(plf's response, at 4). To support its argument that eSpeed's pop-up window feature does not avoid literal infringement, TT suggests that the addition of features does not avoid infringement if all the elements of the patent claims have been adopted, TT is correct in theory. *See Vulcan Engineering Co., Inc. v. Fata Aluminum. Inc.,* 278 F.3d 1366, 1375 (Fed.Cir.2002) ("When the claimed function is performed in the accused system, by the same or equivalent structure, infringement of that claim element is established"); *Texas Instruments, Inc. v. U.S. Int'l Trade Comm'n,* 805 F.2d 1558, 1568 (Fed.Cir.1986) ("As a matter of law, subsequent improvements do not in themselves preclude a finding of infringement") (internal citations omitted).

eSpeed argues that the pop-up window, not the price axis, is the location from which a trader sends his or her trade order, and therefore, its products do not meet all of TT's claim limitations. eSpeed explains:

> The eSpeed products display pop-up windows when a user depresses the mouse in the price ladder. In this pop-up window the trader can confirm the order is correct, change a parameter of ***869** the order, or cancel the order before it is sent to the exchange. This all occurs *after* the initial selection of a cell in the price column of the product.

(defs' reply, at 12) (emphasis in original). Because the order is actually sent from the pop-up window, not the price column, eSpeed asserts its products cannot meet the literal language of our construction of "order entry region"-that selection of a cell in the order entry region does more than initiate an order, it sends or executes the order, eSpeed argues that our construction "forecloses any pop-up window from coverage by the claims because selecting the cell in a price column merely initiates the pop-up window from which the trade can then either be sent, changed, or aborted." (*Id.,* at 13). In support of its argument, eSpeed points to TT's statement of facts. Therein, TT claimed:

> TT never amended the claims to distinguish its invention from all screens having pop-up windows. Instead, TT amended the claims to distinguish screens with order entry regions requiring multiple actions to both initiate and send a trade order, i.e., lacking single action order entry. *For example, a screen that requires one action to initiate an order (e.g., one click on a price) and then another separate action to send the order (e.g., one click on a send/verify button in a pop-up window) was being distinguished* as it does not constitute a single action.

(defs' reply, at 14) (citing plf's statement of facts, ¶ 3) (emphasis in defs' reply).

We think that eSpeed purposefully shifts TT's argument. There is no dispute that in eSpeed's products a trader can click on a price cell in the price column and send a trade order. From the trader's perspective it is possible to execute a trade from the price column. For example, if a trader clicks his mouse on a certain price (one click = depressing the mouse button and immediately releasing the mouse button), his order will be sent for the default quantity at the selected price. (*See* plf's response, exh. E, ¶ 26; *Id.,* exh. C). We have previously held that "order entry region" must be construed from the perspective of the trader, not the computer. *Claim Construction Order,* 2006 WL 3147697, at *8. We explained:

> Thus, from the perspective of the user, selection of an area in the order entry region is the final step in the trader's placement of an order at the market. In other words, the user need not do anything more before the order is entered at the market. If, however, the computer or the exchange had to perform additional steps before the order was actually filled at the exchange, such would still fall within the ambit of "order entry region...."

Id. We think it highly unlikely that a reasonable jury could determine that eSpeed's products do not contain an "order entry region" as defined by TT's patents and this court. Particularly, we believe

that a reasonable jury could determine only that it is the computer that takes the additional steps with regard to executing the trade, as explained by the final sentence cited above. Because infringement is a matter of fact, and we believe that no reasonable jury could side with defendants, we would likely determine that eSpeed's products contain an "order entry region," as defined by this court. Once that determination is made, the parties' doctrine of equivalents argument becomes moot.

CONCLUSION

For the reasons stated above, we grant eSpeed's motion for summary judgment for non-infringement. We deny TT's cross-motion for summary judgment.

N.D.Ill.,2007.
Trading Technologies Intern., Inc. v. eSpeed, Inc.
507 F.Supp.2d 854

END OF DOCUMENT

EXHIBIT 7

595 F.3d 1340, 93 U.S.P.Q.2d 1805
(Cite as: 595 F.3d 1340)

H

United States Court of Appeals,
Federal Circuit.
TRADING TECHNOLOGIES INTERNATIONAL, INC., Plaintiff–Appellant,
v.
ESPEED, INC., Ecco LLC, Ecco Ware Ltd., and Espeed International, Ltd., Defendants–Cross Appellants.

Nos. 2008–1392, 2008–1393, 2008–1422.
Feb. 25, 2010.
Rehearing and Rehearing En Banc Denied April 21, 2010.

Background: Assignee of two patents for commodities trading software brought infringement action against competitors. After construing patent claims, 2006 WL 3147697, 2007 WL 611258, the United States District Court for the Northern District of Illinois, James B. Moran, Senior District Judge, entered summary judgment in favor of one competitor, 507 F.Supp.2d 854, granted summary judgment in part with regard to another competitor's invalidity defense, 507 F.Supp.2d 883, denied motion for judgment as a matter of law (JMOL) with regard to inequitable conduct defense, 581 F.Supp.2d 915, and ruled that infringement of patents was not willful, 2008 WL 63233. Appeal was taken.

Holdings: The Court of Appeals, Rader, Circuit Judge, held that:
(1) trading software with mandatory re-centering features did not literally infringe patent;
(2) software did not infringe under doctrine of equivalents;
(3) prosecution history estoppel precluded patentee from relying on the doctrine of equivalents;
(4) infringement of patents was not willful;
(5) claim limitation "single action of a user input device" in patent was sufficiently definite;
(6) patents were entitled to priority of provisional application; and
(7) inventor's purchase of custom software from software developer was not a sale of the software for purposes of the on-sale bar.

Affirmed.

Lourie, Circuit Judge, concurred in the result.

Clark, District Judge, filed concurring opinion.

West Headnotes

[1] Patents 291 226.6

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k226.5 Substantial Identity of Subject Matter
291k226.6 k. Comparison with claims of patent. Most Cited Cases

Evaluation of summary judgment of non-infringement in a patent case requires two steps: proper claim construction and comparison of those claims to the accused product.

[2] Patents 291 324.5

291 Patents
291XII Infringement
291XII(B) Actions
291k324 Appeal
291k324.5 k. Scope and extent of review in general. Most Cited Cases

Despite the Supreme Court's emphasis on the trial court's central role for patent claim construction, including the evaluation of expert testimony, the Court of Appeals may not give any deference to the trial court's factual decisions underlying its claim construction.

[3] Patents 291 161

291 Patents
291IX Construction and Operation of Letters Patent
291IX(A) In General

291k161 k. State of the art. Most Cited Cases

To construe a patent claim, courts must determine the meaning of disputed terms from the perspective of one of ordinary skill in the pertinent art at the time of filing.

[4] Patents 291 157(1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(A) In General
291k157 General Rules of Construction
291k157(1) k. In general. Most Cited Cases

Patents 291 165(1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k165 Operation and Effect of Claims in General
291k165(1) k. In general. Most Cited Cases

Patent claim terms are generally given their ordinary and customary meaning; the claims themselves provide substantial guidance as to the meaning of particular claim terms.

[5] Patents 291 167(1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k167 Specifications, Drawings, and Models
291k167(1) k. In general. Most Cited Cases

Patent claims must be read in view of the specification, of which they are a part.

[6] Patents 291 167(1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k167 Specifications, Drawings, and Models
291k167(1) k. In general. Most Cited Cases

A patent's specification is always highly relevant to the claim construction analysis.

[7] Patents 291 167(1.1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k167 Specifications, Drawings, and Models
291k167(1.1) k. Specification as limiting or enlarging claims. Most Cited Cases

When consulting the specification to clarify the meaning of patent claim terms, courts must not import limitations into the claims from the specification; therefore, when the specification uses a single embodiment to enable the claims, courts should not limit the broader claim language to that embodiment unless the patentee has demonstrated a clear intention to limit the claim scope using words or expressions of manifest execution or restriction.

[8] Patents 291 165(5)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k165 Operation and Effect of Claims in General
291k165(5) k. Construction of particular claims as affected by other claims. Most Cited Cases

Other claims of the patent can be valuable sources of enlightenment as to the meaning of a claim term.

[9] Patents 291 168(2.1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k168 Proceedings in Patent Office in General
291k168(2) Rejection and Amendment of Claims
291k168(2.1) k. In general. Most Cited Cases

In claim construction, a court should consider the patent's prosecution history, which can often inform the meaning of the claim language by demonstrating how the inventor understood the invention and whether the inventor limited the invention in the course of prosecution, making the claim scope narrower than it would otherwise be.

[10] Patents 291 168(2.1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k168 Proceedings in Patent Office in General
291k168(2) Rejection and Amendment of Claims
291k168(2.1) k. In general. Most Cited Cases

A patentee may, through a clear and unmistakable disavowal in prosecution history, surrender certain claim scope to which he would otherwise have an exclusive right by virtue of the claim language.

[11] Patents 291 101(2)

291 Patents
291IV Applications and Proceedings Thereon
291k101 Claims
291k101(2) k. Construction in general. Most Cited Cases

Term "static" in phrases "static display of prices" and "common static price axis," in patents claiming commodities trading software, meant that values in the price column of trader's display did not normally change positions unless a re-centering command was received; invention's contribution to the prior art, its specification, and its prosecution history showed that the static display of prices could not move without a manual re-centering command from the trader.

[12] Patents 291 235(2)

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k233 Patents for Machines or Manufactures
291k235 Identity of Principle or Mode of Operation
291k235(2) k. Particular patents or devices. Most Cited Cases

Commodities trading software with mandatory re-centering features for trader's price display did not literally infringe patented commodities trading software, which had price levels that did not change positions unless a manual re-centering command was received.

[13] Patents 291 237

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k233 Patents for Machines or Manufactures
291k237 k. Substitution of equivalents. Most Cited Cases

Under the "all-elements rule," a patentee may not assert a theory of equivalence that would entirely vitiate a particular claim element.

[14] Patents 291 168(2.1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k168 Proceedings in Patent Office in General
291k168(2) Rejection and Amendment of Claims
291k168(2.1) k. In general. Most Cited Cases

Under "prosecution history estoppel," a patentee may not seek to recapture as an equivalent subject matter surrendered during prosecution.

[15] Patents 291 237

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k233 Patents for Machines or Manufactures
291k237 k. Substitution of equivalents. Most Cited Cases

Commodities trading software that automatically re-centered its price axis did not infringe, under doctrine of equivalents, patented trading software, which had price levels that did not change positions unless a manual re-centering command was received; although the allegedly infringing software only re-centered once or twice per trading day, the automatic re-centering feature still presented the potential problem of the prior art that allowed the inside market price to move while a trader was trying to secure a deal.

[16] Patents 291 168(3)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k168 Proceedings in Patent Office in General
291k168(3) k. Rejection and amendment of claims of particular patents. Most Cited Cases

Prosecution history estoppel precluded patentee from relying on the doctrine of equivalents to prove that competing commodities trading system which automatically re-centered price levels on trader's display infringed patented trading software which required manual re-centering of price levels; amendments to patents' claims during prosecution clarified that the claimed price levels "do not move" when the inside market changed.

[17] Patents 291 168(2.1)

291 Patents
291IX Construction and Operation of Letters Patent
291IX(B) Limitation of Claims
291k168 Proceedings in Patent Office in General
291k168(2) Rejection and Amendment of Claims
291k168(2.1) k. In general. Most Cited Cases

Prosecution history estoppel applies at the time of infringement to determine whether the applicant surrendered claim scope during prosecution.

[18] Patents 291 227

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k227 k. Intent or purpose, and knowledge. Most Cited Cases

To establish willful infringement, a patentee must show by clear and convincing evidence that the infringer acted despite an objectively high likelihood that its actions constituted infringement of a valid patent; patentee must also show that the infringer knew or should have known of this objectively high likelihood.

[19] Patents 291 227

291 Patents
291XII Infringement
291XII(A) What Constitutes Infringement
291k227 k. Intent or purpose, and knowledge. Most Cited Cases

Manufacturer of commodities trading software did not willfully infringe patented software, where it began redesigning its software immediately after infringement suit commenced and replaced the software with updated software within a few months, and there was no evidence that manufacturer sold the software during that time, or could have updated or disabled software that was already in its customers' computers any earlier.

[20] Patents 291 101(6)

291 Patents
291IV Applications and Proceedings Thereon
291k101 Claims
291k101(6) k. Ambiguity, uncertainty or indefiniteness. Most Cited Cases

Statutory requirement of particularity and distinctness in patent claims is met only when the claims clearly distinguish what is claimed from what went before in the art and clearly circumscribe what is foreclosed from future enterprise; however, absolute clarity is not required. 35 U.S.C.A. § 112.

[21] Patents 291 101(6)

291 Patents
291IV Applications and Proceedings Thereon
291k101 Claims
291k101(6) k. Ambiguity, uncertainty or indefiniteness. Most Cited Cases

Only patent claims not amenable to construction or insolubly ambiguous are indefinite. 35 U.S.C.A. § 112.

[22] Patents 291 101(6)

291 Patents
291IV Applications and Proceedings Thereon
291k101 Claims
291k101(6) k. Ambiguity, uncertainty or indefiniteness. Most Cited Cases

Claim limitation "single action of a user input device" in patent for commodities trading software was sufficiently definite; district court construed the term to mean an action by a user within a short period of time that may comprise one or more clicks of a mouse button or other input device, which distinguished the invention from multiple-action systems found in the prior art. 35 U.S.C.A. § 112.

