QUALIFICATION TESTING OF SCREENED CATEGORY 6 ISO/IEC, EN & TIA/EIA CONNECTING HARDWARE ACCORDING TO REQUIREMENTS OF 2nd EDITION ISO/IEC 11801, CENELEC EN 50173-1:2007, ANSI/TIA/EIA-568-B.2-1, 1st EDITION IEC 60603-7-5 AND IEC 60512-26-100

Produced by Telebox Industries Corp.

Screened Keystone Jack, Category 6, RJ 45
Telebox Identification, P/N TA8661Sx

Prepared by Poul Villien

Project No. 1102563A 2010.10.27
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IDENTIFICATION</td>
<td>3</td>
</tr>
<tr>
<td>2. SURVEY OVER THE WORK</td>
<td>4</td>
</tr>
<tr>
<td>3. APPLIED SPECIFICATIONS</td>
<td>6</td>
</tr>
<tr>
<td>4. CONDITIONS OF TESTING</td>
<td>7</td>
</tr>
<tr>
<td>4.1 Connecting Hardware Types covered by the Qualification Testing</td>
<td>7</td>
</tr>
<tr>
<td>4.2 Electrical Measurements</td>
<td>7</td>
</tr>
<tr>
<td>5. FACTORY INSPECTION</td>
<td>9</td>
</tr>
<tr>
<td>5.1 Company Organization</td>
<td>9</td>
</tr>
<tr>
<td>5.2 Quality Assurance</td>
<td>9</td>
</tr>
<tr>
<td>5.3 Production Facilities</td>
<td>12</td>
</tr>
<tr>
<td>5.4 Final Testing</td>
<td>12</td>
</tr>
<tr>
<td>6. SUMMARIZED TEST RESULTS</td>
<td>15</td>
</tr>
<tr>
<td>6.1 De-Embedded NEXT Values of Applied RJ 45 Plugs</td>
<td>15</td>
</tr>
<tr>
<td>6.2 Return Loss</td>
<td>16</td>
</tr>
<tr>
<td>6.3 Attenuation</td>
<td>17</td>
</tr>
<tr>
<td>6.4 Near End Crosstalk</td>
<td>17</td>
</tr>
<tr>
<td>6.5 Far End Crosstalk</td>
<td>18</td>
</tr>
<tr>
<td>6.6 Input to Output Resistance</td>
<td>19</td>
</tr>
<tr>
<td>6.7 Input to Output Resistance Unbalance</td>
<td>20</td>
</tr>
<tr>
<td>6.8 Current Carrying Capacity</td>
<td>20</td>
</tr>
<tr>
<td>6.9 Propagation Delay</td>
<td>20</td>
</tr>
<tr>
<td>6.10 Delay Skew</td>
<td>21</td>
</tr>
<tr>
<td>6.11 Electromagnetic Performance</td>
<td>21</td>
</tr>
<tr>
<td>6.12 Near End Balance Measured as Transverse Conversion Loss (TCL)</td>
<td>22</td>
</tr>
<tr>
<td>6.13 Far End Balance Measured as Transverse Conversion Transfer Loss (TCTL)</td>
<td>23</td>
</tr>
<tr>
<td>6.14 Transfer Impedance</td>
<td>23</td>
</tr>
<tr>
<td>6.15 Insulation Resistance</td>
<td>24</td>
</tr>
<tr>
<td>6.16 Voltage Proof</td>
<td>24</td>
</tr>
<tr>
<td>7. CONCLUSION</td>
<td>25</td>
</tr>
<tr>
<td>8. APPENDIX: Data Sheets of Transmission Performance versus Frequency</td>
<td>26</td>
</tr>
</tbody>
</table>
1. IDENTIFICATION

Project No.: 1102563A


Connecting Hardware: Screened, Category 6, RJ 45, Keystone Jack

Manufacturer: Telebox Industries Corp.
4F, No. 306, Tatung Road, Sec. 1
Hsichih-Taipei 221
Taiwan, R.O.C.

Telebox Identification: P/N TA8661Sx

PCB Marking: R001-8671 1F00 2

Prepared by: 3P Third Party Testing
Agerm Allé 3
DK-2970 Hoersholm
Denmark

Email: 3Ptest@3Ptest.dk
Phone: + 45 45572200
Fax: + 45 45765708
Homepage: www.3Ptest.dk

Author: Poul Villien
2. **SURVEY OF THE WORK**

3P has performed de-embedded type of qualification testing on samples of screened Category 6 keystone jack from Telebox Industries Corp., P/N TA8661Sx. Samples of the keystone jack have been supplied for the testing at 3P by Telebox Industries Corp. in September 2010. Transfer impedance after ageing has been verified on an earlier sent keystone jack sample having identical type of housing and screen termination.

Testing was carried out in September 2010.

Testing has included a verification of performance according to all relevant international standards. This means that the following specifications stating electrical transmission requirements are covered by the present testing:

- ISO/IEC 2nd Edition 11801, Cat. 6
- CENELEC EN 50173-1:2007, Cat. 6
- ANSI/TIA/EIA-568-B.2-1, Cat. 6
- 1st Edition IEC 60603-7-5, Cat. 6
- IEC 60512-26-100

The transmission performance of the screened Category 6 keystone jack from Telebox Industries Corp., P/N TA8661Sx, having PCB marking R001-8671 1F00 2, does in every respect comply with all specified requirements.

The positive conclusion of the testing covers all products from the qualified production line of Telebox Industries Corp. having identical PCB circuitry and construction of screen. Presently this only includes Telebox Industries Corp. keystone jack,

- P/N TA8661Sx.

The company

Telebox Industries Corp.
4F, No. 306, Tatung Road, Sec. 1
Hsichih-Taipei 221
Taiwan, R.O.C.

is qualified at the Hsichih site to produce the keystone jack with a 3P rating as Screened Category 6 ISO/IEC, EN & TIA/EIA Connecting Hardware.

