~~quick time, ok. In 1 minute because if you are in a company or if you are working with an organization if you are into research, you will not get that much time to go through each and every word that is written in a datasheet. You just need to look know what to look for, where to look for, what are the important things to focus. Once you know that you can ~~uickly~~quickly finish it off.

So, this is the IC that we are looking at DAC terminate to one. Now next we will look at the board, and we will give digital inputs and see what are the analog outputs coming. And see if whatever we have been discussing to understand what all are there in details. Let us see if actually it is working on the board so that you will get the sense of completeness.