[23] Patents 291 110

291 Patents
291IV Applications and Proceedings Thereon
291k110 k. Renewal of application. Most Cited Cases

For patent claims to enjoy the earlier filing date of the provisional application, the prior application itself must describe an invention in sufficient detail that one skilled in the art can clearly conclude that the inventor invented the claimed invention as of the filing date sought; therefore, the provisional application must describe the invention in such a way that one of ordinary skill in the art would understand that the genus that is being claimed has been invented, not just the species of a genus. 35 U.S.C.A. § 112.

[24] Patents 291 323.2(3)

291 Patents
291XII Infringement
291XII(B) Actions
291k323 Final Judgment or Decree
291k323.2 Summary Judgment
291k323.2(3) k. Particular cases. Most Cited Cases

Genuine issue of material fact as to whether inventors' disclosure of a "one click of a mouse" feature in provisional application was sufficient to show that the inventors possessed a "single action of a user input device" as claimed in patents for commodities trading software precluded summary judgment on issue of whether patents could claim priority of the provisional application. 35 U.S.C.A. § 112.

[25] Patents 291 324.5

291 Patents
291XII Infringement
291XII(B) Actions
291k324 Appeal
291k324.5 k. Scope and extent of review in general. Most Cited Cases

Court of Appeals reviews the legal sufficiency of jury instructions on an issue of patent law without deference to the district court.

[26] Evidence 157 506

157 Evidence
157XII Opinion Evidence
157XII(B) Subjects of Expert Testimony
157k506 k. Matters directly in issue. Most

Cited Cases

Expert who testified generally in patent infringement case about the written description requirement but did not offer legal conclusions as to the adequacy of the provisional application's disclosure did not usurp the district court's role of instructing the jury on the law. 35 U.S.C.A. § 112.

[27] Federal Courts 170B 765

170B Federal Courts
170BVIII Courts of Appeals
170BVIII(K) Scope, Standards, and Extent
170BVIII(K)1 In General
170Bk763 Extent of Review Dependent on Nature of Decision Appealed from
170Bk765 k. Judgment notwithstanding verdict. Most Cited Cases

Court of Appeals reverses a denial of a judgment as a matter of law (JMOL) motion only if the jury's factual determinations are not supported by substantial evidence or the legal conclusions implied from the verdict cannot be supported in law by those findings. Fed.Rules Civ.Proc.Rule 50(b), 28 U.S.C.A.

[28] Patents 291 110

291 Patents
291IV Applications and Proceedings Thereon
291k110 k. Renewal of application. Most Cited Cases

Provisional application for patents covering commodities trading software with "single-click" trading feature adequately disclosed "single action" trading feature claimed in the issued patents, entitling the patents to priority of the provisional application; the provisional application distinguished between order entries performed in a single action and multiple-step actions, and one of ordinary skill in the art would have known about other forms of "single action" such as a double-click or pressing a key.

[29] Patents 291 76

291 Patents
291II Patentability
291II(E) Prior Public Use or Sale
291k76 k. What constitutes public sale. Most Cited Cases

Inventor's purchase of custom software incorporating his ideas from software developer for his own secret, personal use was not a sale of the software for purposes of patent statute's on-sale bar; developer produced the software for inventor because inventor lacked the technical expertise to do so, and parties entered into a contract for hourly programming services, not a computer software license. 35 U.S.C.A. § 102(b).

[30] Patents 291 76

291 Patents
291II Patentability
291II(E) Prior Public Use or Sale
291k76 k. What constitutes public sale. Most Cited Cases

Statutory on-sale bar applies when the invention was both the subject of a commercial sale and ready for patenting before the critical date; the transaction at issue must be a "sale" in a commercial law sense. 35 U.S.C.A. § 102(b).

[31] Patents 291 76

291 Patents
291II Patentability
291II(E) Prior Public Use or Sale
291k76 k. What constitutes public sale. Most Cited Cases

A "sale" for purposes of patent statute's on-sale bar is a contract between parties to give and to pass rights of property for consideration which the buyer pays or promises to pay the seller for the thing bought or sold. 35 U.S.C.A. § 102(b).

[32] Patents 291 76

291 Patents
291II Patentability
291II(E) Prior Public Use or Sale
291k76 k. What constitutes public sale. Most Cited Cases

The invention is ready for patenting under the

statutory on-sale bar if there is proof of reduction to practice before the critical date. 35 U.S.C.A. § 102(b).

[33] Patents 291 97.8

291 Patents
291IV Applications and Proceedings Thereon
291k97.7 Unenforceability of Patent; Inequitable Conduct or Fraud on Office
291k97.8 k. In general. Most Cited Cases
(Formerly 291k97)

A patent may be rendered unenforceable for inequitable conduct if an applicant, with intent to mislead or deceive the examiner, fails to disclose material information or submits materially false information to the Patent and Trademark Office (PTO) during prosecution.

[34] Patents 291 324.54

291 Patents
291XII Infringement
291XII(B) Actions
291k324 Appeal
291k324.54 k. Presumptions and discretion of lower court. Most Cited Cases

Patents 291 324.55(2)

291 Patents
291XII Infringement
291XII(B) Actions
291k324 Appeal
291k324.55 Questions of Fact, Verdicts, and Findings
291k324.55(2) k. Clearly erroneous findings. Most Cited Cases

Where a judgment regarding inequitable conduct follows a bench trial in patent case, Court of Appeals reviews the district court's findings of materiality and intent for clear error and its ultimate conclusion for an abuse of discretion.

[35] Patents 291 97.9

291 Patents
291IV Applications and Proceedings Thereon
291k97.7 Unenforceability of Patent; Inequitable Conduct or Fraud on Office
291k97.9 k. What information is material. Most Cited Cases
(Formerly 291k97)

Inventor's use of custom trading software incorporating his idea after the priority date of patent for commodities trading software was not material to the application, and thus patentee's failure to disclose such use to the Patent and Trademark Office (PTO) was not inequitable conduct, where the examiner did not perceive any priority date issue and allowed the claims.

[36] Patents 291 75

291 Patents
291II Patentability
291II(E) Prior Public Use or Sale
291k75 k. What constitutes public use. Most Cited Cases

Experimental uses of the patented invention may in some instances give rise to an issue of patentability.

[37] Patents 291 97.9

291 Patents
291IV Applications and Proceedings Thereon
291k97.7 Unenforceability of Patent; Inequitable Conduct or Fraud on Office
291k97.9 k. What information is material. Most Cited Cases
(Formerly 291k97)

Inventor's testing of custom trading software for his own confidential, personal purposes before filing of patent application was not material to the application, and thus failure to disclose such use to the Patent and Trademark Office (PTO) was not inequitable conduct.

Patents 291 328(2)

291 Patents
291XIII Decisions on the Validity, Construction, and Infringement of Particular Patents
291k328 Patents Enumerated
291k328(2) k. Original utility. Most Cited Cases

6,766,304, 6,772,132. Construed and Ruled Valid by.

***1344** Steven F. Borsand, Trading Technologies International, Inc., of Chicago, IL, argued for plaintiff-appellant. Of counsel on the brief were Paul H. Berghoff, Leif R. Sigmond, Jr., Matthew J. Sampson, Michael D. Gannon, S. Richard Carden, Jennifer M.Kurcz and Paul A. Kafadar, McDonnell Boehnen Hulbert & Berghoff LLP, of Chicago, IL. Of counsel was George I. Lee.

Gary A. Rosen, Law Offices of Gary A. Rosen, P.C., of Philadelphia, PA, argued for defendants-cross appellants. Of counsel on the brief were George C. Lombardi, Raymond C. Perkins and James M. Hilmert, Winston & Strawn, LLP, of Chicago, IL. Of counsel were Ivan M. Poullaos, of Chicago, IL and John K. Hsu, of Washington, DC.

Lora A. Moffatt, Salans LLP, of New York, NY, for amici curiae GL Trade SA, et al. With her on the brief was Walter Scott, Alston & Bird LLP, of New York, NY.

***1345** Before LOURIE, RADER, Circuit Judges, and CLARK, District Judge.[FN1]

> FN1. Honorable Ron Clark, District Judge, United States District Court for the Eastern District of Texas, sitting by designation.

Opinion for the court filed by Circuit Judge RADER, in which District Judge CLARK joins. Circuit Judge LOURIE concurs in the result. Concurring opinion filed by District Judge CLARK.

RADER, Circuit Judge.

The United States District Court for the Northern District of Illinois held that eSpeed, Inc., Ecco LLC, Ecco Ware Ltd., and eSpeed International Ltd. (collectively, "eSpeed") infringed the asserted claims of U.S. Patent No. 6,772,132 ("'132 patent") and U.S. Patent No. 6,766,304 ("'304 patent") with one accused service product, but not willfully. The district court further held that the two other accused products did not literally infringe and then precluded Trading Technologies International, Inc. ("TT") from asserting infringement under the doctrine of equivalents. After giving the patents-in-suit a filing date back to the provisional application, the district court found that the on-sale bar of 35 U.S.C. § 102(b) did not apply. The district court also found no indefiniteness problem in the asserted claims. Finally the district court detected no inequitable conduct during the prosecution of the patents-in-suit. Because this record discloses no reversible error, this court affirms.

I.

TT is the owner by assignment of the '132 and '304 patents. Both patents share a common provisional application filed on March 2, 2000. The United States Patent and Trademark Office ("PTO") issued the '132 patent on August 3, 2004, based on a June 9, 2000 application. The PTO issued the '304 patent on July 20, 2004, based on a June 27, 2001 application. The '304 patent is a divisional of the '132 patent. The specifications of the patents are, for all relevant purposes, identical.

The patents claim software for displaying the market for a commodity traded in an electronic exchange. '132 patent col.3 ll.11–16. The software's graphical user interface ("GUI") includes "a dynamic display for a plurality of bids and for a plurality of asks in the market for the commodity and a static display of prices corresponding to the plurality of bids and asks." *Id.* The claimed invention facilitates more accurate and efficient orders in this trading environment. *Id.* col.3 ll.21–24.

Prior art computer trading displays showed the best bid price and the best ask price (together, "the inside market") in fixed, predetermined grids. The best bid price is the highest price at which there is an offer to buy the contract. The best ask price is the lowest price at which there is an offer to sell the contract. The inside market is the focal point of trading activity because these offers most accurately reflect the current price of the commodity.

Returning to the prior art, these displays had grids for the inside market that never changed. As the market fluctuated, however, the prices listed in those grids changed—often times very rapidly. To buy at the inside market, a trader, for example, placed the mouse cursor on the grids for the inside market and clicked the mouse. Of course, as traders sent bids and offers to the market, the price and quantity of the traded commodity changed. These changes altered the inside market. In the prior art era with fixed grids for the

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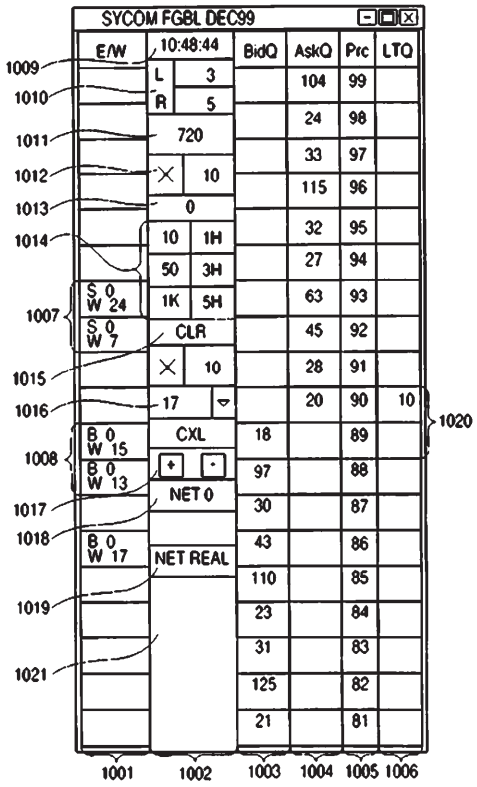
inside market, traders had a problem. A trader who wished to place an order at a ***1346** particular price would miss that market opportunity if the inside market moved as the trader tried to enter an order. In a fast moving market, missing an intended price could happen often and have very significant economic consequences.

FIG. 3



'132 patent, figs.3, 4. The figures display the bids and offers for a certain commodity in an electronic exchange. Column 1005 labeled "Prc" shows the contract prices. *Id.* col.7 ll.36–38. Column 1003 labeled "BidQ" and column 1004 labeled "AskQ" respectively show the bid quantities and the ask quantities for the associated price. *Id.* col.7 ll.35–36. In Figure 3, the inside market labeled 1020 indicates the best bid price of 89 and the best ask price of 90. *Id.* col.7 ll.40–42. A trader may enter an order by clicking in the bid or ask grid corresponding to the trader's price. *Id.* col.4 ll.9–19.

Figure 4 displays the same market at a later time. The bid and ask quantities dynamically change in response to market fluctuations. *Id.* col.7 ll.48–51. In

The invention addressed the problem by implementing static price levels. Figures 3 and 4 of the '132 patent illustrate the invention.

