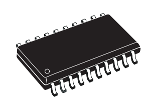
TS634

DUAL WIDE BAND OPERATIONAL AMPLIFIER FOR ADSL LINE INTERFACE

- LOW NOISE : **3.2nV/√Hz, 1.5pA/√Hz**
- HIGH OUTPUT CURRENT : **160mA** min.
- VERY LOW HARMONIC AND INTERMODULATION DISTORTION
- HIGH SLEW RATE : **40V/μs**
- SPECIFIED FOR **25Ω** LOAD



D
SO20 Batwing
(Plastic Micropackage)

DESCRIPTION

This device is particularly intended for applications where multiple carriers must be amplified simultaneously with very low intermodulation products. It has been mainly designed to fit with ADSL chip-set such as ST70134 or ST70135.

The TS634 is a high output current dual operational amplifier, with a large gain-bandwidth product (130MHz) and capable of driving a 25Ω load at 12V power supply. The TS634 is fitted out with Power Down function in order to decrease the consumption.

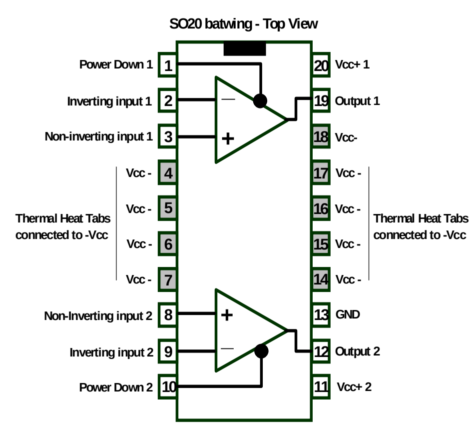
The TS634 is housed in SO20 batwing plastic package for a very low thermal resistance.

ORDER CODE

Part Number	Temperature Range	Package	
		D	P
TS634ID	-40, +85°C	•	

D=Small Outline Package (SO) - also available in Tape & Reel (DT)

PIN CONNECTIONS (top view)



APPLICATION

- UPSTREAM line driver for Asymmetric Digital Subscriber Line (ADSL) (NT).

ABSOLUTE MAXIMUM RATINGS

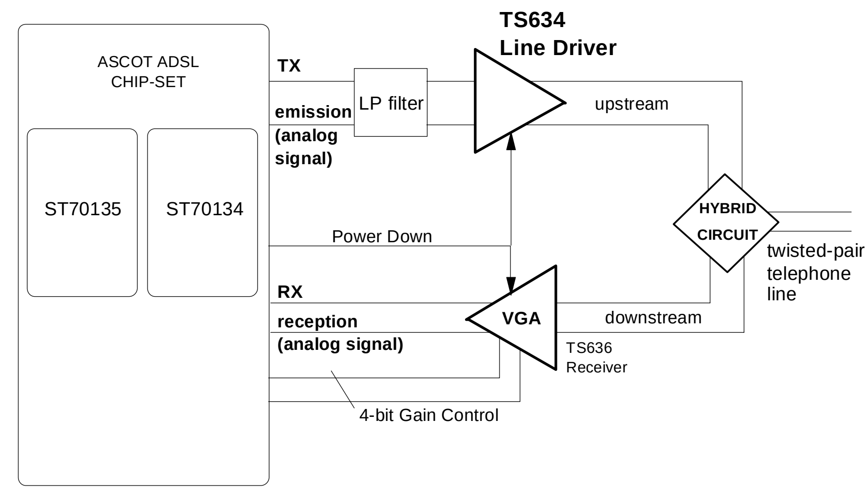
Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage 1)	±7	V
V_{id}	Differential Input Voltage 2)	±2	V
V_{in}	Input Voltage Range 3)	±6	V
T_{oper}	Operating Free Air Temperature Range TS634TS634ID	-40 to +85	°C
T_{std}	Storage Temperature	-65 to +150	°C
T_j	Maximum Junction Temperature	150	°C
SO20-Batwing			
R_{thjc}	Thermal Resistance Junction to Case	25	°C/W
R_{thja}	Thermal Resistance Junction to Ambient Area	45	°C/W
$P_{max.}$	Maximum Power Dissipation (@25°C)	2.7	W

1. All voltages values, except differential voltage are with respect to network terminal.
2. Differential voltages are non-inverting input terminal with respect to the inverting input terminal.
3. The magnitude of input and output voltages must never exceed V_{CC} +0.3V.