The qualification will be valid until failure to pass one of the maintenance of qualification test programmes, which will be performed at 12 months intervals.
It should be noted that the present testing does not include the reliability test programmes specified in ISO/IEC, CENELEC, ANSI/TIA/EIA and IEC standards. Only the transmission performance is covered by the 3P testing. It is assumed that the reliability of the applied RJ 45 jacks is adequate to secure safe interconnection to the patch cords throughout a lifetime of normal application of the connecting hardware.
3. APPLIED SPECIFICATIONS

The transmission performance requirements of the following specifications have been covered by the connecting hardware testing:

- ISO/IEC 2nd Edition Generic Cabling Standard 11801, Cat. 6
- CENELEC Generic Cabling Standard EN 50173-1:2007, Cat. 6
- ANSI/TIA/EIA Generic Cabling Standard 568-B.2-1, Cat. 6
- 1st Edition IEC 60603-7-5, Cat. 6
- IEC 60512-26-100
4. CONDITIONS OF TESTING

4.1 Connecting Hardware Types covered by the Qualification Testing

The qualification testing has been carried out on supplied samples of screened Category 6 keystone jack from Telebox Industries Corp., P/N TA8661Sx.

The positive conclusion of the testing covers all products from the qualified production line of Telebox Industries Corp. having identical PCB circuitry and construction of screen. Presently this only includes Telebox Industries Corp. keystone jack,

- P/N TA8661Sx.

The marking of the PC board was R001-8671 1F00 2.

4.2 Electrical Measurements

The following electrical transmission parameters have been measured for all pairs or combination of pairs for the tested connecting hardware samples:

- Return loss from 1 MHz - 250 MHz, measured from both sides of the connecting hardware
- Attenuation from 1 MHz - 250 MHz
- Pair-pair near end crosstalk from 1 MHz - 250 MHz, measured from both sides of the connecting hardware
- Pair-pair far end crosstalk from 1 MHz - 250 MHz, measured for all 2×6 combinations of pairs
- DC resistance
- DC resistance unbalance
- Current carrying capacity
- Propagation delay from 1 MHz - 250 MHz
- Delay skew from 1 MHz - 250 MHz
- Coupling attenuation and EMC performance from 30 MHz - 1 GHz, recorded as both near and far end measurements
- Near end balance from 1 MHz - 250 MHz, measured as TCL from both sides of the connecting hardware
- Far end balance from 1 MHz - 250 MHz, measured as TCTL from both sides of the connecting hardware
- Transfer impedance from 1 MHz - 100 MHz
- Insulation resistance
- Voltage proof
The following instruments were applied for the electrical measurements:

- HP Network Analyzer, type 8753ES with Internal S-Parameter Test Set
- HP Network Analyzer, type 8753D with Internal S-Parameter Test Set
- BH Electronics Baluns, type 040-0093
- 3P Baluns, type 3P-250-Cat6-C
- 3P Balun, type 3P-600-Cat7
- Rohde & Schwarz Absorbing Clamp, type MDS-21
- HP Milliohmometer, type 4338A
- HP LCR Meter, type 4263B
- HP High Resistance Meter, type 4339A
- Danbridge Insulation Tester, type JP12A
- 3P Transfer Impedance test equipment
5. FACTORY INSPECTION

The quality assurance and production facilities of the Hsichih site of Telebox Industries Corp. have been approved by 3P during the inspection visit 17th August 2010. It is concluded by 3P that generally quality assurance, working procedures, capabilities, production facilities and extent of end product testing should be acceptable to secure a continuous production of a high quality Screened Category 6 ISO/IEC, EN & TIA/EIA Connecting Hardware.

However, one minor observation has been found:

- The printed circuit board of the tested Cat. 6 keystone jack did not have an identification of production week and producer as specified in the internal quality procedures of Telebox Industries Corp.

This minor observation, which will be corrected during the production, do not affect the suitability of the production of connecting hardware.

The results of the factory inspection is described in the following 4 sections.

5.1 Company Organisation

The overall company organisation plan of Telebox Industries Corp. is presented in page 9.

The following key management positions apply at Telebox Industries Corp.:

- Managing Director: Ray Chang
- Quality Deputy Manager: Alex Chang
- Production Control Manager: Richard Shih
- Deputy Production Manager: Daniel Lee
- Production Control Deputy Manager: John Huang
- Research & Development Manager: David Wu
- Electronic Manager: David Wu
- Sales Manager: Richard Shih

It is concluded that quality assurance and production is in the same level in organisation.

5.2 Quality Assurance

Quality manager of Telebox Industries Corp. is Alex Chang.

All major quality issues are discussed in the quality committee, which consists of the department managers. The quality committee meets on a monthly basis under leadership of the quality manager. The quality committee is the forum in which general discussions and final conclusion of quality issues are taken.

Telebox Industries Corp. has quality assurance approved according to ISO 9001:2008. Approval was granted by "TÜV CERT Certification Body of TÜV Rheinland Group", Certificate No. 01 100 822 043836 dated 15th January 2010. Next update of approval is scheduled before 4th January 2012.
Company Organisation Plan for Telebox Industries Corp.

Managing Director
Ray Chang

- Quality Committee
  - Alex Chang

- Chief Accountant
  - Sandy Hong

- Sales Manager
  - Richard Shih

- Administration Manager
  - Mufasa Liu

  - Deputy Production Manager
    - Danny Lee

  - Deputy Purchasing Manager
    - Carol Huang

  - Production Control Deputy Manager
    - John Huang

  - Electronic Manager
    - David Wu

- Quality Deputy Manager
  - Alex Chang

- R&D Manager
  - David Wu

  - Construction Design Senior Deputy Manager
    - Peter Tu

  - Construction Design Deputy Manager
    - Susan Huang

- Industrial Engineer
  - Kang Chen
Furthermore, the environmental management system is approved according to ISO 14001:2004. Approval was granted by TÜV CERT Certification Body of TÜV Rheinland Group", Certificate No. 01 104 822 043836 dated 8th April 2008. Next update of approval is scheduled before 7th April 2011.