FIG. 4

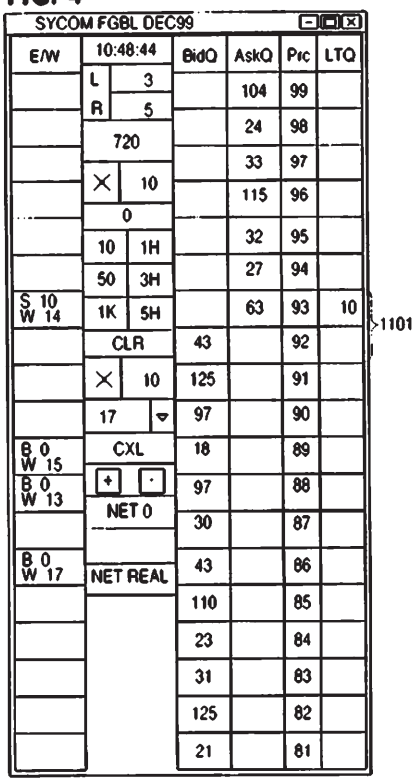


Figure 4, the inside market has shifted upward such that the best bid price is now 92 and the best ask price is 93. *Id.* col.8 ll.38–48. While the inside market has changed, the values in the price column remained fixed. *Id.* col.8 ll.44–48. Over time, the inside market could shift to prices not currently displayed on the trader's screen. *Id.* col. 8 ll.49–51. In this case, the price column must be re-centered to keep the inside market in view. *Id.* col.8 ll.49–60.

***1347** The claimed invention features static price levels. These unmoving figures have numerous advantages over the prior art. First, a trader can visually follow the market movement as the inside market shifts up and down along the price column. *Id.* col.5 ll.58–65. Second, and perhaps most important, a trader has confidence in making an offer at the intended

price. *Id.* col.3 ll.3–4. Because the invention has static price levels, the order entry region will remain associated with the same price. Therefore, the trader does not need to worry about "clicking on" or entering an order at the instant after a price change. Thus, the invention prevents accidental orders at an unintended price. The patents tout that these improvements ensure fast and accurate execution of trades. *Id.* col.3 ll.21–24.

eSpeed, Inc. provides an electronic exchange for trading commodities. It also designs and sells trading platforms for use with its electronic exchange. On August 12, 2004, TT initiated this suit against eSpeed, Inc., alleging that eSpeed, Inc.'s trading platforms infringed TT's patents. After eSpeed, Inc. acquired Ecco LLC in October 2004, TT joined Ecco LLC in the suit. In December 2005, TT amended its complaint to join the subsidiaries eSpeed International, Inc. and Ecco Ware Ltd. This opinion refers to all defendants collectively as "eSpeed." TT asserts the following claims against eSpeed: claims 1, 2, 7, 14, 15, 20, 23–25, 27, 28, 40, 45, 47, 48, 50, and 52 of the '132 patent; and claims 1, 11, 14, 15, and 26 of the '304 patent. Claim 1 is the representative claim for both patents.

Claim 1 of the '132 patent:

> A method of placing a trade order for a commodity on an electronic exchange having an inside market with a highest bid price and a lowest ask price, using a graphical user interface and a user input device, said method comprising:
>
> setting a preset parameter for the trade order;
>
> displaying market depth of the commodity, through a dynamic display of a plurality of bids and a plurality of asks in the market for the commodity, including at least a portion of the bid and ask quantities of the commodity, the dynamic display being aligned with a *static display of prices* corresponding thereto, *wherein the static display of prices does not move in response to a change in the inside market;*
>
> displaying an order entry region aligned with the *static display prices* comprising a plurality of areas for receiving commands from the user input devices to send trade orders, each area corresponding to a price of the *static display of prices;* and
>
> selecting a particular area in the order entry region through *single action of the user input device* with a pointer of the user input device positioned over the particular area to set a plurality of additional parameters for the trade order and send the trade order to the electronic exchange.

'132 patent col. 12 ll.1–27 (emphases added).

Claim 1 of the '304 patent:

> A method for displaying market information relating to and facilitating trading of a commodity being traded in an electronic exchange having an inside market with a highest bid price and a lowest ask price on a graphical user interface, the method comprising:
>
> dynamically displaying a first indicator in one of a plurality of locations in a bid display region, each location in the bid display region corresponding to a price level along a *common static* ****1348*** *price axis,* the first indicator representing quantity associated with at least one order to buy the commodity at the highest bid price currently available in the market;
>
> dynamically displaying a second indicator in one of a plurality of locations in an ask display region, each location in the ask display region corresponding to a price level along the *common static price axis,* the second indicator representing quantity associated with at least one order to sell the commodity at the lowest ask price currently available in the market;
>
> displaying the bid and ask display regions in relation to fixed price levels positioned along the *common static price axis* such that when the inside market changes, the price levels along the common static price axis do not move and at least one of the first and second indicators moves in the bid or ask display regions relative to the common static price axis;
>
> displaying an order entry region comprising a plurality of locations for receiving commands to

> send trade orders, each location corresponding to a price level along the *common static price* axis; and
>
> in response to a selection of a particular location of the order entry region by a *single action of a user input device,* setting a plurality of parameters for a trade order relating to the commodity and sending the trade order to the electronic exchange.

'304 patent col. 12 ll.35–col. 13 ll.3 (emphases added).

TT accuses the following categories of eSpeed software of infringement: (1) Futures View, Autospeed Basis, and Price Ladder (collectively, "Futures View"); (2) Dual Dynamic and Ecco Scalper ("Dual Dynamic"); and (3) eSpeedometer and Ecco eSpeedometer ("eSpeedometer"). These accused products are identical in all relevant aspects. eSpeed concedes that Futures View satisfies all claim limitations. The parties dispute whether Dual Dynamic and eSpeedometer have a "static display of prices" or "static price axis." This dispute turns on the way that the accused products re-center the price levels when the inside market moves away from the center of the display.

eSpeed sold Futures View before the patents-in-suit issued. Dual Dynamics is a redesign of Futures View. Dual Dynamic has two re-centering features. First, a trader can click a mouse to manually re-center the price levels. Second, Dual Dynamic automatically and instantaneously re-centers the price levels so as to move the inside market back to the field of the trader's view if the inside market shifted a pre-determined number of ticks from the center of the display. Traders could not disable this automatic re-centering feature. eSpeedometer is the second redesign of Futures View. eSpeedometer has an automatic re-centering feature only. Unlike Dual Dynamic, the entire display slowly drifts towards the center of the trader's screen after each and every change in the inside market.

eSpeed manufactured and sold the accused products at different times during the suit. eSpeed began selling Futures View long before TT's patents-in-suit issued in August 2004. Just before the hearing for a preliminary injunction in this case in December 2004, eSpeed pulled Futures View off the market and replaced it with Dual Dynamic. After the district court found that Dual Dynamic likely infringed the patents-in-suit, eSpeed launched eSpeedometer.

In this case, the district court entered numerous orders on claim construction, motions for summary judgment, motions in ***1349** limine, and motions for a judgment as a matter of law ("JMOL"). After holding a three-day claim construction hearing, the district court issued a claim construction order. Of particular importance to this appeal, the district court construed the word "static" in the limitation "static display of prices" in the '132 patent and in the limitation "common static price axis" in the '304 patent. Based on the claim construction, eSpeed moved for summary judgment of non-infringement for Dual Dynamic and eSpeedometer.

The district court found that neither product literally infringed. The district court also found that Dual Dynamic did not infringe under the doctrine of equivalents because finding otherwise would vitiate the claim element "static." The district court held that prosecution history estoppel precluded application of the doctrine of equivalents as to eSpeedometer. Therefore, the district court granted summary judgment of non-infringement as to both the Dual Dynamic and eSpeedometer redesigns.

In September and October 2007, the district court held a four-week jury trial. During the trial, the district court granted TT's motion in limine to preclude eSpeed from asserting an on-sale bar defense at trial. The district court also granted-in-part TT's motion in limine to preclude expert testimony that the construction of "single action of a user input device" was indefinite. On October 10, 2007, the jury found that Futures View willfully infringed the patents-in-suit. The jury also awarded the patents-in-suit the benefit of their provisional application's filing date. Based on that finding, the jury determined that the prior art did not anticipate or render obvious the claimed invention. The jury awarded TT $3,500,000 in damages based on a reasonable royalty.

After the jury trial, the district court held a two-day bench trial on inequitable conduct. Based on that record, the trial court ruled that eSpeed did not show that TT engaged in inequitable conduct. The

district court also denied eSpeed's JMOL motions on validity, indefiniteness, priority date, and the patent misuse defense, but vacated the jury's finding of willful infringement and remitted the damages award to $2,539,468. The district court further denied TT's motions for enhanced damages and for attorney fees.

The district court entered its final judgment on May 22, 2008. Both eSpeed and TT appealed to this court on May 27, 2008. The judgment on which TT based its appeal was not final at that time. The district court then re-entered its final judgment *nunc pro tunc* on June 13, 2008. Because this court ruled that appellate jurisdiction ripened upon the entry of the judgment *nunc pro tunc,* it has jurisdiction under 28 U.S.C. § 1295(a).

II.

Both TT and eSpeed raise numerous issues on appeal. TT's appeal focuses on patent infringement. First, TT appeals the claim construction of "common static price axis" and "a static display of price." Second, TT argues that Dual Dynamic and eSpeedometer infringe the patents-in-suit based on TT's proposed claim construction. Third, TT asserts that a finding that Dual Dynamic infringes under the doctrine of equivalents would not vitiate the claim element "static." Fourth, TT argues that prosecution history estoppel does not preclude showing that eSpeedometer infringes under the doctrine of equivalents. Finally, TT claims that the district court incorrectly granted eSpeed's JMOL motion on willful infringement.

eSpeed's cross-appeal focuses on patent validity. First, eSpeed argues that the ***1350** patents-in-suit do not deserve priority back to March 2, 2000—the filing date of the provisional application. Second, eSpeed claims that the patents-in-suit are invalid under the on-sale bar because Harris Brumfield, one of the inventors of the patents-in-suit, entered into a sales contract with TT more than one year before March 2, 2000. Third, eSpeed argues that the term "single action of a user input device" is indefinite. Finally, eSpeed claims that TT engaged in inequitable conduct by failing to submit Brumfield's custom software embodying the patented invention to the PTO during the prosecution of the patents-in-suit.

III.

A.

[1] The district court granted summary judgment of non-infringement for the Dual Dynamic and eSpeedometer products. This court reviews a grant of summary judgment without deference. *O2 Micro Int'l, Ltd. v. Monolithic Power Sys.*, 467 F.3d 1355, 1359 (Fed.Cir.2006). Evaluation of summary judgment of non-infringement requires two steps-proper claim construction and comparison of those claims to the accused product. *Abbott Labs. v. Sandoz, Inc.*, 566 F.3d 1282, 1288 (Fed.Cir.2009). Because the parties dispute the meaning of terms in the asserted claims, this court reviews the district court's claim construction order under the requirements of *Markman v. Westview Instruments, Inc.*, 517 U.S. 370, 116 S.Ct. 1384, 134 L.Ed.2d 577 (1996).

The Supreme Court in *Markman* held that "the construction of a patent, including terms of art within its claim, is exclusively within the province of the court." *Id.* at 372, 116 S.Ct. 1384. The Supreme Court recognized that claim construction "falls somewhere between a pristine legal standard and a simple historical fact." *Id.* at 388, 116 S.Ct. 1384 (quoting *Miller v. Fenton,* 474 U.S. 104, 114, 106 S.Ct. 445, 88 L.Ed.2d 405 (1985)). Although claim construction is not a purely legal matter, the Supreme Court found "sufficient reason to treat construction of terms of art like many other responsibilities that we cede to a judge in the normal course of trial, notwithstanding its evidentiary underpinnings." *Id.* at 390, 116 S.Ct. 1384.

Nevertheless, in *Cybor Corp. v. FAS Technologies, Inc.*, 138 F.3d 1448 (Fed.Cir.1998) (en banc), this court interpreted *Markman* as holding that claim construction was solely a question of law, which this court should review without deference. *Id.* at 1451. The question presented before the Supreme Court was "whether the interpretation of a so-called patent claim ... is a matter of law reserved entirely for the court, or subject to a *Seventh Amendment* guarantee that a jury will determine the meaning of any disputed term of an art about which expert testimony is offered." *Markman,* 517 U.S. at 372, 116 S.Ct. 1384. Although the Supreme Court addressed only the role of the trial court in claim construction, this court understood that "the Supreme Court was addressing under which category, fact or law, claim construction should fall." *Cybor,* 138 F.3d at 1455. This court concluded that "[n]othing in the Supreme Court's opinion supports the view that the Court endorsed a silent, third option—that claim construction may involve subsidiary or underlying questions of fact." *Id.*

An examination of the Supreme Court's ruling in *Markman* shows multiple references to factual components of claim construction:

• "[C]onstruing a term of art following receipt of evidence" is "a mongrel practice." *Id.* at 378 [116 S.Ct. 1384].

***1351** • Claim construction "falls somewhere between a pristine legal standard and a simple historical fact." *Id.* at 388 [116 S.Ct. 1384].

• "We accordingly think there is sufficient reason to treat construction of terms of art like many other responsibilities that we cede to a judge in the normal course of trial, notwithstanding its evidentiary underpinnings." *Id.* at 390 [116 S.Ct. 1384].

These references in the Supreme Court opinion leaves this court stranded between the language in the Court's decision and the language in this court's *Cybor* decision.

In order to resolve this case, this court must confront findings by the trial court about the meaning of the disputed claim term "static." In reaching the meaning of that term, the trial court explored and made findings about the technical background of the invention—the inventive features and the timing of those features against the backdrop of the prior art. In addition, the district court determined the meaning that an artisan of ordinary skill in this discipline would assign the term "static." The trial court also made findings about the understanding of such an ordinary artisan about the metes and bounds of the asserted claims. In still another factual setting, the district court determined the way that the ordinary artisan would interpret the patent applicant's statements made to the PTO examiner during the prosecution of the patents-in-suit. These factual determinations about the timing and nature of the history of the patent acquisition process also informed the trial court's claim construction. In sum, claim construction involves many technical, scientific, and timing issues that require full examination of the evidence and factual resolution of any disputes before setting the meaning of the disputed terms.