OPERATING CONDITIONS

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage	±2.5 to ±6	V
V_{icm}	Common Mode Input Voltage	$(V_{CC}) +2$ to $(V_{CC}^{+}) -1$	V

APPLICATION: ADSL LINE INTERFACE



ELECTRICAL CHARACTERISTICS V_{CC} = ±6Volts, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
DC PERFORMANCE						
ΔV_{io}	Differential Input Offset Voltage	T_{amb} = 25°C			6	mV
I_{io}	Input Offset Current	T_{amb}		0.2	3	µA
		$T_{min.} < T_{amb} < T_{max.}$			5	
I_{ib}	Input Bias Current	T_{amb}		5	15	µA
		$T_{min.} < T_{amb} < T_{max.}$			30	
CMR	Common Mode Rejection Ratio	V_{ic} = 2V to 2V, T_{amb}	90	108		dB
		$T_{min.} < T_{amb} < T_{max.}$	70			
SVR	Supply Voltage Rejection Ratio	V_{ic} = ±6V to ±4V, T_{amb}	70	88		dB
		$T_{min.} < T_{amb} < T_{max.}$	50			
I_{CC}	Total Supply Current per Operator	No load, V_{out} = 0		14		mA
DYNAMIC PERFORMANCE						
V_{OH}	High Level Output Voltage	I_{out} = 160mA R_L connected to GND	4	4.5		V
V_{OL}	Low Level Output Voltage	I_{out} = 160mA R_L connected to GND		-4.5	-4	V
A_{VD}	Large Signal Voltage Gain	V_{out} = 7V peak R_L = 25Ω, T_{amb}	6500	11000		V/V
		$T_{min.} < T_{amb} < T_{max.}$	5000			
GBP	Gain Bandwidth Product	A_{VCL} = +7, f = 20MHz R_L = 100Ω		130		MHz
SR	Slew Rate	A_{VCL} = +7, R_L = 50Ω	23	40		V/µs
I_{sink} I_{source}	Output Current	V_{id} = ±1V, T_{amb}	160			mA
		$T_{min.} < T_{amb} < T_{max.}$	140			
ΦM14	Phase Margin at A_{VCL} = 14dB	R_L = 25Ω//15pF		60		°
ΦM6	Phase Margin at A_{VCL} = 6dB	R_L = 25Ω//15pF		40		°
NOISE AND DISTORTION						
en	Equivalent Input Noise Voltage	f = 100kHz		3.2		nV/√Hz
in	Equivalent Input Noise Current	f = 100kHz		1.5		pA/√Hz
THD	Total Harmonic Distortion	V_{out} = 4Vpp, f = 100kHz A_{VCL} = -10 R_L = 25Ω//15pF		-69		dB
$IM2_{-10}$	2nd Order Intermodulation Product	F1 = 80kHz, F2 = 70kHz V_{out} = 8Vpp, A_{VCL} = -10 Load = 25Ω//15pF		-77		dBc
$IM3_{-10}$	3rd Order Intermodulation Product	F1 = 80kHz, F2 = 70kHz V_{out} = 8Vpp, A_{VCL} = -10 Load = 25Ω//15pF		-77		dBc