The quality manual has been inspected by 3P at the visit without giving cause to remarks.

Traceability of connecting hardware performance applies at Telebox Industries Corp. by part number and the production week printed on the printed wiring board. Purchase order number is used for traceability if available from the customer, but not printed on the delivery.

The printed circuit board of the tested screened Cat 6 keystone jack did not have an identification of production week and producer as specified in the internal quality procedures of Telebox Industries Corp.

The quality assurance system at Telebox Industries Corp. is recognized by the following companies and organisations:

- TÜV Rheinland
- 3P

A quality record of subsuppliers is kept and maintained by Telebox Industries Corp. All supplied printed wiring boards are identified by part number, and with producer code and production week. The latest design version is identified by a completely new sample number. Plated contact wires and IDC contacts are delivered with certificates for plating and materials, and are containing test data for gold and nickel thicknesses and base metal composition. The first delivery is identified by a full quality report. Later deliveries includes thickness data only. All supplied contact components are stored using humidity and temperature controlled conditions.

Batch size of printed circuit boards is typically between 1000 and 5000 pieces.

A new type of connector is approved by complete electrical measurements of two samples. The first sample is a first production sample and the second sample is randomly selected from the first production batch.

All measuring and test equipment were properly identified with a tag showing instrument number and calibration expiration date. Calibration data were properly filed. Calibration is carried out by external source (company IPE). Calibration of network analysers is done every 24 months.

11 persons (19 % of total staff) and equipment operators are working with quality assurance and quality control at Telebox Industries Corp.

 Incoming control

External sub-suppliers are only used for plated contact wires and non-critical connector parts.

Telebox Industries Corp. has two different printed wiring board suppliers. The main printed circuit board supplier is having the generally best performance history.
Incoming inspection and approval of printed wiring boards includes dimensional measurements and testing of hole diameters. Furthermore two samples are mounted with components, soldered and measured for near end crosstalk performance. The printed wiring board delivery is approved after passing of visual, dimensional and electrical requirements.

Internally produced, pressure moulded and stamped components, are also included in the incoming inspection system. Some pressure moulded parts are delivered from external suppliers.

Adhesion of contact platings is verified for each batch by bending of contacts and inspection for flaking of platings.

Traceability of incoming components is possible by the order number.

A first-in /first-out principle applies at Telebox Industries Corp.

5.3 Production Facilities

All production of connecting hardware is carried out at the Hsichih factory of Telebox Industries Corp.

Pressure moulding of plastic parts and stamping of metallic parts are applied at Telebox Industries Corp. Dimensional measurements and visual control are carried by the operator on samples from the running production.

Telebox Industries Corp. has manual assembly line for both keystone jacks and keystone jacks. A sequence of mounting, soldering and visual inspection of each individual type of contact and connector part is applied. Operator training, and detailed, illustrated instruction guides are applied for each production process. dc resistance testing of each port of all finished connectors is applied.

Keystone jacks are only produced using hand mounting and hand soldering. Keystone jacks are produced using hand mounting of components, wave soldering of contacts at 275°C and hand soldering of screen contacts.

A lead free soldering process is applied.

Telebox Industries Corp. is planning to implement pressure fit mounting of components instead of soldering.

A 100 % control for visual appearance, for shorts and interrupted connections, and for near end crosstalk in forward direction is carried out after the assembly operation.

5.4 Final Testing

Evaluation of internal testing data demonstrated generally fine performance. However, two minor observations have been made:

- The same NEXT limit is applied for all pair combinations and test plug levels. This is correctly done in all cases except for pair combination 3/6-4/5 low and high limit plug levels. These two plug levels have a 1,5 dB more relaxed requirement. Consequently Telebox measures these plug levels using a too strict requirement.
• The applied NEXT limit is having a 5 dB too strict plateau value. An 80 dB plateau is used while 75 dB is specified.

Any failing components are offered to the customer with documented performance data.

Results of testing are stored in paper form together with the tested sample.

Comparative measurements at Telebox Industries Corp. and 3P have been carried out for return loss, attenuation and near end crosstalk of a specific Cat. 6 patch panel. Different ports of the panel have been measured by Telebox Industries Corp. and 3P, but the circuit design of all ports is the same. The measurements generally showed fine correlation between 3P and Telebox Industries Corp. for parameters close to the limit. However, some differences in results were observed as detailed below.

A. Return loss and attenuation traces at Telebox Industries Corp. have some reflections which are not found in the 3P traces. The reflections are likely caused by the connection leads which are kept very short in the 3P measurements.

B. Two of the pair combinations in the Telebox Industries Corp. NEXT measurements have better margin to the limit than measured at 3P and also compared with the Telebox Industries Corp. measurement for the same pair combination from the opposite side of the patch panel. The reason for the too positive measurements can not be concluded by 3P, but generally it is a good guide for evaluation of the correctness of NEXT measurements that the near and far end margins and traces should normally be similar (there are exceptions to this general guide).

The below data for final testing at Telebox Industries Corp. applies, i.e. 4 % of a lot is tested for NEXT of selected pair combinations. The lot is approved if less than 30 % of the samples or 2 % of the lot are failing the requirements. 6 more out of 100 samples are tested if failing conditions are found. The lot will be rejected if less than 70 % of the samples pass requirements.