Of course, as the Supreme Court repeatedly clarified in *Markman,* the trial court occupies the best vantage point and possesses the best tools to resolve those evidentiary questions:

• "[A] jury's capabilities to evaluate demeanor to sense the mainsprings of human conduct or to reflect community standards are much less significant than a trained ability to evaluate the testimony in relation to the overall structure of the patent." *Id.* at 389–90 [116 S.Ct. 1384] (citations and internal quotation marks omitted).

• "The decisionmaker vested with the task of construing the patent is in the better position to ascertain whether an expert's proposed definition fully comports with the specification and claims and so will preserve the patent's internal coherence." *Id.* at 390 [116 S.Ct. 1384].

[2] Despite the Supreme Court's emphasis on the trial court's central role for claim construction, including the evaluation of expert testimony, this court may not give any deference to the trial court's factual decisions underlying its claim construction. This court's prior *en banc* decision requires a review of the district court's claim construction without the slightest iota of deference. *See Cybor,* 138 F.3d at 1451.

B.

[3][4] To construe a claim, courts must determine the meaning of disputed terms from the perspective of one of ordinary skill in the pertinent art at the time of filing. *Chamberlain Group, Inc. v. Lear Corp.,* 516 F.3d 1331, 1335 (Fed.Cir.2008). The claim terms "are generally given their ordinary and customary meaning." *Phillips v. AWH Corp.,* 415 F.3d 1303, 1312 (Fed.Cir.2005) (en banc) (quoting ***1352***Vitronics Corp. v. Conceptronic, Inc.,* 90 F.3d 1576, 1582 (Fed.Cir.1996)). "[T]he claims themselves provide substantial guidance as to the meaning of particular claim terms." *Id.* at 1314.

[5][6][7][8] But the claims "must be read in view of the specification, of which they are a part." *Markman v. Westview Instruments, Inc.,* 52 F.3d 967, 979 (Fed.Cir.1995) (en banc), *aff'd,* 517 U.S. 370, 116 S.Ct. 1384, 134 L.Ed.2d 577 (1996). A patent's specification "is always highly relevant to the claim construction analysis." *Phillips,* 415 F.3d at 1315 (quoting *Vitronics,* 90 F.3d at 1582 (Fed.Cir.1996)). When consulting the specification to clarify the meaning of

claim terms, courts must not import limitations into the claims from the specification. *Abbott Labs.*, 566 F.3d at 1288. Therefore, when the specification uses a single embodiment to enable the claims, courts should not limit the broader claim language to that embodiment "unless the patentee has demonstrated a clear intention to limit the claim scope using 'words or expressions of manifest execution or restriction.' " *Liebel–Flarsheim Co. v. Medrad, Inc.*, 358 F.3d 898, 905 (Fed.Cir.2004) (quoting *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1327 (Fed.Cir.2002)). In addition, "other claims of the patent ... can also be valuable sources of enlightenment as to the meaning of a claim term." *Id.* (citing *Vitronics*, 90 F.3d at 1582).

[9][10] In claim construction "a court 'should also consider the patent's prosecution history....' " *Phillips*, 415 F.3d at 1318 (quoting *Markman*, 52 F.3d at 980). "[T]he prosecution history can often inform the meaning of the claim language by demonstrating how the inventor understood the invention and whether the inventor limited the invention in the course of prosecution, making the claim scope narrower than it would otherwise be." *Id.* (citing *Vitronics*, 90 F.3d at 1582–83). For example, "a patentee may, through a clear and unmistakable disavowal in prosecution history, surrender certain claim scope to which he would otherwise have an exclusive right by virtue of the claim language." *Vita–Mix Corp. v. Basic Holding, Inc.*, 581 F.3d 1317, 1324 (Fed.Cir.2009) (citations omitted). At the same time, because prosecution history represents an ongoing negotiation between the PTO and the inventor, "it often lacks the clarity of the specification and thus is less useful for claim construction purposes." *Netcraft Corp. v. eBay, Inc.*, 549 F.3d 1394, (Fed.Cir.2008).

[11] TT disputes the construction of the word "static" in the phrase "static display of prices" in the '132 patent and in the phrase "common static price axis" in the '304 patent. All asserted claims of the '132 patent include the limitation "static display of prices." Likewise, all asserted claims of the '304 patent include the limitation "common static price axis." TT and eSpeed agree that the difference in terminology between "static display of prices" and "common static price axis" is immaterial.

The district court construed "static display of prices" in the '132 patent as "a display of prices comprising price levels that do not change positions unless a *manual* re-centering command is received." *Trading Techs. Int'l, Inc. v. eSpeed, Inc.*, 2006 WL 3147697, at *4, 2006 U.S. Dist. LEXIS 80153, at *11 (N.D.Ill. Oct. 31, 2006) (emphasis added). The district court similarly construed "common static price axis" as "a line comprising price levels that do not change positions unless a *manual* re-centering command is received and where the line of prices corresponds to at least one bid value and one ask value." *Id.* (emphasis added). A "price level" is "a level on which a designated price or price ***1353** representation resides." *Id.* at *5, 2006 U.S. Dist. LEXIS 80153, at *15. The district court later clarified that "a static condition—requires permanency" and, thus, "the price axis never changes positions unless by manual re-centering or re-positioning." *Trading Techs. Int'l, Inc. v. eSpeed, Inc.*, 2007 WL 611258, at *4, 2007 U.S. Dist. LEXIS 12965, at *20, 22 (N.D.Ill. Feb. 21, 2007) (emphasis added). Under the district court's construction, the patents-in-suit only cover software with a manual re-centering feature and without automatic re-centering feature. Given that Dual Dynamic and eSpeedometer automatically re-center the price columns in response to changes in the inside market, TT argues for a broader construction of the word "static" (i.e., "static" does not mean immovable).

The inventors acted as their own lexicographers and defined the word "static:"

> The values in the price column are static; that is, they do not normally change positions unless a re-centering command is received (discussed in detail later).

'132 patent col.7 ll.46–48; '304 patent col.7 ll.65–67. The district court made two important changes to this express definition in construing the word "static." First, the district court added the word "manual" in front of the term "re-centering command." Second, it deleted the word "normally." The district court's definition may seem narrower than the inventors' express definition at first glance. However, the claims, the rest of the specification, and the prosecution history support the district court's definition. Therefore, this court, after reconstruing this term based on its own understanding of the claims, specification, prosecution history, and record, agrees with the district court's claim construction of the word "static."

In the first place, the "re-centering command" must indeed occur as a result of a manual entry. The specification shows that the inventors defined the term "static" in the specification. Notably, that definition expressly promises to discuss "a re-centering command ... later" in the specification. *Id.* From that point forward, the specification only discusses manual re-centering commands. The specification contains no reference to automatic re-centering. Perhaps in response to the promise to discuss re-centering later, the patents describe the invention as follows:

> As the market ascends or descends the price column, the inside market might go above or below the price column displayed on a trader's screen. Usually a trader will want to be able to see the inside market to assess future trades. The system of *the present invention* addresses this problem with a one click centering feature.

'132 patent col.8 ll.49–54; '304 patent col.9 ll.14–19 (emphasis added). This reference to "the present invention" strongly suggests that the claimed re-centering command requires a manual input, specifically, a mouse click. *See Honeywell Int'l, Inc. v. ITT Indus.*, 452 F.3d 1312, 1318 (Fed.Cir.2006) (concluding that the invention was limited to a fuel filter because the specification referred to the fuel filter as "this invention" and "the present invention").

This court recognizes that this interpretation relies heavily on the specification and risks reading improperly a preferred embodiment into the claim. *See Saunders Group, Inc. v. Comfortrac, Inc.*, 492 F.3d 1326, 1332 (Fed.Cir.2007) (holding that claim scope is not limited to the disclosed embodiments "unless the patentee has demonstrated a clear intention to [do so]"). This court takes some comfort against this risk from the inventors' use of the term "the present invention" rather than "a preferred embodiment" or just "an embodiment." The inventors' own specification ***1354** strongly suggests that the claimed re-centering feature is manual.

Because an inventor must evince a "clear intention" to limit the claim terms to a specification embodiment, this court examines other claims to detect any contrary intentions. In that respect, this court observes that all claims of the '132 patent have a "wherein" clause explaining that "the static display of prices does not move in response to a change in the inside market." '132 patent col.12 l.1–col.16 l.57. Although the "wherein" clause does not exclude automatic re-centering from the claim scope (it does not exclude software that automatically re-centers whenever the trader enters an order, for example), it expressly excludes software that automatically re-centers when the inside market changes. These clauses thus support the district court's claim construction.

TT argues that even if this court construes the "re-centering command" as manual, this court cannot limit the claims to only the enumerated elements (i.e., manual re-centering command). According to TT, because the claims use the transitional phrase "comprising," they also cover un-recited features such as automatic re-centering. To the contrary, automatic re-centering is not an additional feature, but rather negates a claimed requirement that the price level remains static and does not move. *See Spectrum Int'l v. Sterilite Corp.*, 164 F.3d 1372, 1380 (Fed.Cir.1998) (" 'Comprising' is not a weasel word with which to abrogate claim limitations."). A price level that *only* moves in response to a manual re-centering command cannot also move in response to an automatic re-centering command. Thus, this court construes the claims to require a manual re-centering command.

The claims also contain a limitation that "the price axis *never* changes positions unless by manual re-centering or re-positioning." *Trading Techs.*, 2007 WL 611258, at *4, 2007 U.S. Dist. LEXIS 12965, at *22. The district court found that the ordinary and customary meaning of "static" was "motionless: not moving or changing, or fixed in position." *Trading Techs.*, 2006 WL 3147697, at *4, 2006 U.S. Dist. LEXIS 80153, at *11. TT did not present evidence or dispute that a person of ordinary skill in the art would understand the word "static" differently. Moreover, allowing the price axis to automatically change positions would defy the invention's goal to "ensure[ ] fast and accurate execution of trades." '132 patent col.3 ll.5–6. The invention would present the same problem as the prior inventions if the price axis moved automatically even in rare instances. The "static display of prices" could automatically re-center just as the trader was getting ready to execute a trade, causing the trader to miss the intended price.

Also, the inventors jettisoned the word "normal-

ly" during prosecution. The PTO examiner initially rejected the claims because the term " 'static display' [was] vague and indefinite." The examiner requested the applicants "to claim 'to what extent', 'to what degree', and 'on what basis' the displays 'change.' " In response, the applicants explained that "the values in the price column ... *do not change* (unless a re-centering command is received)." The examiner allowed the claims at least partly based on the understanding that the price column did not re-center itself automatically. The manual re-centering feature also avoided the possibility of mistakes when the price column moved automatically at the same time a trader wished to make a purchase. Of course, traders might make mistakes despite precautions built into the software. Nonetheless, to "provide the trader with improved efficiency and versatility in placing,"***1355** '132 patent col.3 ll.21–24, the price column cannot shift unexpectedly.

This court also addresses claim 55 of the '132 patent, a dependent claim from claim 1:

> The method of claim 1 wherein the market depth is based on an exchange order book and *the static display of prices never moves in response to a price change* in the exchange order book relating to a price which is displayed.

Id. col.16 ll.52–55 (emphasis added). TT argues that construing "static" to mean the price axis never moves would render dependent claim 55 superfluous. To the contrary, claim 55 adds another limitation to claim 1, namely, that the market depth is based on "an exchange order book." Moreover, problems with any overlapping claim scope "will be overcome by a contrary construction dictated by the written description or prosecution history." *Regents v. Dakocytomation*, 517 F.3d 1364, 1375 (Fed.Cir.2008). The invention's contribution to the prior art, its specification, and its prosecution history show that the static display of prices cannot move without a manual re-centering command from the trader. Accordingly, the district court correctly construed the disputed word "static."

[12] Because Dual Dynamic and eSpeedometer systems have mandatory re-centering features, these products do not infringe the patents-in-suit based on the district court's construction of the word "static." With that feature, these products lack "price levels that do not change positions unless a manual re-centering command is received." This court affirms the district court's finding that Dual Dynamic and eSpeedometer do not literally infringe the patents-in-suit.

IV.

[13][14] The district court prevented TT from relying on the doctrine of equivalents. The trial court reasoned that claim vitation barred assertion of infringement by equivalents against the Dual Dynamic system. The trial court reasoned that prosecution history estoppel barred TT from asserting equivalents against the eSpeedometer system. The Supreme Court discussed these "legal limitations on the application of the doctrine of equivalents" in *Warner–Jenkinson Co., Inc. v. Hilton Davis Chemical Co.*, 520 U.S. 17, 39 n. 8, 117 S.Ct. 1040, 137 L.Ed.2d 146 (1997). Under the "all-elements rule," a patentee may not assert "a theory of equivalen[ce] [that] would entirely vitiate a particular claim element." *Id.* Under prosecution history estoppel, a patentee may not seek to recapture as an equivalent subject matter surrendered during prosecution. *Id.* This court reviews both legal limitations without deference. *Lockheed Martin Corp. v. Space Sys./Loral, Inc.*, 324 F.3d 1308, 1318 (Fed.Cir.2003).