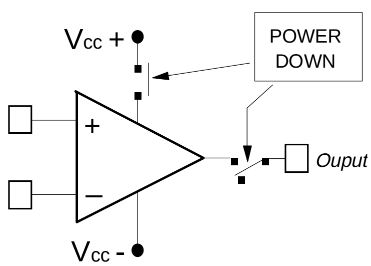
POWER DOWN MODE

V_{CC} = ±6Volts, T_{amb} = 25°C

Symbol	Parameter	Min.	Typ.	Max	Unit
V_{pdw}	Thershold Voltage for Power Down Mode				V
	Low Level		0	0.8	
	High Level	2	3.3		
Icc_{pdw}	Total Power Down Mode Current Consumption			150	µA
R_{pdw}	Power Down Mode Ouput Impedance		1.4		MΩ
C_{pdw}	Power Down Mode Output Capacitance		33		pF

STANDBY CONTROL		OPERATOR STATUS	
operator 1	**operator 2**	**operator 1**	**operator 2**
$V_{high\ level}$	$V_{low\ level}$	Standby	Active
$V_{high\ level}$	$V_{high\ level}$	Standby	Standby
$V_{low\ level}$	$V_{low\ level}$	Active	Active
$V_{low\ level}$	$V_{high\ level}$	Active	Standby

POWER DOWN EQUIVALENT SCHEMATIC



OUPUT IMPEDANCE IN POWER DOWN MODE

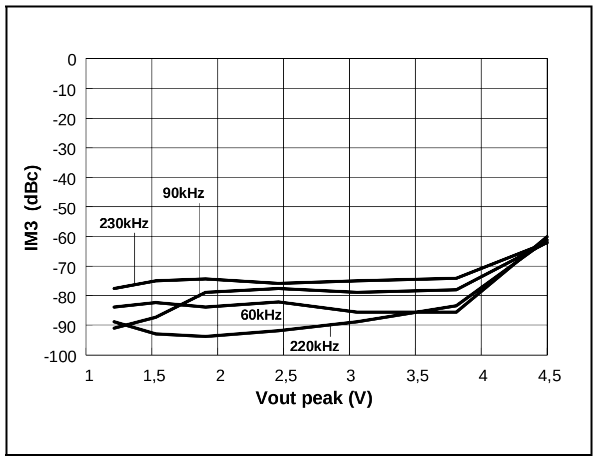
In Power Down Mode the output of the driver is in "high impedance" state. It is really the case for the static mode. Regarding the dynamic mode, the impedance decreases due to a capacitive effect of the collector-substrat and base collector junction. The impedance behaviour comes capacitive, typically: 1.4MΩ // 33pF.

INTERMODULATION DISTORTION

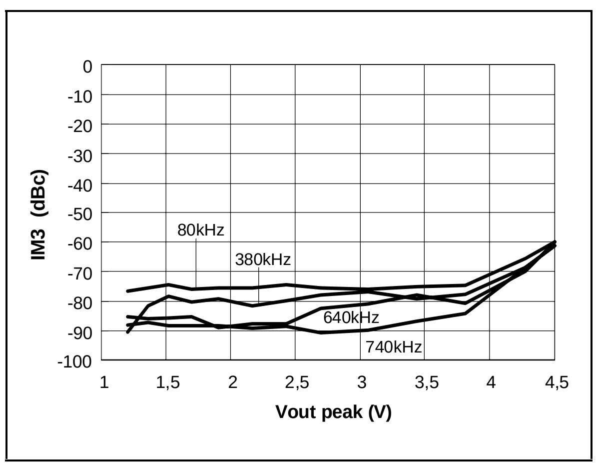
The curves shown below are the measurements results of a single operator wired as an adder with a gain of 15dB. The operational amplifier is supplied by a symmetric ±6V and is loaded with 25Ω. Two synthesizers (Rhode & Schwartz SME) generate two frequencies (tones) (70 & 80kHz or 180 & 280kHz). An HP3585 spectrum analyzer measures the spurious level at different frequencies. The curves are traced for different output levels (the value in the X axis is the value of each tone). The output levels of the two tones are the same. The generators and spectrum analyzer are phase locked to enhance measurement precision.