• Near End Crosstalk measurements, high and low plug testing: 4 %, measured from both sides for:
  All positions of patch panels: Pair combination 3/6-4/5
  Keystone jacks: Pair combinations 1/2-3/5 and 3/6-4/5

• Near End Crosstalk for all pair combinations, Insertion Loss, Return Loss, Far End Crosstalk, TCL and TCTL measurements:
  Type testing

• Coupling Attenuation and Transfer Impedance Measurements:
  Testing carried out by 3P in connection with the qualification and maintenance of qualification programmes

• High Voltage testing and Insulation Resistance Measurements:
  Type testing
• dc resistance: 100 %
• short circuits: 100 %

End product measurement of high frequency performance is done in the production area as the last step of the assembly line.
The following instruments were applied at Telebox Industries Corp. for performing the ongoing quality assurance testing:

High Frequency Testing:

- HP Network Analyzer, type 8753E (2 units)
- Agilent ENA Network Analyzer, type E5062A (2 units)
- BH Electronics Baluns, types 040-0092 and 040-0093
- North Hills Baluns, type 0322 BFX
- 3P Baluns, type 3P-250-Cat6-C
- Transfer impedance test equipment, type 3P construction

dc Resistance and Short Circuit Testing:

- Microtest dc test equipment, type CT-8768
- Microtest dc test equipment, type CT-8687
- Wayne Kerr LCR Meter, type 4273
- Chen Hwa Milliohmmeter, type 502AC
- Instek AC/DC Withstand Voltage / Insulation Tester, type GPI-735

Visual Control:

- CNC video measuring system, type KAM-3020

Mechanical Testing:

- Push-pull gauge, type AK5
- Mating cycle tester, type ux-51

Material Analysis:

- X-ray metal analyser, type OXFORD X-MET 3000TXR
6. SUMMARIZED TEST RESULTS

The electrical transmission performance testing has been carried out on samples of screened Category 6 keystone jack from Telebox Industries Corp., P/N TA8661Sx. Measurements have been made to 250 MHz.

Summarized test results are presented in the following clauses, while recordings of electrical performance versus frequency are found in the appendix. The tables in the present section generally inform about the headroom to a specified worst case limiting function which is specified under the table concerned. The various recordings of electrical performance versus frequency in the appendix contains, in red colour, this limiting function specified for the parameter in question.

The transmission measurements have been carried out using the test configurations specified in the ISO/IEC, CENELEC, ANSI/TIA/EIA-568-B.2-1 and IEC 60512-26-100 standards. This means that the following three conditions are covered by the testing:

1. All noise parameters are measured from both the plug and connecting block sides (for far end crosstalk with signal injection and receiving on each pair of a specific pair combination). For reasons of simplification only the worst case recordings of these two measurements are presented in the appendix. The summarized results of all bi-directional measurements are presented in the tables of the relevant sub-clause.

2. All electrical high frequency parameters have been measured using "common and differential mode" (Y-term.) termination.

3. The measurements of near end crosstalk has been carried out using all of the specified low, central and high limit de-embedded NEXT plugs. The worst case recordings in question are presented in the appendix. The summarized results of all low, central and high limit plug measurements are presented in the tables of clause 6.4.

The low limit plug is in the present report understood to be the plug having the lowest numerical de-embedded NEXT value, i.e. the "worst" NEXT performance, while the high limit plug is understood to be the plug having the highest numerical de-embedded NEXT value, i.e. the "best" NEXT performance. Both phase angle and absolute value of the applied plugs are in compliance with the requirements of both ANSI/TIA/EIA-568-B.2-1 and IEC 60512-26-100 standards. However, only the measured low, central and high absolute de-embedded NEXT values at 100 MHz are presented in table 6.1.

6.1 De-Embedded NEXT Values of Applied RJ 45 Plugs

Summarized results of testing of the applied low, central and high limit plugs are found in table 6.1, and include all six pair combinations measured for absolute value at 100 MHz, as this is the spot frequency for which de-embedded NEXT performance is traditionally reported. Both absolute value and phase angle have been measured from 1 MHz to 250 MHz and comply with the specified limits in the full frequency range for all six pair combinations for all applied plugs. However, for simplification these test data are neither presented in table 6.1 nor as recordings in the appendix.
Table 6.1 Summarized Results of De-Embedded NEXT Measurements of Absolute Value for Applied RJ 45 Plugs at 100 MHz

<table>
<thead>
<tr>
<th>COMBINATION OF PAIRS</th>
<th>DE-EMBEDDED NEXT AT 100 MHz (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absolute value for low limit plugs</td>
</tr>
<tr>
<td>1/2 - 3/6</td>
<td>46,5</td>
</tr>
<tr>
<td>1/2 - 4/5</td>
<td>57,0</td>
</tr>
<tr>
<td>1/2 - 7/8</td>
<td>60,0</td>
</tr>
<tr>
<td>3/6 - 4/5</td>
<td>36,4</td>
</tr>
<tr>
<td>3/6 - 4/5</td>
<td>-</td>
</tr>
<tr>
<td>3/6 - 7/8</td>
<td>46,5</td>
</tr>
<tr>
<td>4/5 - 7/8</td>
<td>57,0</td>
</tr>
</tbody>
</table>

It is concluded from table 6.1 and testing performed at 3P that the performance of the applied test plugs complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz.

6.2 Return Loss

Summarized results of the testing are found in table 6.2, and include all four tested pairs measured from both sides of the connecting hardware. Worst case recordings of return loss versus frequency covering both sides of the connecting hardware are found in page 27 of the appendix.

Table 6.2 Summarized Results of Return Loss Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>PAIR</th>
<th>RETURN LOSS MARGIN TO LIMIT (dB)¹²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>7,4 ( 6,4)</td>
</tr>
<tr>
<td>3/6</td>
<td>10,3 (10,0)</td>
</tr>
<tr>
<td>4/5</td>
<td>7,8 ( 6,7)</td>
</tr>
<tr>
<td>7/8</td>
<td>6,5 ( 5,7)</td>
</tr>
</tbody>
</table>

¹: Return Loss requirements are defined by the function:

\[ 64 - 20 \log(f) \text{ dB} \]

where \( f \) is frequency in MHz. Calculated requirements below 30 dB are equaled to this value.

²: The first value is measurement from the RJ 45 plug side, while the corresponding measurement from the connecting block side is presented in brackets.