The all-elements rule requires this court to consider "the totality of circumstances of each case and determine whether the alleged equivalent can be fairly characterized as an insubstantial change from the claimed subject matter without rendering the pertinent limitation meaningless." *Freedman Seating Co. v. Am. Seating Co.*, 420 F.3d 1350, 1359 (Fed.Cir.2005). In other words, this rule empowers a court to perform again the standard "insubstantial variation" test for equivalency, but this time as a question of law. Claim vitiation applies when there is a "clear, substantial difference or a difference in kind" between the claim limitation and the accused product. *Id.* at 1360. It does not apply when there is a "subtle difference in degree." *Id.*

***1356** In this case, the trial court considered whether an occasional automatic re-centering of the price axis in Dual Dynamic is equivalent to "never chang[ing] positions unless by manual re-centering or re-positioning." The court determined that the automatic re-centering would render the claim limitation "static"—synonymous with only manual re-centering—meaningless. The trial court's construction of the claim limitation "static" specifically

excludes any automatic re-centering. See *SciMed Life Sys. v. Advanced Cardiovacsular Sys.,* 242 F.3d 1337, 1347 (Fed.Cir.2001) ("[I]f a patent states that the claimed device must be 'non-metallic,' the patentee cannot assert the patent against a metallic device on the ground that a metallic device is equivalent to a non-metallic device.").

[15] On appeal, this court observes that the Dual Dynamic system may only automatically re-center its price axis once or twice per trading day. Still this occasional automatic re-centering is not a "subtle difference of degree" because the claim forbids all automatic re-centering. This court concludes that the occasional automatic re-centering is not merely an insubstantial variation. The relevant standard for measuring the difference in this instance is not the frequency of automatic re-centering. Instead this court must detect the difference between a price axis that moves only in response to the trader's instruction and a price axis that adjusts itself without prompting. This difference is not subtle. Rather, as discussed above, this difference lies at the heart of the advantages of the patented invention over prior art. Specifically the invention "ensures fast and accurate execution of trades." ' 132 patent col.3 ll.5–6. Dual Dynamic's automatic re-centering feature still presents the potential problem of the prior art that allowed the inside market price to move while a trader was trying to secure a deal. Thus Dual Dynamic's automatic re-centering feature is substantially different from the claimed invention and cannot fall within the scope of the claims under the doctrine of equivalents without doing violence to the "static" claim element. Accordingly, this court affirms the trial court's judgment that TT cannot rely on the doctrine of equivalents to show that Dual Dynamic infringes.

[16] This court further agrees with the district court that prosecution history estoppel precludes TT from relying on the doctrine of equivalents to prove the eSpeedometer system infringes. After the USPTO issued a notice of allowance, TT submitted for the first time a prior art reference that described a static price display and petitioned to have the application withdrawn from issuance. TT then amended claim 22 of the '132 patent, which ultimately issued as claim 1, as follows (deletions marked in brackets, additions underlined):

> displaying [the] market depth of [a] *the* commodity [traded in a market], through a dynamic display of a plurality of bids and a plurality of asks in the market for the commodity, including *at least a portion of* the bid and ask quantities of the commodity, *the dynamic display being* aligned with a static display of prices corresponding thereto, *wherein the static display of prices does not move in response to a change in the inside market;*

Similarly, TT amended claim 41 of the '304 patent, which ultimately issued as claim 1, as follows:

> displaying the bid and ask display regions in relation to fixed price levels positioned along the common static price axis such that *when the inside market changes, the price levels along the common static price axis do not move and at least one of* the first and second indicators***1357** [can] moves in the bid [and] or ask display regions relative to the common static price axis [when the inside market changes];

The PTO examiner then allowed the claims. The amendments clarified that the claimed price levels "do not move" when the inside market changes. Therefore, the applicants clearly surrendered a GUI with price levels that move in response to inside market changes.

[17] TT argues that amending the claims to require that the price levels "do not move" did not narrow the claim scope, because the claims already included the term "static," which the district court has construed to mean that the price levels "do not move." This contention, however, is circular. Placed in the proper context of the timing for claim construction and prosecution history estoppel, the district court properly prevented the recapture of surrendered subject matter. The trial court construed the claims as amended and properly limited the claims to manual re-centering. Prosecution history estoppel applies at the time of infringement to determine whether the applicant surrendered claim scope *during* prosecution. *See Warner–Jenkinson,* 520 U.S. at 39 n. 8, 117 S.Ct. 1040. TT's argument assumes that the trial court and this court would have construed "static" the same without the full prosecution history. This court need not engage in this conjecture because the inventors narrowed the claim scope during prosecution. Thus, both claim construction and prosecution history estoppel operate in this case with similar limited results. The first limits the claims to manual re-centering. The latter prevents TT from asserting that eSpeedometer is

an equivalent, because its price level automatically drifts towards the center of the display after every change in the inside market. Thus, during prosecution, the inventors surrendered any subject matter that moves automatically. Accordingly, this court affirms as a matter of law the district court's finding that Dual Dynamic and eSpeedometer do not infringe the patents-in-suit under the doctrine of equivalents.

V.

The district court granted eSpeed's motion for JMOL that it did not willfully infringe the patents-in-suit. This court reviews a district court's grant of a motion for JMOL under the law of the regional circuit, in this case the United States Court of Appeals for the Seventh Circuit. *Harris Corp. v. Ericsson Inc.*, 417 F.3d 1241, 1248 (Fed.Cir.2005). The Seventh Circuit reviews a district court's grant of a JMOL motion without deference, while viewing all the evidence in the light most favorable to the nonmoving party. *Harper v. Albert*, 400 F.3d 1052, 1061 (7th Cir.2005). JMOL is proper when "a party has been fully heard on an issue and there is no legally sufficient evidentiary basis for a reasonable jury to find for that party on that issue." Fed.R.Civ.P. 50(a).

[18] In *In re Seagate Technology, LLC*, 497 F.3d 1360, 1371 (Fed.Cir.2007) (en banc), this court held that "proof of willful infringement permitting enhanced damages requires at least a showing of objective recklessness." "[A] patentee must show by clear and convincing evidence that the infringer acted despite an objectively high likelihood that its actions constituted infringement of a valid patent." *Id.* The patentee must also show that the infringer knew or should have known of this objectively high likelihood. *Id.*

[19] TT's argument focuses on eSpeed's post-issuance activities from August to December 2004, during which eSpeed's customers continued to use Futures View to trade on its electronic exchange. The ***1358** parties do not dispute that eSpeed began redesigning Futures View immediately after this suit commenced and replaced Futures View with the redesigned Dual Dynamic by the end of December 2004. Prompt redesign efforts and complete removal of infringing products in a span of a few months suggest that eSpeed was not objectively reckless.

Also, TT offered no evidence that eSpeed sold Futures View to new customers during the contested time period. Nor did TT offer any evidence that eSpeed could have disabled the infringing feature or removed Futures View that was already installed on the customers' computers. eSpeed replaced Futures View with Dual Dynamic via a mandatory software update in December 2004; however, this does not prove that eSpeed could have updated its software before this date. The record shows that some customers paid monthly license fees on Futures View after August 2004. Nonetheless, eSpeed was merely receiving monthly installments on licenses that it had previously sold. Moreover, eSpeed could not have terminated these licenses without providing three months advance notice.

Because the record shows no objective recklessness during the contested period of time, no reasonable jury could have found that eSpeed willfully infringed the patents-in-suit. Therefore, this court affirms the district court's grant of JMOL motion on willful infringement.

VI.

[20][21] The parties dispute whether the limitation "single action of a user input device" is indefinite as construed. A patent specification must "conclude with one or more claims particularly pointing out and distinctively claiming the subject matter which the applicant regards as his invention." 35 U.S.C. § 112, ¶ 2. "The statutory requirement of particularity and distinctness in claims is met only when [the claims] clearly distinguish what is claimed from what went before in the art and clearly circumscribe what is foreclosed from future enterprise." *United Carbon Co. v. Binney & Smith Co.*, 317 U.S. 228, 236, 63 S.Ct. 165, 87 L.Ed. 232 (1942). However, absolute clarity is not required. *Datamize, LLC v. Plumtree Software, Inc.*, 417 F.3d 1342, 1347 (Fed.Cir.2005). Only claims "not amenable to construction" or "insolubly ambiguous" are indefinite. *Id.* (citation omitted). This court reviews definiteness without deference. *AllVoice Computing v. Nuance Commc'ns*, 504 F.3d 1236, 1240 (Fed.Cir.2007).

[22] This court agrees with the district court that the claim term as construed is sufficiently definite. The district court construed "single action of a user input device" to mean "an action by a user within a short period of time that may comprise one or more clicks of a mouse button or other input device."

Trading Techs., 2006 WL 3147697, at *4, 2006 U.S. Dist. LEXIS 80153, at *11. In this context, the word "an action" means one user action. An action may include multiple sub-elements as long as the user views all sub-elements as one user action (e.g., double-click comprising of two single-clicks is "an action"). The invention is different from prior art inventions that required a trader to click on multiple locations before submitting the order. The district court's construction correctly sets objective boundaries by distinguishing the invention from multiple-action systems found in the prior art.

Moreover, one of ordinary skill in the art would distinguish user actions as singular or multiple. The claim construction provides an example of a singular action—one or more clicks of a mouse button. ***1359** Importantly, the district court's construction requires that the "action" must be done in a "short period of time." Although a "short period of time" may vary slightly from one circumstance to the next, an artisan of ordinary skill would not find the term insolubly ambiguous. In fact, eSpeed's expert agreed that the following actions are all single actions: a single mouse click, double mouse clicks, a single key press, and a modal shift on the keyboard (such as combination of the Control key or the Alt key with another key). eSpeed's expert also agreed that other actions, such as a right click followed by a left click, and pressing two keys in sequential order, constituted multiple actions. Given the record and the trial court's definition of the term "single action," this court agrees that the claim terms set forth the boundaries of the claim scope.

VII.

The jury found that the patents-in-suit claimed priority to their provisional application, which was filed on March 2, 2000. Every claim of the patents-in-suit recites use of a "single action of a user input device." In contrast, the provisional application never refers to a "single action of a user input device," but instead refers solely to "a single click of a computer mouse."

[23] Claims enjoy the earlier filing date only if the provisional application provided adequate written description under 35 U.S.C. § 112, ¶ 1. *New Railhead Mfg. v. Vermeer Mfg.*, 298 F.3d 1290, 1294 (Fed.Cir.2002). The "prior application itself must describe an invention ... in sufficient detail that one skilled in the art can clearly conclude that the inventor invented the claimed invention as of the filing date sought." *Lockwood v. Am. Airlines*, 107 F.3d 1565, 1572 (Fed.Cir.1997). Therefore, the provisional application must describe the invention in such a way that one of ordinary skill in the art "would understand that the genus that is being claimed has been invented, not just the species of a genus." *Carnegie Mellon Univ. v. Hoffmann–La Roche, Inc.*, 541 F.3d 1115, 1124 (Fed.Cir.2008).

eSpeed alleges that the district court erred in finding that one of ordinary skill in the art would understand the provisional application to mean that traders could enter orders through a "single action of a user input device." Specifically, eSpeed disputes the district court's summary judgment ruling, jury instruction, decision to admit expert testimony, and JMOL ruling on priority date.

[24] First, eSpeed argues that the district court incorrectly denied its motion for summary judgment on the ground that there was a triable issue as to whether the provisional application's disclosure was adequate. This court reviews a denial of a motion for summary judgment for an abuse of discretion. *Cross Med. Prods. v. Medtronic Sofamor Danek, Inc.*, 424 F.3d 1293, 1302 (Fed.Cir.2005). On summary judgment, the parties' experts disagreed that the provisional application showed possession of forms of order entry other than "a single click of a computer mouse." Harris Brumfield, one of the inventors of the patents-in-suit, suggested that "one click of a mouse" is merely one way of entering orders on the exchange. Therefore, the parties created a dispute of material fact about whether the disclosure of a species, i.e., "one click of a mouse," was sufficient to show that the inventors possessed the genus, i.e., "single action of a user input device." The district court did not abuse its discretion by determining that the parties' irreconcilable testimony created a dispute of material fact, precluding a grant of summary judgment on this issue.

***1360** [25] Second, eSpeed also argues that the court incorrectly instructed the jury on the law of written description. This court reviews "the legal sufficiency of jury instructions on an issue of patent law without deference to the district court." *Amgen Inc. v. F. Hoffmann–La Roche, Ltd.*, 580 F.3d 1340, 1368 (Fed.Cir.2009) (citation omitted). In its brief, eSpeed quotes one sentence from the jury instruction. The district court's jury instruction was much longer

and included the following sentence:

> To provide adequate support you must find that the Provisional Application shows that one reasonably skilled in the art, reading the Provisional Application that explicitly calls for "single-click" user entry, would have known that patentee had possession of a broader "single action of a user input device."

This jury instruction comports with this court's law on written description. Moreover this instruction gave the jury adequate information to make a decision based on the possession standard of this court. This court finds that the jury instruction was not legally erroneous.

[26] eSpeed argues as well that the testimony of TT's expert, Larry Nixon, was improper. This court reviews a district court's decision to admit expert testimony under regional circuit law. *Micro Chem., Inc. v. Lextron, Inc.*, 317 F.3d 1387, 1391 (Fed.Cir.2003). The Seventh Circuit reviews such evidentiary rulings for abuse of discretion. *Liquid Dynamics Corp. v. Vaughan Co., Inc.*, 449 F.3d 1209, 1218 (Fed.Cir.2006). Larry Nixon testified generally about the written description requirement and did not offer legal conclusions as to the adequacy of the provisional application's disclosure. While offering general opinions on patent practices, he did not usurp the district court's role of instructing the jury on the law. Therefore, the district court did not abuse its discretion by permitting his testimony.