3rd ORDER INTERMODULATION

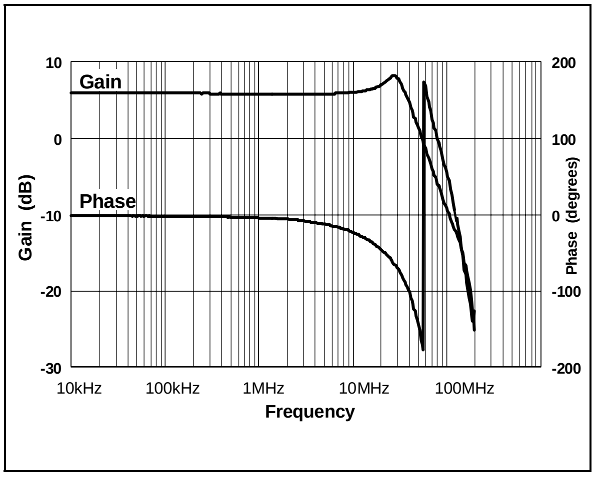
2 tones : 70kHz and 80kHz



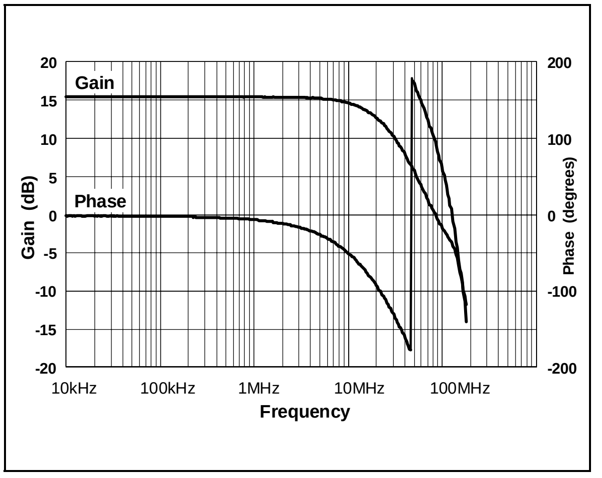
2 tones : 180kHz and 280kHz



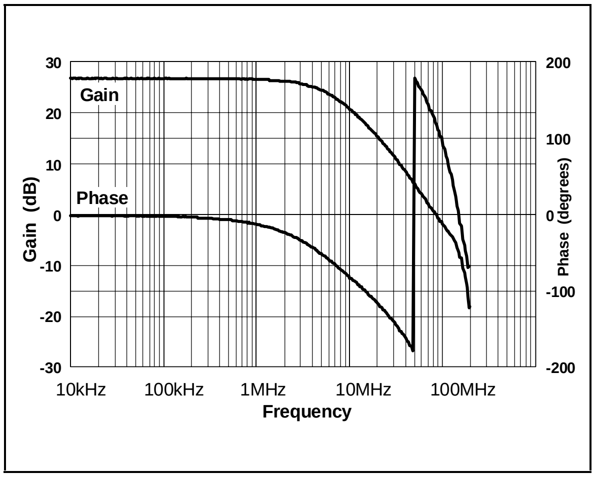
Closed Loop Gain and Phase vs. Frequency
Gain=+2, Vcc=±6V, RL=25Ω