It is concluded from table 6.2 and return loss recordings in page 27 that return loss complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz for both sides of the connecting hardware.
6.3 Attenuation

Summarized results of the testing are found in table 6.3, and include all four tested pairs measured from one side of the connecting hardware. Recordings of attenuation versus frequency are found in page 28 of the appendix.

Table 6.3 Summarized Results of Attenuation Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>PAIR</th>
<th>MAX. ATTENUATION (dB)¹</th>
<th>ATTENUATION MARGIN TO LIMIT (%)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 MHz</td>
<td>10 MHz</td>
</tr>
<tr>
<td>1/2</td>
<td>0,00</td>
<td>0,01</td>
</tr>
<tr>
<td>3/6</td>
<td>0,00</td>
<td>0,00</td>
</tr>
<tr>
<td>4/5</td>
<td>0,00</td>
<td>0,00</td>
</tr>
<tr>
<td>7/8</td>
<td>0,00</td>
<td>0,01</td>
</tr>
<tr>
<td>Specified</td>
<td>0,10</td>
<td>0,10</td>
</tr>
</tbody>
</table>

¹: Attenuation requirements are defined by the function:

\[ 0,02 \sqrt{f} \text{ dB} \]

where \( f \) is frequency in MHz. Calculated requirements below 0,1 dB are equaled to this value.

It is concluded from table 6.3 and attenuation recordings in page 28 that attenuation complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz.

6.4 Near End Crosstalk

Summarized results of the testing are found in table 6.4, and include all six combinations of the four tested pairs measured from both sides of the connecting hardware. Worst case recordings of pair-pair near end crosstalk versus frequency for both low, central and high limit plug measurements, each covering both sides of the connecting hardware, are found in pages 29 - 35 of the appendix.
Table 6.4 Summarized Results of Pair - Pair Near End Crosstalk Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>COMBINATION OF PAIRS</th>
<th>PAIR - PAIR NEXT MARGIN TO LIMIT (dB)¹²</th>
<th>Low limit plug</th>
<th>Central limit plug</th>
<th>High limit plug</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 - 3/6</td>
<td>6.4 (4,5)</td>
<td>- ( - )</td>
<td>6.4 (5,6)</td>
<td></td>
</tr>
<tr>
<td>1/2 - 4/5</td>
<td>0.3 (0.1)</td>
<td>- ( - )</td>
<td>6.7 (4,9)</td>
<td></td>
</tr>
<tr>
<td>1/2 - 7/8</td>
<td>5.5 (6,3)</td>
<td>- ( - )</td>
<td>- ( - )</td>
<td></td>
</tr>
<tr>
<td>3/6 - 4/5</td>
<td>2.0 (4,3)</td>
<td>2.6 (9,6)</td>
<td>4.5 (7,4)</td>
<td></td>
</tr>
<tr>
<td>3/6 - 7/8</td>
<td>14.9 (6,9)</td>
<td>- ( - )</td>
<td>1.2 (0,1)</td>
<td></td>
</tr>
<tr>
<td>4/5 - 7/8</td>
<td>1.8 (1,5)</td>
<td>- ( - )</td>
<td>5.5 (0,8)</td>
<td></td>
</tr>
</tbody>
</table>

¹: Pair-Pair Near End Crosstalk requirements are defined by the functions:

For all pair combinations except 3/6 - 4/5, low and high limit plugs: 94,0-20log(f) dB
For pair combination 3/6 - 4/5, low and high limit plugs: 92,5-20log(f) dB,

where f is frequency in MHz. Calculated requirements more strict than 75 dB are equaled to this value.

²: The first value is measurement from the RJ 45 plug side, while the corresponding measurement from the connecting block side is presented in brackets. For pair combinations 1/2-3/6, 1/2-4/5, 1/2-7/8, 3/6-7/8 and 4/5-7/8 the central limit plug measurements are not specified. For pair combination 1/2-7/8 the high limit plug measurement is not specified.

It is concluded from table 6.4 and pair - pair near end crosstalk recordings in pages 29 - 35 that pair - pair near end crosstalk complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz for all six combinations of plug performance limit and sides of connecting hardware.

The documentation of power sum near end crosstalk has not been included in the present testing as only informative limits are proposed in ISO/IEC 11801, and ANSI/TIA/EIA-568-B.2-1 does not specify this parameter.

### 6.5 Far End Crosstalk

Summarized results of the testing are found in tables 6.5 for pair-pair far end crosstalk and include all 2×6 combinations of the four tested pairs. Worst case recordings of pair-pair far end crosstalk versus frequency covering all 2×6 combinations of the four tested pairs are found in page 36 of the appendix.
Table 6.5 Summarized Results of Pair - Pair Far End Crosstalk Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>COMBINATION OF PAIRS</th>
<th>PAIR - PAIR FEXT MARGIN TO LIMIT (dB)(^1,2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 - 3/6</td>
<td>20.3 (29.0)</td>
</tr>
<tr>
<td>1/2 - 4/5</td>
<td>13.6 (13.9)</td>
</tr>
<tr>
<td>1/2 - 7/8</td>
<td>26.3 (35.1)</td>
</tr>
<tr>
<td>3/6 - 4/5</td>
<td>13.1 (18.6)</td>
</tr>
<tr>
<td>3/6 - 7/8</td>
<td>8.1 ( 7.8)</td>
</tr>
<tr>
<td>4/5 - 7/8</td>
<td>7.1 ( 6.9)</td>
</tr>
</tbody>
</table>

\(^1\): Pair-Pair Far End Crosstalk requirements are defined by the function:

\[ 83.1 - 20\log(f) \text{ dB}, \]

where \( f \) is frequency in MHz. Calculated requirements more strict than 75 dB are equaled to this value.

\(^2\): The first value is measurement with signal injection on the first of the listed pairs, while the corresponding measurement with signal injection on the second of the listed pairs is presented in brackets.

It is concluded from table 6.5 and pair - pair far end crosstalk recordings in page 36 that pair - pair far end crosstalk complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz for all 2×6 pair combinations.