[27] Finally, eSpeed contests the district court's denial of its Rule 50(b) motion for JMOL. This court reverses a denial of a JMOL motion "only if the jury's factual determinations are not supported by substantial evidence or the legal conclusions implied from the verdict cannot be supported in law by those findings." *Tronzo v. Biomet, Inc.*, 156 F.3d 1154, 1157 (Fed.Cir.1998).

eSpeed did not submit its Rule 50(a) JMOL motion at the close of evidence. This case, however, is not an instance where the district court entertained a Rule 50(b) JMOL motion that was not preserved before the jury verdict. Instead, the district court explicitly permitted each party to preserve JMOL motions by offering "place holders" with "the details to be filled in later." Albeit in abbreviated form, the district court found that eSpeed had presented and preserved its Rule 50(a) JMOL motion. This court is "not disposed to override" a district court's determination of non-waiver. *Gaus v. Conair Corp.*, 363 F.3d 1284, 1287 (Fed.Cir.2004).

[28] Turning to the merits, the record shows substantial evidence to support the jury's verdict that the provisional application's written description was adequate. TT's expert, Craig Pirrong explained that the provisional application distinguished between order entries performed in a single action and multiple-step actions. He did not distinguish a single-click from other types of single actions. Therefore, one of ordinary skill in the art could read the provisional application to encompass any single actions.

Moreover, the parties' experts did not dispute that one of ordinary skill in the art would have known about other forms of "single action" such as a double-click or ***1361** pressing a key. Considering the undisputed knowledge of those skilled in the art, disclosure of a species in this case provides sufficient written description support for a later filed claim directed to a very similar and understandable genus. Accordingly, the patents-in-suit are entitled to claim priority to the provisional application.

VIII.

[29] eSpeed also appeals the district court's grant of motion in limine precluding it from alleging the on-sale bar defense. The facts relevant to the on-sale bar defense are fairly simple. In September 1998, Harris Brumfield, one of the inventors of the patents-in-suit and an avid trader on electronic exchanges, conceived an idea that formed the basis of the invention. Brumfield hired TT to build trading software based on his idea. On September 29, 1998, TT and Brumfield entered into Individual Consulting Agreement # 2 ("ICA2"), which provided that "TT will build a new trading window according to specifications provided to TT by Harris Brumfield." In mid-February 1999, TT delivered a "market depth trader workstation" to Brumfield. On March 2, 1999, Brumfield agreed to pay TT for the custom software.

[30][31][32] An on-sale bar under 35 U.S.C. § 102(b) applies when the invention was both the subject of a commercial sale and ready for patenting before the critical date. *Pfaff v. Wells Elecs., Inc.*, 525 U.S. 55, 67, 119 S.Ct. 304, 142 L.Ed.2d 261 (1998). The transaction at issue must be a "sale" in a com-

mercial law sense. *Allen Eng'g Corp. v. Bartell Indus., Inc.*, 299 F.3d 1336, 1352 (Fed.Cir.2002). "[A] sale is a contract between parties to give and to pass rights of property for consideration which the buyer pays or promises to pay the seller for the thing bought or sold." *In re Caveney*, 761 F.2d 671, 676 (Fed.Cir.1985). The invention is ready for patenting, *inter alia,* if there is "proof of reduction to practice before the critical date." *Plumtree Software, Inc. v. Datamize, LLC*, 473 F.3d 1152, 1161 (Fed.Cir.2006). The district court granted TT's motion in limine to preclude eSpeed from arguing a prior sale of the invention. TT characterizes this as a de facto summary judgment dismissing eSpeed's on-sale bar defense under 35 U.S.C. § 102(b).

This court affirms the district court's de facto summary judgment that ICA2 was not a sales transaction for a product embodying the patented invention. Under ICA2, TT promised to develop trading software for Brumfield because he lacked the technical expertise to do so. ICA2 was a contract for providing hourly programming services to Brumfield—not a computer software license. Brumfield did not sell or offer for sale anything embodying the invention. Therefore, the trial court properly determined that the invention had not been offered for a commercial sale.

eSpeed's reliance on *Brasseler, U.S.A. I, L.P. v. Stryker Sales Corp.*, 182 F.3d 888 (Fed.Cir.1999), to characterize ICA2 as a commercial software license is misplaced. In *Brasseler,* the buyer and the seller of the contract each employed some inventors of the patented invention. *Id.* at 890. This court found a commercial sale because the seller manufactured over 3,000 products embodying the invention and sold it solely to the buyer. *Id.* at 890. Thus, the transaction in this 1999 Federal Circuit case is far more than occurred here. No product was ever sold to Brumfield. Also, this court in *Brasseler* in dicta suggested that the outcome would be different in "a case in which an individual inventor takes a design to a fabricator and pays the fabricator for its services in fabricating a few sample products." *Id.* at 891. Inventors can request another entity's services in ***1362** developing products embodying the invention without triggering the on-sale bar. Brumfield's request to TT to make software for his own secret, personal use could not constitute a sale under 35 U.S.C. § 102(b).

IX.

[33][34] A patent may be rendered unenforceable for inequitable conduct if an applicant, with intent to mislead or deceive the examiner, fails to disclose material information or submits materially false information to the PTO during prosecution. *Digital Control Inc. v. Charles Mach. Works*, 437 F.3d 1309, 1313 (Fed.Cir.2006) (citation omitted). Where a judgment regarding inequitable conduct follows a bench trial, as it did here, this court reviews the district court's findings of materiality and intent for clear error and its ultimate conclusion for an abuse of discretion. *ACCO Brands, Inc. v. ABA Locks Mfg. Co.*, 501 F.3d 1307, 1314 (Fed.Cir.2007). The district court held that TT did not engage in inequitable conduct by not disclosing Brumfield's custom software to the PTO because the software was not material to the question of patentability. This court agrees.

[35] The first issue this court addresses is whether the use of Brumfield's software between March 2 and June 9, 1999 was material. The district court found that TT relied on the March 2, 1999 priority date in good faith, and that TT did not need to disclose Brumfield's use of software past this priority date. The record also suggests that the examiner never questioned the March 2, 1999 priority date. In submitting a brochure for MD—Trader, one of TT's commercial embodiments of the patents-in-suit, TT stated to the examiner that the brochure was disclosed to the public no earlier than March 2, 1999. This disclosure would have triggered a request for further information if the examiner had detected a priority date issue. Instead, the examiner did not perceive any issue and allowed the claims. The district court did not clearly err by finding that Brumfield's software was immaterial given that his use of the software after the priority date would not have changed the examiner's analysis of the patent. *See Reactive Metals & Alloys Corp. v. ESM, Inc.*, 769 F.2d 1578, 1583 (Fed.Cir.1985) ("[T]here is no point in bringing sales activities to the examiner's attention which, for example, did not occur before the one-year grace period simply to have the examiner 'decide' that the sales were not early enough to trigger the time bar.")

[36][37] The second issue is whether TT should have disclosed any pre-March 2, 1999 activities to the PTO. eSpeed argues that TT should have disclosed TT's "sale" of the custom software to Brumfield. However, as discussed above, ICA2 was not a com-

mercial transaction; a reasonable examiner would not have regarded ICA2 as material to the issue of patentability. eSpeed also argues that TT should have disclosed Brumfield's testing of the custom software before March 2, 1999. Experimental uses of the patented invention may in some instances give rise to an issue of patentability. *See* Manville Sales Corp. v. Paramount Sys., Inc., 917 F.2d 544, 552 (Fed.Cir.1990). In this case, however, the record shows that Brumfield tested the software for his own confidential, personal purposes. *See* Elizabeth v. Am. Nicholson Pavement Co., 97 U.S. 126, 134–35, 24 L.Ed. 1000 (1878). The district court did not clearly err by finding that a reasonable examiner similarly would not have regarded such experimental use as material. Brumfield kept the software secret until TT and Brumfield decided to file a provisional application. Accordingly, the district court did not abuse its discretion in ***1363** finding that the TT did not engage in inequitable conduct.

X.

For the above-stated reasons, this court affirms on all issues presented on appeal.

AFFIRMED.

LOURIE, Circuit Judge, concurs in the result.

CLARK, District Judge, concurring.

Believing that the judgment is correct and that the opinion correctly analyzes the issues in this case in light of current law, I concur. I write separately to respectfully suggest that the current *de novo* standard of review for claim construction may result in the unintended consequences of discouraging settlement, encouraging appeals, and, in some cases, multiplying the proceedings.

Determination of the meaning that would have been attributed to a claim term by one of ordinary skill in a sophisticated field of art on the date of filing often requires examination of extrinsic evidence—a determination of crucial facts underlying the dispute, as outlined by Judge Rader in the majority opinion. On some occasions, a determination will be made based, in part, on the weight to be given to conflicting extrinsic evidence or even to an evaluation of an expert's credibility.

The standard of review that will be applied by a higher court sets one of the important benchmarks against which competent counsel evaluates decisions regarding settlement and appeal. The importance is highlighted by the fact that every brief must state the standard of review. *See* Fed. R.App. P. 28(a)(9)(B), (b)(5); Fed. Cir. R. 28(a)(10),(b).

The *de novo* review standard has at least two practical results, neither of which furthers the goal of the "just, speedy, and inexpensive determination of every action and proceeding." Fed.R.Civ.P. 1. First, rejection of settlement is encouraged, and a decision to appeal is almost compelled, where counsel believes the client's position is valid, even if debatable, depending on the view taken of extrinsic evidence. It is a natural reaction upon receiving an unfavorable claim construction from a trial court to conclude that one's own view of complicated facts will be better understood by the judges of the Federal Circuit, who generally have more experience with patent cases, and who, by their own authoritative rule, review the claim construction without regard to any determination the lower court has made.

A patentee has the opportunity to write clearly enough so that the meaning of the claims can be determined from the specification. What public policy is advanced by a rule requiring the determination of underlying facts by more than one court, especially when the likely result is that another group of citizens will be required to "volunteer" for lengthy jury duty on remand?

A second, although less common, consequence of the *de novo* review standard is the opportunity it offers to the party that presents a case with an eye toward appeal rather than the verdict. Skilled counsel who believes a client may not be well received by a jury is tempted to build error into the record by asking for construction of additional terms, and/or presenting only a skeleton argument at the claim construction stage. This is risky, but it would be unusual for this Court to consider a point waived if a particular claim construction had been requested of the trial court and some argument made, but the clearest explanation was presented on appeal. An appellate court normally does not consider an unpreserved point of ***1364** error, but a more sharply focused argument regarding points presented on appeal, from among those that are technically preserved, is actually the goal of the appellate specialist. This tactic would be less inviting if claim construction was officially accorded some measure of deference, even if it was applied only in those cases in

which resort to extrinsic evidence was necessary.

C.A.Fed. (Ill.),2010.
Trading Technologies Intern., Inc. v. eSpeed, Inc.
595 F.3d 1340, 93 U.S.P.Q.2d 1805

END OF DOCUMENT

EXHIBIT 8

The Random House College Dictionary

REVISED EDITION

Based on The Random House Dictionary of the English Language

THE UNABRIDGED EDITION

JESS STEIN • EDITOR IN CHIEF

TABLE OF CONTENTS

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nn.s/ur
Manufactured in the United States of America

as those forming the beard of wheat, barley, etc. **3.** any similar bristle. [ME *awne, agune* < Scand; cf. Icel *ögn* husk, c. Goth *ahana*, OHG *agana, ahana* (> G *Ahne*)] —**awned,** *adj.* —**awn′less,** *adj.*

awn·ing (ô′ning), *n.* **1.** a rooflike shelter of canvas or other material extending over a doorway, from the top of a window, over a deck, etc., in order to provide protection, as from the sun. **2.** a shelter. [?] —**awn′inged,** *adj.*

a·woke (ə wōk′), *v.* a pt. and pp. of **awake.**

A.W.O.L. (*pronounced as initials or, in Mil. slang,* ā′wôl), away from military duties without permission, but without the intention of deserting. Also, **a.w.o.l.** [*A(bsent) W(ith)-o(ut) L(eave)*]

a·wry (ə rī′), *adv., adj.* **1.** with a turn or twist to one side; askew: *to glance or look awry.* **2.** away from the expected or proper direction; amiss; wrong: *Our plans went awry.* [ME *on wry.* See A-[1], WRY]

ax (aks), *n., pl.* **ax·es** (ak′siz), *v.,* **axed, ax·ing.** —*n.* **1.** an instrument with a bladed head on a handle or helve, used for hewing, cleaving, chopping, etc. **2. get the ax,** *Informal.* to be dismissed, expelled, or rejected summarily. **3. have an ax to grind,** *Informal.* to have a personal or selfish motive. —*v.t.* **4.** to shape or trim with an ax. **5.** to chop, cut, split, or sever with an ax. **6.** *Informal.* to dismiss, restrict, or destroy brutally. Also, **axe.** [ME; OE *æx;* akin to Goth *aqizi,* OHG *acchus* (> G *Axt*), L *ascia* (< **acsiā*), Gk *axínē*] —**ax′like′,** *adj.*

Axes
A, Common ax
B, Hatchet
C, Stonemason's ax

ax., axiom.

a·xen·ic (ā zen′ik), *adj.* uncontaminated; germfree.