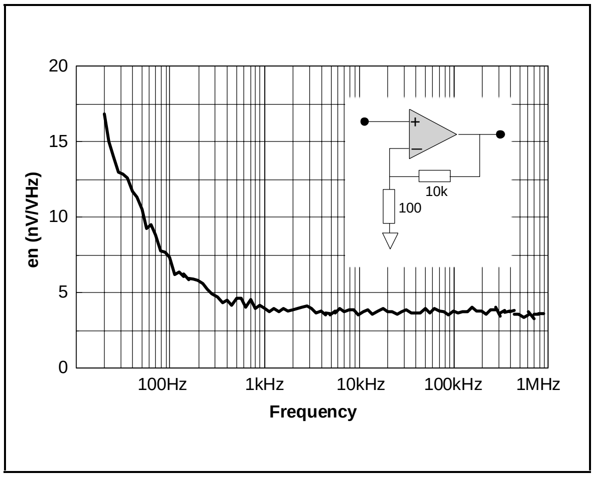
Closed Loop Gain and Phase vs. Frequency
Gain=+6, Vcc=±6V, RL=25Ω



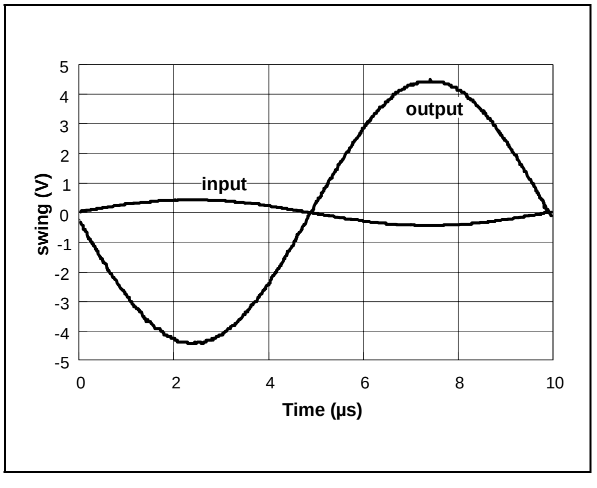
Closed Loop Gain and Phase vs. Frequency
Gain=+11, Vcc=±6V, RL=25Ω



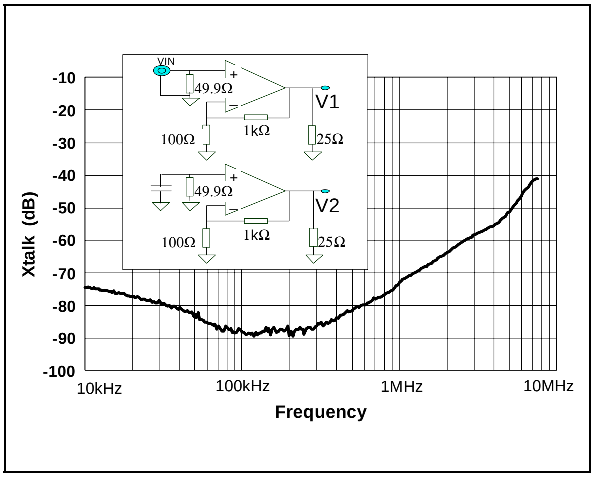
Equivalent Input Voltage Noise
Gain=+100, Vcc=±6V, no load



Maximum Output Swing
Vcc=±6V, RL=25Ω



Channel Separation (Xtalk) vs. Frequency
XTalk=20Log(V2/V1), Vcc=±6V, RL=25Ω

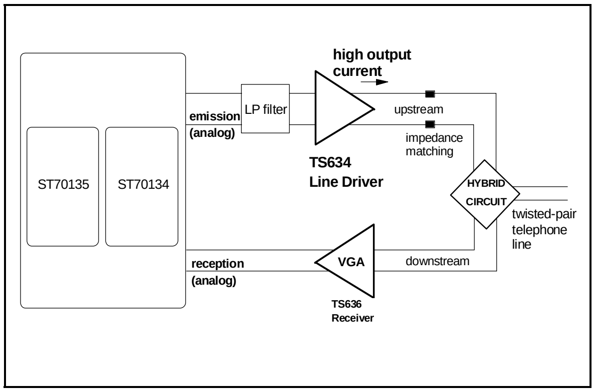


THE TS634 AS LINE DRIVER ON ADSL LINE INTERFACE. SINGLE SUPPLY IMPLEMENTATION WITH PASSIVE OR ACTIVE IMPEDANCE MATCHING.