The documentation of power sum far end crosstalk has not been included in the present testing as only informative limits are proposed in ISO/IEC 11801, and ANSI/TIA/EIA-568-B.2-1 does not specify this parameter.

6.6 Input to Output Resistance

Results of the testing are found in table 6.6, and include all 8 tested conductor paths measured from one side of the connecting hardware.
It is concluded from table 6.6 that input to output resistance complies with the specified Category 6 requirements.

6.7 Input to Output Resistance Unbalance

The worst case value of input to output resistance unbalance is 38 mΩ, which is in compliance with the specified max. 50 mΩ.

It is concluded that input to output resistance unbalance complies with the specified Category 6 requirements.

6.8 Current Carrying Capacity

Current carrying capacity has been measured by subjecting each conductor and the screen to a simultaneous exposure of 0.75 A at 60°C for 30 minutes.

The increase in temperature was 6°C, which is in compliance with the specified max. 30°C. Continuity of conductor and screen paths was maintained. No degradation of connecting hardware was observed after the testing.

It is concluded that current carrying capacity complies with the specified Category 6 requirements.

6.9 Propagation Delay

Summarized results of the testing are found in table 6.9, and include all four tested pairs measured from one side of the connecting hardware.
Table 6.9 Summarized Results of Propagation Delay Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>PAIR</th>
<th>PROPAGATION DELAY (nsec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>Max. 0,6</td>
</tr>
<tr>
<td>3/6</td>
<td>Max. 0,6</td>
</tr>
<tr>
<td>4/5</td>
<td>Max. 0,6</td>
</tr>
<tr>
<td>7/8</td>
<td>Max. 0,6</td>
</tr>
<tr>
<td>Specified</td>
<td>Max. 2,5</td>
</tr>
</tbody>
</table>

It is concluded from table 6.9 that propagation delay complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz.

6.10 Delay Skew

Summarized results of the testing are found in table 6.10, and include all six combinations of the four tested pairs measured from one side of the connecting hardware.

Table 6.10 Summarized Results of Delay Skew Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>COMBINATION OF PAIRS</th>
<th>DELAY SKEW (nsec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 - 3/6</td>
<td>Max. 0,015</td>
</tr>
<tr>
<td>1/2 - 4/5</td>
<td>Max. 0,028</td>
</tr>
<tr>
<td>1/2 - 7/8</td>
<td>Max. 0,029</td>
</tr>
<tr>
<td>3/6 - 4/5</td>
<td>Max. 0,013</td>
</tr>
<tr>
<td>3/6 - 7/8</td>
<td>Max. 0,014</td>
</tr>
<tr>
<td>4/5 - 7/8</td>
<td>Max. 0,001</td>
</tr>
<tr>
<td>Specified</td>
<td>Max. 1,25</td>
</tr>
</tbody>
</table>

It is concluded from table 6.10 that delay skew complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz.

6.11 Electromagnetic Performance

Summarized results of coupling attenuation measurements are found in table 6.11, and include all four tested pairs recorded as both near and far end measurements. The connecting hardware is connected with overall foil and braid screened horizontal cable and RJ 45 plug terminated individual foil and overall braid screened flexible cable. Worst case recording of electromagnetic performance is found in page 37 of the appendix.
Table 6.11 Summarized Results of Coupling Attenuation Measurements

<table>
<thead>
<tr>
<th>PAIR</th>
<th>COUPLING ATTENUATION MARGIN TO LIMIT (dB)$^{1,2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>28 (21)</td>
</tr>
<tr>
<td>3/6</td>
<td>30 (25)</td>
</tr>
<tr>
<td>4/5</td>
<td>37 (32)</td>
</tr>
<tr>
<td>7/8</td>
<td>27 (25)</td>
</tr>
</tbody>
</table>

1: Coupling attenuation requirements are defined by the functions:

45 dB between 30 MHz and 100 MHz

$45 - 20\log\left(\frac{f}{100}\right)\ dB$ between 100 MHz and 1 GHz,

where $f$ is frequency in MHz.

2: The first value is near end measurement (from the RJ 45 plug side), while the corresponding far end measurement (from the connecting block side) is presented in brackets.

It is concluded from table 6.11 and coupling attenuation recordings in page 37 that coupling attenuation complies with the specified Category 6 requirements when recorded as both near and far end measurement.

6.12 Near End Balance Measured as Transverse Conversion Loss (TCL)

Summarized results of the testing are found in table 6.12 for near end balance measured as TCL, and include all four tested pairs measured from both sides of the connecting hardware. Worst case recordings of TCL versus frequency from both sides of the connecting hardware are found in page 38 of the appendix.

Table 6.12 Summarized Results of Near End Balance (TCL) Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>PAIR</th>
<th>BALANCE (TCL) MARGIN TO LIMIT (dB)$^{1,2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>15,2 (11,8)</td>
</tr>
<tr>
<td>3/6</td>
<td>15,5 (13,1)</td>
</tr>
<tr>
<td>4/5</td>
<td>23,4 (15,7)</td>
</tr>
<tr>
<td>7/8</td>
<td>14,4 (17,9)</td>
</tr>
</tbody>
</table>

1: Requirements to Near End Balance, measured as TCL, are defined by the function:

$68 - 20\log(f)\ dB$,

where $f$ is frequency in MHz. Calculated requirements more strict than 50 dB are equaled to this value.

2: The first value is measurement from the RJ 45 plug side, while the corresponding measurement from the connecting block side is presented in brackets.
It is concluded from table 6.12 and the TCL recordings in page 38 that the transverse conversion loss (near end balance) complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz for both sides of connecting hardware.

6.13 Far End Balance Measured as Transverse Conversion Transfer Loss (TCTL)

Summarized results of the testing are found in table 6.13 for far end balance measured as TCTL, and include all four tested pairs measured from both sides of the connecting hardware. Worst case recordings of TCTL versus frequency from both sides of the connecting hardware are found in page 39 of the appendix.