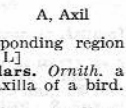
ax·es[1] (ak′sēz), *n.* pl. of **axis**[1].

ax·es[2] (ak′siz), *n.* pl. of **ax.**

axi-, a word element meaning "axis": *axial.* Also, **axo-**; *esp. before a vowel,* **ax-.** [comb. form repr. L *axi(s)* axle, wheel; c. Gk *áxōn,* Skt *ákṣas,* Lith *ašis,* OE *eax*]

ax·i·al (ak′sē əl), *adj.* **1.** of, pertaining to, characterized by, or forming an axis: *an axial relationship.* **2.** situated in an axis or on the axis. Also, **ax·ile** (ak′sil, -sīl). —**ax′i·al′i·ty,** *n.*

ax·i·al·ly (ak′sē ə lē), *adv.* in the line of the axis.



A, Axil

ax′ial skel′eton, *Anat.* the skeleton of the head and trunk.

ax·il (ak′sil), *n. Bot.* the angle between the upper side of a leaf or stem and the supporting stem or branch. [< L *axill(a)* armpit]

ax·il·la (ak sil′ə), *n., pl.* **ax·il·lae** (ak sil′ē). **1.** *Anat.* the armpit. **2.** *Ornith.* the corresponding region under the wing of a bird. **3.** *Bot.* an axil. [< L]

ax·il·lar (ak′sə lər), *n.* **1.** Usually, **axillars.** *Ornith.* a number of the feathers growing from the axilla of a bird. **2.** *Biol.* any axillary part.

ax·il·lar·y (ak′sə ler′ē), *adj., n., pl.* **-lar·ies.** —*adj.* **1.** pertaining to the axilla. **2.** *Bot.* pertaining to or growing from the axil. —*n.* **3.** Usually, **axillaries.** *Ornith.* axillars.

ax·i·ol·o·gy (ak′sē ol′ə jē), *n.* the branch of philosophy dealing with values, as those of ethics, aesthetics, or religion. [< Gk *áxio(s)* worthy, estimable + -LOGY] —**ax·i·o·log·i·cal** (ak′sē ə loj′i kəl), *adj.* —**ax′i·o·log′i·cal·ly,** *adv.* —**ax′i·ol′o·gist,** *n.*

ax·i·om (ak′sē əm), *n.* **1.** a self-evident truth. **2.** a universally accepted principle or rule. **3.** *Logic, Math.* a proposition that is assumed without proof for the sake of studying the consequences that follow from it. [late ME < L *axiōm(a)* < Gk: something worthy = *axió(ein)* (to) reckon worthy + *-ma* n. suffix]

ax·i·o·mat·ic (ak′sē ə mat′ik), *adj.* **1.** pertaining to or of the nature of an axiom; self-evident. **2.** aphoristic. Also, **ax′i·o·mat′i·cal.** [< Gk *axiōmatikós* = *axiōmat-* (s. of *axíōma* AXIOM) + *-ikos* -IC] —**ax′i·o·mat′i·cal·ly,** *adv.*

ax·is[1] (ak′sis), *n., pl.* **ax·es** (ak′sēz). **1.** the line about which a rotating body turns or may be supposed to turn. **2.** a central line bisecting a body, form, or the like, and in relation to which symmetry is determined. **3.** *Anat.* **a.** a central or principal structure, about which something turns or is arranged: *the skeletal axis.* **b.** the second cervical vertebra. **4.** *Bot.* the longitudinal support on which organs or parts are arranged; the stem and root; the central line of any body. **5.** *Analytic Geom.* any line used as a fixed reference in conjunction with one or more other references for determining the position of a point or of a series of points forming a curve or a surface. Cf. **x-axis, y-axis. 6.** *Fine Arts.* an imaginary line, in a given formal structure, about which a form, area, or plane is organized. **7.** an alliance of two or more nations to coordinate their foreign and military policies. **8. the Axis,** (in World War II) Germany, Italy, and Japan, often with Bulgaria, Hungary, and Rumania. **9.** a principal line of development, movement, etc. [< L *axis* an axletree, axle, axis. See AXON, AX] —**ax·ised** (ak′sist), *adj.*

ax·is[2] (ak′sis), *n., pl.* **ax·is·es.** a deer, *Axis axis,* of India and Ceylon, having a reddish-brown coat spotted with white. Also, called **ax′is deer′.** [< L *axis* a wild animal of India]

ax·le (ak′səl), *n.* **1.** *Mach.* the pin, bar, shaft, or the like, on which or by means of which a wheel or pair of wheels rotates. **2.** the spindle at either end of an axletree. **3.** an axletree. [ME *axel,* OE *eaxl* shoulder, crossbeam (in *eaxlegespann*); c. OHG *ahsala* shoulder (> G *Achsel*), Icel *öxull,* L *āla* (< **akslā*)] —**ax′led,** *adj.*

ax·le·tree (ak′səl trē′), *n.* a bar, fixed crosswise under an animal-drawn vehicle, with a rounded spindle at each end upon which a wheel rotates. [ME]

ax·man (aks′mən), *n., pl.* **-men.** a person who wields an ax.

Ax′min·ster car′pet (aks′min′stər), a carpet having a stiff, ribbed backing, as of jute, and an even yarn pile that is usually cut. [named after a town in SW England, although orig. manufactured in the U.S.]

axo-, var. of **axi-,** esp. before a consonant.

ax·o·lotl (ak′sə lot′l), *n.* any larval salamander of the genus *Ambystoma,* found esp. in lakes and ponds of the southwestern U.S. and Mexico, that is capable of breeding in its larval state. [< Nahuatl]


Axolotl, *Ambystoma mexicanum* (Length 6 to 12 in.)

ax·on (ak′son), *n. Anat.* the appendage of the neuron that transmits impulses away from the cell. Also, **ax·one** (ak′sōn). [< NL < Gk *áxōn* an axle, axis; c. L *axis*] —**ax′on·al,** *adj.*

ax·o·no·met·ric (ak′sə nō me′trik, -nə-), *adj. Drafting.* designating a method of projection (**ax′onomet′ric projec′tion**) in which a three-dimensional object is represented by a drawing (**ax′onomet′ric draw′ing**) having all lines drawn to exact scale, resulting in the optical distortion of diagonals and curves. Cf. **cabinet** (def. 17), **isometric** (def. 4), **oblique** (def. 13). See illus. at **isometric.** [< Gk *áxōn* (see AXON) + -o- + -METRIC]

ay[1] (ā), *adv. Literary or Dial.* ever; always. Also, **aye.** [ME *ei, ai* < Scand; cf. Icel *ei,* c. OE *ā* ever]

ay[2] (ā), *interj. Dial.* Ah! Oh!

ay[3] (ī), *adv., n.* aye[1].

A·ya·cu·cho (ä′yä kōō′chō), *n.* a city in SW Peru: victory of Bolívar over Spanish troops 1824. 40,000 (est. 1961).

a·yah (ä′yə), *n.* (in India) a native maid or nurse. [< Hindi *āyā* < Pg *aia* female servant < L *avia* grandmother]

a·ya·tol·lah (ä′yə tō′lə), *n.* (among Shiites) a title in the religious hierarchy achieved by scholars who have demonstrated highly advanced knowledge of Islamic law. [< Pers < Ar *āyat* sign or token (of) + ALLAH]

aye[1] (ī), *adv.* **1.** yes. —*n.* **2.** an affirmative vote or voter. Also, **ay.** [earlier *I,* ME *yie,* alter. of *ye,* OE *gī* YEA]

aye[2] (ā), *adv.* ay[1].

aye-aye (ī′ī′), *n.* a nocturnal lemur, *Daubentonia madagascariensis,* of Madagascar, feeding on insects and fruit, and having rodentlike incisors and long fingers. [< F < Malagasy *aiay,* prob. imit. of its cry]


Aye-aye (Total length 3 ft.; tail 22 in.)

A·ye·sha (ä′ē shä′), *n.* Aisha.

a·yin (ä′yin; *Heb.* ä′yən), *n.* the 16th letter of the Hebrew alphabet. [< Heb]

Ay·ma·ra (ī′mä rä′), *n., pl.* **-ras,** (*esp. collectively*) **-ra** for 1. **1.** a member of an Indian people living in the mountainous regions around Lake Titicaca in Bolivia and Peru. **2.** the language of the Aymara people. [< Sp *armará, aymará,* of AmerInd orig.] —**Ay′ma·ran′,** *adj.*

Ay·mé (e mā′), *n.* **Mar·cel** (mar sel′), born 1902, French novelist and short-story writer.

Ayn·tab (in tab′), *n.* Aintab.

Ayr (ãr), *n.* **1.** a seaport in and the county seat of Ayrshire. 46,200 (est. 1965). **2.** Ayrshire (def. 2).

Ayr·shire (ãr′shēr, -shər), *n.* **1.** one of a Scottish breed of hardy dairy cattle having long, curving horns. **2.** Also called **Ayr.** a county in SW Scotland. 347,670 (est. 1965); 1132 sq. mi. *Co. seat:* Ayr.

A·yub Khan (ä yōōb′ kän′), **Mohammed,** 1907–74, Pakistani political leader: president 1958–69.

A·yur·ve·da (ä′yər vā′də), *n.* the ancient Hindu art of medicine and of prolonging life. [< Skt = *āyur-* life, vital power + *veda* knowledge] —**A′yur·ve′dic,** *adj.*

AZ, Arizona (approved esp. for use with zip code).

az-, var. of **azo-,** esp. before a vowel: *azine.*

a·zal·ea (ə zāl′yə), *n.* any ericaceous plant of a particular group (*Azalea*) of the genus *Rhododendron,* comprising species with variously colored flowers. [< NL < Gk *azalḗa,* n. use of fem. of *azalḗos* dry; so named as growing in dry soil]

a·zan (ä zän′), *n.* (in Islamic countries) the call to prayer proclaimed five times a day by the muezzin. [< Ar *adhān* invitation. See MUEZZIN]

A·za·ña (ä thä′nyä), *n.* **Ma·nuel** (mä nwel′), (*Manuel Azaña y Díez*), 1880–1940, Spanish statesman: prime minister 1931–33, 1936; president 1936–39.

A·za·zel (ə zā′zəl, az′ə zel′), *n.* **1.** the scapegoat released on the Day of Atonement, or its destination, hell. Lev. 16:8, 10, 21. **2.** *Islamic Myth.* the jinn who became Shaitan. **3.** one of the fallen angels.

a·zed·a·rach (ə zed′ə rak′), *n.* chinaberry (def. 1). [< F *azédarac* << Pers *āzād dirakht* noble tree]

a·ze·o·trope (ə zē′ə trōp′), *n. Physical Chem.* any liquid mixture having constant minimum and maximum boiling points and distilling off without decomposition and in a fixed ratio, as isopropyl alcohol and water. [A-[6] + Gk *zé(ein)* (to) boil + -o- + -TROPE] —**a·ze·o·trop·ic** (ā′zē ə trop′ik), *adj.* —**a·ze·ot·ro·py** (ā′zē ot′rə pē), **a′ze·ot′ro·pism,** *n.*

A·zer·bai·jan (ä′zər bī jän′, az′ər bī jan′; *Russ.* ä′zyir bī jän′), *n.* **1.** Official name, **Azerbaijan′ So′viet So′cialist Repub′lic.** a constituent republic of the Soviet Union, in Caucasia. 4,500,000 (est. 1965); ab. 33,000 sq. mi. *Cap.:* Baku. **2.** a province in NW Iran. 2,859,132 (1956); ab. 35,000 sq. mi. *Cap.:* Tabriz. Also, **A′zer·bai·dzhan′.**

A·zer·bai·ja·ni (ä′zər bī jä′nē, az′ər bī jan′ē), *n., pl.* **-ja·nis,** (*esp. collectively*) **-ja·ni.** a native or inhabitant of Azerbaijan.

az·ide (az′id, -id, ā′zīd, ā′zid), *n. Chem.* any compound containing the azido group, as sodium azide, NaN_3. [AZ- + -IDE]

az′i·do group′ (az′i dō′), *Chem.* the univalent group, N_3–, derived from hydrazoic acid. Also called **az′ido·rad′i·cal.** [AZID(E) + -O-]

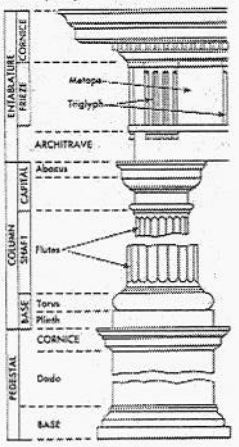
A·zil·ian (ə zil′yən, -ē ən, ə zil′-), *adj.* of, pertaining to, or characteristic of a Mesolithic culture of southern France. [named after Mas d'*Azil,* town in S France, where the culture flourished; see -IAN]

az·i·muth (az′ə məth), *n.* **1.** *Astron., Navig.* the arc of the

of the New World by Columbus and his landing in the West Indies on October 12, 1492.

col·u·mel·la (kol′yə mel′ə), *n., pl.* **-mel·lae** (-mel′ē). *Anat., Zool., Bot.* a small columnlike part; axis. [< L: small column = *colum-* (var. of *column-*, s. of *columna* COLUMN) + *-ella* dim. suffix] —**col·u·mel′lar,** *adj.* —**col·u·mel·late** (kol′yə mel′it, -āt), *adj.*

col·umn (kol′əm), *n.* **1.** *Archit.* **a.** a rigid, relatively slender, upright support, composed of relatively few pieces. **b.** a decorative pillar, most often composed of stone and typically having a cylindrical or polygonal shaft with a capital and usually a base. **2.** any columnlike object, mass, or formation: *a column of smoke.* **3.** a vertical arrangement on a page of horizontal lines of type, usually justified: *There are two columns on this page.* **4.** a vertical row or list. **5.** a regular article or feature in a newspaper or magazine. **6.** a formation of ships in single file. **7.** a long, narrow formation of troops in which there are more members in line in the direction of movement than at right angles to the direction (distinguished from *line*). [late ME *columne* < L *columna* = *colum(e)n* peak + *-a* fem. ending; akin to EX)CEL; r. late ME *colompne* < MF] —**col·umned** (kol′əmd), **col·um·nat·ed** (kol′əmnā′tid), *adj.*