THE LINE INTERFACE - ADSL Remote Terminal (RT):

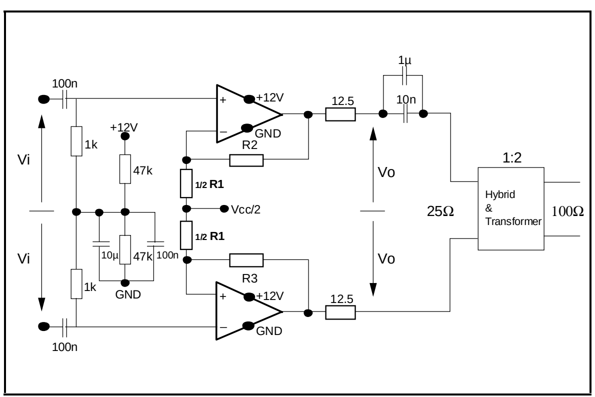
The Figure1 shows a typical analog line interface used for ADSL service. On this note, the accent will be made on the emission path. The TS634 is used as a dual line driver for the upstream signal.

Figure 1 : Typical ADSL Line Interface



For the remote terminal it is required to create an ADSL modem easy to plug in a PC. In such an application, the driver should be implemented with a +12 volts single power supply. This +12V supply is available on PCI connector of purchase.
The Figure 2 shows a single +12V supply circuit that uses the TS634 as a remote terminal transmitter in differential mode.

Figure 2 : TS634 as a differential line driver with a +12V single supply



The driver is biased with a mid supply (nominaly +6V), in order to maintain the DC component of the signal at +6V. This allows the maximum dynamic range between 0 and +12 V. Several options are possible to provide this bias supply (such as a virtual ground using an operational amplifier), such as a two-resistance divider which is the cheapest solution. A high resistance value is required to limit the current consumption. On the other hand, the current must be high enough to bias the inverting input of the TS634. If we consider this bias current (5µA) as the 1% of the current through the resistance divider (500µA) to keep a stable mid supply, two 47kΩ resistances can be used.

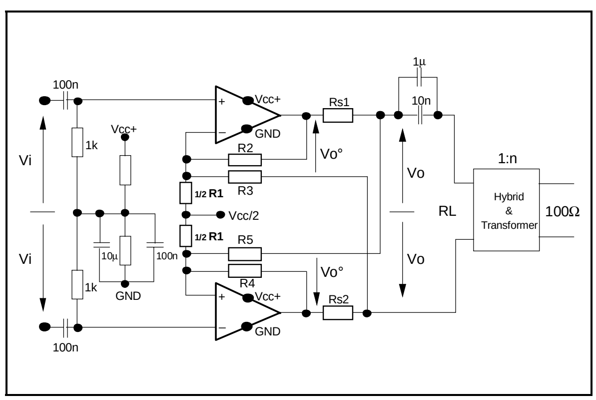
The input provides two high pass filters with a break frequency of about 1.6kHz which is necessary to remove the DC component of the input signal. To avoid DC current flowing in the primary of the transformer, an output capacitor is used. The this case the load impedance is 25Ω for each driver.

For the ADSL upstream path necessary to avoid any distortion. In this simple non-inverting amplification configuration, it will be easy to implement a Sallen-Key lowpass filter by using the TS634. For ADSL over POTS, a maximum frequency of 135kHz is reached. For ADSL over ISDN, the maximum frequency will be 276kHz.