Table 6.13 Summarized Results of Far End Balance (TCTL) Measurements from 1 MHz to 250 MHz

<table>
<thead>
<tr>
<th>PAIR</th>
<th>BALANCE (TCTL) MARGIN TO LIMIT (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>20.6 (15.3)</td>
</tr>
<tr>
<td>3/6</td>
<td>17.7 (12.9)</td>
</tr>
<tr>
<td>4/5</td>
<td>14.3 (14.4)</td>
</tr>
<tr>
<td>7/8</td>
<td>22.7 (23.0)</td>
</tr>
</tbody>
</table>

1: Requirements to Far End Balance, measured as TCTL, are defined by the function:

\[ 68 - 20 \log(f) \text{ dB} \]

where \( f \) is frequency in MHz. Calculated requirements more strict than 50 dB are equaled to this value.

2: The first value is measurement from the RJ 45 plug side, while the corresponding measurement from the connecting block side is presented in brackets.

It is concluded from table 6.13 and the TCTL recordings in page 39 that the transverse conversion transfer loss (far end balance) complies with the specified Category 6 requirements in the complete frequency range from 1 MHz to 250 MHz for both sides of connecting hardware.

6.14 Transfer Impedance

Summarized results of the testing are found in table 6.14, and include measurements of the connecting hardware before and after ageing at 70 °C for 21 days. Transfer impedance is measured on a sample with connector screen mounted with an overall foil screened horizontal cable. Recordings of transfer impedance, both initially and after ageing, are found in page 40 of the appendix.
Table 6.14 Summarized Results of Transfer Impedance Measurements

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>TRANSFER IMPEDANCE MARGIN TO LIMIT (%)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before ageing</td>
<td>17</td>
</tr>
<tr>
<td>After ageing</td>
<td>6</td>
</tr>
</tbody>
</table>

¹: Transfer Impedance requirements are defined by the functions:

\[
\begin{align*}
40\sqrt{f} \text{ m}\Omega & \text{ between } 1 \text{ MHz and } 4 \text{ MHz} \\
20f \text{ m}\Omega & \text{ between } 4 \text{ MHz and } 100 \text{ MHz},
\end{align*}
\]

where \( f \) is frequency in MHz.

It is concluded from table 6.14 and transfer impedance recordings in page 40 that transfer impedance complies with the specified Category 6 requirements both before and after ageing at 70°C for 21 days. The transfer impedance requirements have been successfully passed using the most critical type of cable termination.

6.15 Insulation Resistance

The worst case insulation resistance between any combination of conductors is 550,000 MΩ, which is in compliance with the specified min. 100 MΩ. The applied test voltage was 500 Vdc.

It is concluded that insulation resistance complies with the specified Category 6 requirements.

6.16 Voltage Proof

No flash-over, breakdown or other deterioration was found by application of 1000 Vdc between any combination of conductors and by application of 1500 Vdc between screen and conductors.

It is concluded that the voltage proof performance complies with the specified Category 6 requirements.
7. CONCLUSION

Samples of the screened Category 6 keystone jack from Telebox Industries Corp. have been subjected to de-embedded type of qualification testing according to 3P requirements for Screened Category 6 ISO/IEC, EN & TIA/EIA Connecting Hardware.

The transmission performance of the screened Category 6 keystone jack from Telebox Industries Corp., P/N TA8661Sx, having PCB marking R001-8671 1F00 2, does in every respect comply with the requirements of the following international standards:

- ISO/IEC 2nd Edition 11801, Cat. 6
- CENELEC EN 50173-1:2007, Cat. 6
- ANSI/TIA/EIA-568-B.2-1, Cat. 6
- 1st Edition IEC 60603-7-5, Cat. 6
- IEC 60512-26-100

The positive conclusion of the testing covers all products from the qualified production line of Telebox Industries Corp. having identical PCB circuitry and construction of screen. Presently this only includes Telebox Industries Corp. keystone jack,

- P/N TA8661Sx.

The company

Telebox Industries Corp.
4F, No. 306, Tatung Road, Sec. 1
Hsichih-Taipei 221
Taiwan, R.O.C.

is qualified at the Hsichih site to produce the keystone jack with a 3P rating as Screened Category 6 ISO/IEC, EN & TIA/EIA Connecting Hardware.

The qualification will be valid until failure to pass one of the maintenance of qualification test programmes, which will be performed at 12 months intervals.

It should be noted that the present testing does not include the reliability test programmes specified in ISO/IEC, CENELEC, ANSI/TIA/EIA and IEC standards. Only the transmission performance is covered by the 3P testing. It is assumed that the reliability of the applied RJ 45 jacks is adequate to secure safe interconnection to the patch cords throughout a lifetime of normal application of the connecting hardware.
8. **APPENDIX: Data Sheets of Transmission Performance versus Frequency**

All characteristic and most critical recordings of transmission performance are presented in the following way:

Page 27  
Worst case recordings of return loss for all four pairs between 1 MHz and 250 MHz.

Page 28  
Recordings of attenuation for all four pairs between 1 MHz and 250 MHz.

Pages 29 - 35  
Worst case recordings of pair-pair near end crosstalk for all six combinations of pairs between 1 MHz and 250 MHz. Each page includes recordings of one specific pair combination measured using low and, if applicable, high limit plugs. For pair combination 3/6 - 4/5 the worst case central limit plug recording is presented in a separate page due to the different mated pair performance limits specified for low/high and central limit plugs.

Page 36  
Worst case recordings of pair-pair far end crosstalk for all 2×6 combinations of pairs between 1 MHz and 250 MHz.

Page 37  
Worst case recording of electromagnetic performance between 30 MHz and 1 GHz.

Page 38  
Worst case recordings of near end balance measured as TCL for all four pairs between 1 MHz and 250 MHz.

Page 39  
Worst case recordings of far end balance measured as TCTL for all four pairs between 1 MHz and 250 MHz.