INCREASING THE LINE LEVEL BY USING AN ACTIVE IMPEDANCE MATCHING

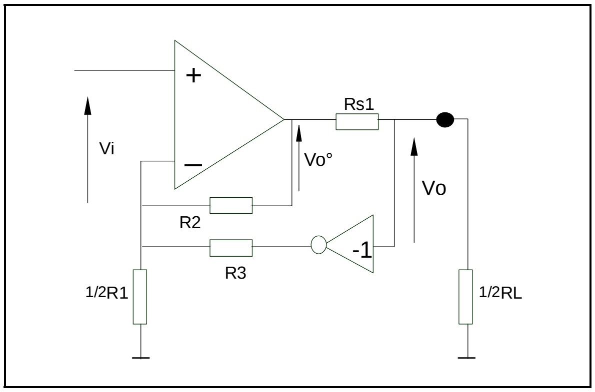
With passive matching, the output signal amplitude of the driver must be twice the amplitude on the load. To go beyond this limitation an active maching impedance can be used. With this technique it is possible to keep good impedance matching with an amplitude on the load higher than the half of the ouput driver amplitude. This concept is shown in Figure 3 for a differential line.

Figure 3 : TS634 as a differential line driver with an active impedance matching



Component calculation:
Let us consider the equivalent circuit for a single ended configuration, Figure 4.

Figure 4 : Single ended equivalent circuit



Let us consider the unloaded system. Assuming the currents through R1, R2 and R3 as respectively:

$$\frac{2Vi}{R1}, \frac{(Vi - Vo°)}{R2} and \frac{(Vi + Vo)}{R3}$$

As Vo° equals Vo without load, the gain in this case becomes :

$$G = \frac{Vo(noload)}{Vi} = \frac{1 + \frac{2R2}{R1} + \frac{R2}{R3}}{1 - \frac{R2}{R3}}$$

The gain, for the loaded system will be (1):

$$GL = \frac{Vo(withload)}{Vi} = \frac{1}{2}\frac{1 + \frac{2R2}{R1} + \frac{R2}{R3}}{1 - \frac{R2}{R3}},(1)$$

As shown in figure5, this system is an ideal generator with a synthesized impedance as the internal impedance of the system. From this, the output voltage becomes:

$$Vo = (ViG) - (RoIout),(2)$$

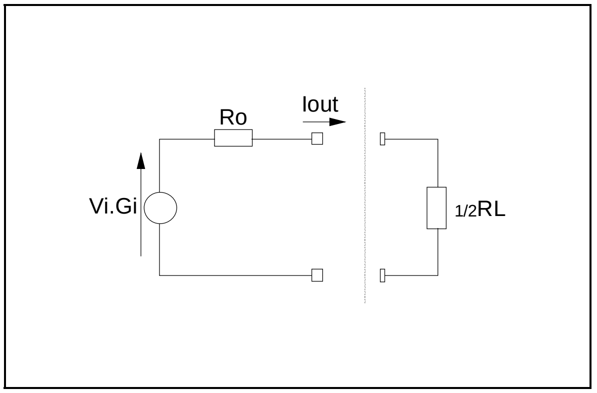
with Ro the synthesized impedance and Iout the output current. On the other hand Vo can be expressed as:

$$Vo = \frac{Vi\left(1 + \frac{2R2}{R1} + \frac{R2}{R3}\right)}{1 - \frac{R2}{R3}} - \frac{Rs1Iout}{1 - \frac{R2}{R3}},(3)$$

By identification of both equations (2) and (3), the synthesized impedance is, with Rs1=Rs2=Rs:

$$Ro = \frac{Rs}{1 - \frac{R2}{R3}},(4)$$

Figure 5 : Equivalent schematic. Ro is the synthesized impedance



Unlike the level Vo° required for a passive impedance, Vo° will be smaller than 2Vo in our case. Let us write Vo°=kVo with k the matching factor varying between 1 and 2. Assuming that the current through R3 is negligeable, it comes the following resistance divider:

$$Ro = \frac{kVoRL}{RL + 2Rs1}$$

After choosing the k factor, Rs will equal to 1/2RL(k-1).
A good impedance matching assumes:

$$Ro = \frac{1}{2}RL,(5)$$

From (4) and (5) it becomes:

$$\frac{R2}{R3} = 1 - \frac{2Rs}{RL},(6)$$

By fixing an arbitrary value for R2, (6) gives:

$$R3 = \frac{R2}{1 - \frac{2Rs}{RL}}$$

Finally, the values of R2 and R3 allow us to extract R1 from (1), and it comes:

$$R1 = \frac{2R2}{2\left(1 - \frac{R2}{R3}\right)GL - 1 - \frac{R2}{R3}},(7)$$

with GL the required gain.

GL (gain for the loaded system)	GL is fixed for the application requirements GL=Vo/Vi=0.5(1+2R2/R1+R2/R3)/(1-R2/R3)
R1	2R2/[2(1-R2/R3)GL-1-R2/R3]
R2 (=R4)	Abritrary fixed
R3 (=R5)	R2/(1-Rs/0.5RL)
Rs	0.5RL(k-1)

CAPABILITIES

The table below shows the calculated components for different values of k. In this case R2=1000Ω and the gain=16dB. The last column displays the maximum amplitude level on the line regarding the TS634 maximum output capabilities (18Vpp diff.) and a 1:2 line transformer ratio.

Active matching					
k	R1 (Ω)	R3 (Ω)	Rs (Ω)	TS634 Output Level to get 12.4Vpp on the line (Vpp diff)	Maximum Line level (Vpp diff)
1.3	820	1500	3.9	8	27.5
1.4	490	1600	5.1	8.7	25.7
1.5	360	2200	6.2	9.3	25.3
1.6	270	2400	7.5	9.9	23.7
1.7	240	3300	9.1	10.5	22.3
Passive matching				12.4	18

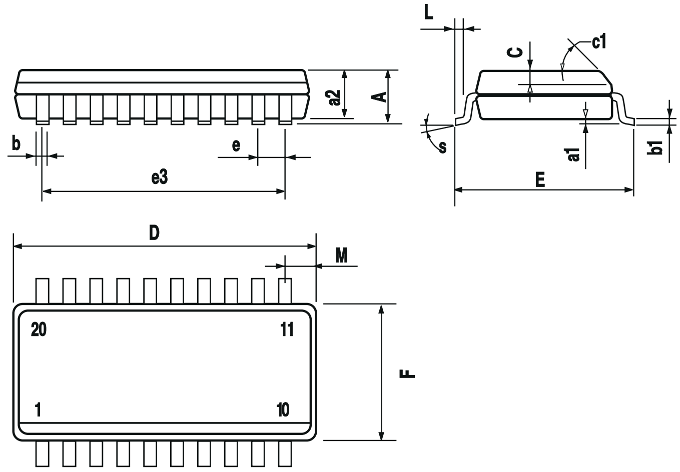
MEASUREMENT OF THE POWER CONSUMPTION

Conditions:

Power Supply: 12V
Passive impedance matching
Transformer turns ratio: 2
Maximun level required on the line: 12.4Vpp
Maximum output level of the driver: 12.4Vpp
Crest factor: 5.3 (Vp/Vrms)
The TS634 power consumption during emission on 900 and 4550 meter twisted pair telephone lines: **450mW**

PACKAGE MECHANICAL DATA

20 PINS - PLASTIC MICROPACKAGE (SO)



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			2.65			0.104
a1	0.1		0.3	0.004		0.012
a2			2.45			0.096
b	0.35		0.49	0.014		0.019
b1	0.23		0.32	0.009		0.013
C		0.5			0.020	
c1	45° (typ.)					
D	12.6		13.0	0.496		0.512
E	10		10.65	0.394		0.419
e		1.27			0.050	
e3		11.43			0.450	
F	7.4		7.6	0.291		0.299
L	0.5		1.27	0.020		0.050
M			0.75			0.030
S	8° (max.)					