Page 40  
Recording of transfer impedance between 1 MHz and 100 MHz before and after ageing.
Pair 1/2: Worst case is measurement from connecting block side.
Pair 3/6: Worst case is measurement from connecting block side.
Pair 4/5: Worst case is measurement from connecting block side.
Pair 7/8: Worst case is measurement from connecting block side.

Limiting function: Category 6 limit:
The worst case of Return Loss for all four pairs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Recordings of Attenuation for all four pairs from 1 MHz to 250 MHz.

Date: 2010.09.17

Pair 1/2:  
Pair 3/6:  
Pair 4/5:  
Pair 7/8:  

Limiting function:  
Category 6 limit:  

The Attenuation for all four pairs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recordings of Near End Crosstalk for pair combination 1/2 - 3/6 measured with low and high limit plugs from 1 MHz to 250 MHz.

Date: 2010.09.15

Low limit plug [46.5 dB]: Worst case is measurement from connecting block side.
High limit plug [49.5 dB]: Worst case is measurement from connecting block side.

Limiting function: Category 6 limit: The worst case of Near End Cross-talk for pair combination 1/2 – 3/6 measured with both low and high limit plugs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recordings of Near End Crosstalk for pair combination 1/2 - 4/5 measured with low and high limit plugs from 1 MHz to 250 MHz.

Date: 2010.09.15

Low limit plug [57.0 dB]: Worst case is measurement from connecting block side.

High limit plug [70.0 dB]: Worst case is measurement from connecting block side.

Limiting function: Category 6 limit: The worst case of Near End Cross-talk for pair combination 1/2 - 4/5 measured with both low and high limit plugs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Low limit plug [60.0 dB]:  Worst case is measurement from plug side.

Limiting function: 
Category 6 limit:

The worst case of Near End Cross-talk for pair combination 1/2 – 7/8 measured with low limit plug complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Low limit plug [36.4 dB]:  Worst case is measurement from plug side.
High limit plug [37.6 dB]:  Worst case is measurement from plug side.

The worst case of Near End Cross-talk for pair combination 3/6 – 4/5 measured with both low and high limit plugs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Central limit plug [37,0 dB]:
Worst case is measurement from plug side.

Limiting function:
Category 6 limit:

The worst case of Near End Crosstalk for pair combination 3/6 – 4/5 measured with central limit plug complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.
Low limit plug [46,5 dB]: Worst case is measurement from connecting block side.
High limit plug [49,5 dB]: Worst case is measurement from connecting block side.

Limiting function: Category 6 limit:

The worst case of Near End Crosstalk for pair combination 3/6 – 7/8 measured with both low and high limit plugs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recordings of Near End Crosstalk for pair combination 4/5 - 7/8 measured with low and high limit plugs from 1 MHz to 250 MHz.

Date: 2010.09.15

Low limit plug [57.0 dB]:  Worst case is measurement from connecting block side.
High limit plug [70.0 dB]:  Worst case is measurement from connecting block side.

Limiting function:  Category 6 limit:  The worst case of Near End Cross-talk for pair combination 4/5 – 7/8 measured with both low and high limit plugs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recordings of Far End Crosstalk for all six pair combinations from 1 MHz to 250 MHz.

Date: 2010.09.17

Pair combination 1/2 – 3/6: Worst case is signal injection on pair 1/2.
Pair combination 1/2 – 4/5: Worst case is signal injection on pair 1/2.
Pair combination 1/2 – 7/8: Worst case is signal injection on pair 1/2.

Limiting function:
Category 6 limit:

The worst case of Far End Crosstalk for all six pair combinations complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recording of EMC Performance from 30 MHz to 1 GHz. The measurement is based on recordings of Coupling Attenuation for all four pairs of the connecting hardware.

Measured on connecting hardware assembled with overall foil and braid screened horizontal cable and individual foil and overall braid screened flexible cable, and tested in aerial span. The cable alone was having EMC performance of min. 80 dB.

Date: 2010.09.21

EMC Performance: 66 dB
Derived EMC function:

Pair 1/2:
Pair 3/6:
Pair 4/5:
Pair 7/8:

Limiting function: Category 6 limit:

The EMC Performance is derived from the interception of a limiting function with the worst case Coupling Attenuation value at any frequency for any pair. The constant value from 30 MHz to 100 MHz is defined as the EMC performance.

3P Project No. 1102563A
Worst case recordings of Transverse Conversion Loss (TCL) for all four pairs from 1 MHz to 250 MHz.

Date: 2010.09.20

Pair 1/2:  Worst case is measurement from connecting block side.
Pair 3/6:  Worst case is measurement from connecting block side.
Pair 4/5:  Worst case is measurement from connecting block side.
Pair 7/8:  Worst case is measurement from plug side.

Limiting function:  Category 6 limit:  The worst case of Transverse Conversion Loss for all four pairs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Worst case recordings of Transverse Conversion Transfer Loss (TCTL) for all four pairs from 1 MHz to 250 MHz.

Date: 2010.09.20

Pair 1/2: Worst case is measurement from connecting block side.
Pair 3/6: Worst case is measurement from connecting block side.
Pair 4/5: Worst case is measurement from plug side.
Pair 7/8: Worst case is measurement from plug side.

Limiting function: Category 6 limit: The worst case of Transverse Conversion Transfer Loss for all four pairs complies with the specified Category 6 limit in the complete frequency range from 1 MHz to 250 MHz.

3P Project No. 1102563A
Recordings of Transfer Impedance from 1 MHz to 100 MHz.

Measured on the same modular jack sample before and after aging at 70°C for 21 days. The connector is tested terminated with overall foil screened horizontal cable, in 1,0 meter tri-axial method tube.

Date: 2010.09.02

Initial measurement: 
Measurement after ageing: 

Limiting function: 
Category 6 limit: 

The Transfer Impedance complies with the specified Category 6 limit both before and after ageing in the complete frequency range from 1 MHz to 100 MHz.

3P Project No. 1102563A