Column, Roman Doric order

—**Syn. 1.** COLUMN, PILLAR refer to upright supports in architectural structures. PILLAR is the general word: *the pillars supporting the roof.* A COLUMN is a particular kind of pillar, esp. one with an identifiable shaft, base, and capital: *columns of the Corinthian order.*

co·lum·nar (kə lum′nər), *adj.* **1.** shaped like a column. **2.** characterized by columns: *columnar architecture.* **3.** Also, **co·lum′nal.** printed, arranged, etc., in columns. [< LL *columnār(is)*]

co·lum·ni·a·tion (kə lum′nē ā′shən), *n. Archit.* **1.** the employment of columns. **2.** the system of columns in a structure. [abstracted from (INTER)COLUMNIATION]

col·umn·ist (kol′əm nist, -ə mist), *n.* the writer or editor of a journalistic column.

co·lure (kə lo͝or′, kō-, kō′lo͝or), *n. Astron.* either of two great circles of the celestial sphere intersecting each other at the poles, one passing through both equinoxes and the other through both solstices. [< LL *colūr(us)* < Gk *kólour(os)* dock-tailed = *kól(os)* docked + *our(á)* tail + *-os* adj. suffix]

col·za (kol′zə), *n.* rape². [< F < D *koolzaad* = *kool* COLE + *zaad* SEED]

col′za oil′. See **rape oil.**

com-, a prefix meaning "with," "together," "in association," and (with intensive force) "completely," occurring in loan words from Latin (*commit*): used in the formation of compound words before *b, p, m: combine; compare; commingle.* Also, **co-, con-, col-, cor-.** [< L, var. of prep. *cum* with]

Com., 1. Commander. 2. Commission. 3. Commissioner. 4. Commodore.

com., 1. comedy. 2. commerce. 3. common. 4. commonly. 5. committee.

co·ma¹ (kō′mə), *n., pl.* **-mas.** a state of prolonged unconsciousness due to disease, injury, poison, etc.; stupor. [< Gk *kôma* deep sleep]

co·ma² (kō′mə), *n., pl.* **-mae** (-mē). **1.** *Astron.* the nebulous envelope around the nucleus of a comet. **2.** *Optics.* a monochromatic aberration of a lens or other optical system in which the image from a point source cannot be brought into focus, the image of a point having the shape of a comet. **3.** *Bot.* **a.** a tuft of silky hairs at the end of a seed. **b.** the leafy crown of a tree; cluster of leaves at the end of a stem. **c.** a terminal cluster of bracts, as in the pineapple. [< L: hair < Gk *kómē*]


Coma² (def. 3a) on seed of milkweed, *Asclepias syriaca*

Co·ma Ber·e·ni·ces (kō′mə ber′ə nī′sēz), *gen.* **Co·mae Ber·e·ni·ces** (kō′mē ber′ə nī′sēz). *Astron.* Berenice's Hair, a northern constellation situated north of Virgo and between Boötes and Leo. [< L]

co·mak·er (kō mā′kər, kō′mā′kər), *n. Finance.* a person who formally undertakes to discharge the duties of the maker of an instrument, esp. a promissory note, in the event of the maker's default.

Co·man·che (kō man′chē, kə-), *n., pl.* **-ches,** (*esp. collectively*) **-che** for 1. **1.** a member of a Shoshonean tribe, formerly ranging from Wyoming to Texas, now in Oklahoma. **2.** their speech, a dialect of Shoshone. [< MexSp < Shoshone]

Co·man·che·an (kō man′chē ən, kə), *Geol.* —*adj.* **1.** pertaining to an epoch or series of rocks in parts of North America comprising the early portion of the Cretaceous period or system. —*n.* **2.** an epoch or series of early Cretaceous rocks typically represented in the Gulf of Mexico region.

co·man·dan·te (kom′ən dan′tē; *Sp.*, *It.* kō′män dän′te), *n., pl.* **-tes** (-tēz; *Sp.* -tes), *It.* **-ti** (-tē). commandant. [< Sp, It]

co·mate¹ (kō māt′), *n.* a companion. [co- + MATE¹]

co·mate² (kō′māt), *adj.* **1.** *Bot.* having a coma. **2.** hairy; tufted. [< L *comāt(us)*]

com·a·tose (kom′ə tōs′, kō′mə-), *adj.* **1.** affected with or characterized by coma: *The patient was comatose after the stroke.* **2.** lacking alertness or energy; lethargic. [< Gk *komat-* (s. of *kôma* COMA¹) + -OSE¹] —**com′a·tose′ly,** *adv.*

co·mat·u·lid (kə mach′ə lid), *n.* a free-swimming, stalkless crinoid; a feather star. [< NL *Comatulid(ae)* = *Comatul(a)* genus name (see COMATE²) + *-idae* -IDAE]

comb¹ (kōm), *n.* **1.** a toothed strip of bone, metal, plastic, etc., for arranging the hair or holding it in place. **2.** a currycomb. **3.** any comblike instrument, object, or formation. **4.** a machine for separating choice cotton or worsted fibers from noil. **5.** the fleshy, more or less serrated excrescence or growth on the head of certain gallinaceous birds, esp. the domestic fowl. **6.** something resembling or suggesting this, as the crest of a wave. **7.** a honeycomb, or any similar group of cells. —*v.t.* **8.** to arrange or adorn (the hair) with or as with a comb. **9.** to remove (anything undesirable) with or as with a comb: *to comb burs from one's hair.* **10.** to search everywhere in: *to comb the files.* **11.** to separate (wool fibers) with a comb. —*v.i.* **12.** to roll over or break at the crest, as a wave. [ME: OE *comb, camb*; c. OHG *kamb* (G *Kamm*), Icel *kambr*, Gk *gómphos* pin, peg, *gomphíos* molar tooth; see CAM]

comb² (kōōm, kōm), *n.* combe.

comb., combining.

com·bat (*v.* kəm bat′, kom′bat, kum′-; *n.* kom′bat, kum′-), *v.*, **-bat·ed, -bat·ing** or (*esp. Brit.*) **-bat·ted, -bat·ting,** *n.* —*v.t.* **1.** to fight or contend against; oppose vigorously. —*v.i.* **2.** to fight; contend: *to combat with crippling diseases.* —*n.* **3.** a controversy, or fight between two ideals, men, etc. **4.** *Mil.* active fighting between enemy forces. [< MF *combatt(re)* < VL **combattere* = L *com-* COM- + *battuere* to strike, beat] —**Syn. 1, 2.** struggle, contest. **3.** contention, battle. See **fight.**

com·bat·ant (kəm bat′ənt, kom′bə tənt, kum′-), *n.* **1.** a person or group that fights. —*adj.* **2.** combating; fighting: *the combatant armies.* **3.** disposed to combat. [late ME *combataunt* < MF *combatant.* See COMBAT, -ANT]

com′bat boot′, a heavy leather shoe having a buckled extension above the ankle and a sole and heel of hard rubber.

com′bat fatigue′. See **battle fatigue.**

Com′bat In′fantryman Badge′, a U.S. military badge awarded to an infantryman in recognition of satisfactory performance of duty in ground combat.

com·bat·ive (kəm bat′iv, kom′bə tiv, kum′-), *adj.* ready or inclined to fight; pugnacious. —**com·bat′ive·ly,** *adv.* —**com·bat′ive·ness,** *n.*

combe (kōōm, kōm), *n. Brit.* a narrow valley or deep hollow, esp. one enclosed on all but one side. Also, **comb, coomb, coombe.** [OE *cumb* valley < Celt; cf. Gaulish *cumbā*, Welsh *cwm* valley]

combed′ yarn′, cotton or worsted yarn of fibers laid parallel, superior in smoothness to carded yarn.

com·ber (kō′mər), *n.* **1.** a person or thing that combs. **2.** a long, curling wave.

com·bi·na·tion (kom′bə nā′shən), *n.* **1.** the act of combining. **2.** the state of being combined. **3.** a number of things combined: *a combination of ideas.* **4.** something formed by combining: *A chord is a combination of notes.* **5.** an alliance of persons or parties. **6.** the set or series of numbers or letters used in setting the mechanism of a combination lock. **7.** the parts of the mechanism operated by this. **8.** *Math.* **a.** the arrangement of a number of individuals into various groups, as *a, b,* and *c* into *ab, ac,* and *bc.* **b.** a group thus formed. [< LL *combīnātiōn-* (s. of *combīnātiō*) = *combīnāt(us)* combined (see COMBINE, -ATE¹) + *-iōn-* -ION] —**com′bi·na′tion·al,** *adj.*

—**Syn. 1.** association, union, coalescence. **3.** mixture, amalgamation, amalgam. COMBINATION, COMPOSITE, COMPOUND all mean a union of individual parts. COMBINATION implies a grouping that is close but that may easily be dissolved. A COMPOSITE is a stronger union, in which the parts have become subordinate to a unity. COMPOUND implies a more or less complete merging of individual parts into an organic whole. **5.** association, federation, coalition; bloc.

combina′tion last′, a shoe last that has a narrower heel or instep than the standard last.

combina′tion lock′, a lock opened by turning one or more dials a given number of times through a particular set of positions in a prescribed order and direction.

com·bi·na·tive (kom′bə nā′tiv, kəm bī′nə-), *adj.* **1.** tending or serving to combine. **2.** of, pertaining to, or resulting from combination.

com·bi·na·to·ri·al (kəm bī′nə tōr′ē əl, -tōr′-), *adj. Math.* of or pertaining to combination, or the modes, properties, etc., of combinations. Also, **com·bi′na·to′ry.**

combinato′rial anal′ysis, *Math.* the branch of mathematics that deals with permutations and combinations, esp. used in statistics and probability.

com·bine (*v.* kəm bīn′; *n.* kom′bīn), *v.*, **-bined, -bin·ing,** *n.* —*v.t.* **1.** to bring or join into a close union or whole; unite; associate; coalesce: *She combined the ingredients to make the dough.* —*v.i.* **2.** to unite; coalesce: *The clay combined with the water to form a milky suspension.* **3.** to unite for a common purpose; join forces: *After the two armies had combined, they proved invincible.* **4.** to enter into chemical union. —*n.* **5.** a combination. **6.** *U.S. Informal.* a combination of persons or groups for the furtherance of their political, commercial, or other interests. **7.** a machine for cutting and threshing grain in the field. [late ME *combynyn* < LL *combīnāre* = *com-* COM- + *bīn-* (s. of *bīnī* two by two) + *-ā-* v. suffix + *-re* inf. ending] —**com·bin′a·bil′i·ty,** *n.* —**com·bin′a·ble,** *adj.* —**com·bin′er,** *n.* —**Syn. 1.** compound, amalgamate. **6.** merger, alignment, bloc. —**Ant. 1, 2.** separate.

comb·ings (kō′miŋgz), *n.pl.* hairs removed with a comb or a brush.

combin′ing form′, *Gram.* a linguistic form used only in compound words, never independently, as *hemato-* in *hematology.*

combin′ing weight′, *Chem.* the atomic weight of an atom or radical divided by its valence.

comb′ jel′ly (kōm), ctenophore.

Obs. a quantity of goods. [late ME *commodite* < MF < L *commoditās-* (s. of *commoditās*). See COMMODE, -ITY]

commod′ity exchange′, an exchange for the buying and selling of commodities (such as butter, coffee, sugar, and grains) for future delivery.

com·mo·dore (kom′ə dôr′, -dōr′), *n.* **1.** *U.S. Navy.* (not used in peacetime) a grade of flag officer next in rank below a rear admiral. **2.** *Brit. Navy.* an officer in temporary command of a squadron, sometimes over a captain on the same ship. **3.** (in the U.S. Navy and Merchant Marine) the senior captain when two or more ships are cruising in company or the officer in command of a convoy. **4.** the senior captain of a line of merchant vessels. **5.** the president or head of a yacht club or boat club. [var. of *commandore* = COMMAND + *-ore*, unexplained var. of *-or*[2]]

Com·mo·dus (kom′ə dəs), *n.* **Lucius Ae·li·us Aurelius** (ē′lē əs), A.D. 161–192, Roman emperor 180–192; son and successor of Marcus Aurelius.

com·mon (kom′ən), *adj.* **1.** belonging equally to or shared alike by two or more or all in question: *common property; common interests.* **2.** pertaining or belonging equally to an entire community, nation, or culture; public: *a common language.* **3.** joint; united: *a common defense.* **4.** widely and unfavorably known; notorious: *a common thief.* **5.** widespread; general: *common knowledge.* **6.** of frequent occurrence; usual; familiar: *a common mistake.* **7.** hackneyed; trite. **8.** of mediocre or inferior quality; mean; low: *a rough-textured suit of the most common fabric.* **9.** coarse or vulgar: *common manners.* **10.** having no rank, station, distinction, etc.; ordinary: *a common soldier.* **11.** *Anat.* forming or formed by two or more parts or branches: *the common carotid arteries.* **12.** *Pros.* (of a syllable) able to be considered as either long or short. **13.** *Gram.* **a.** not belonging to an inflectional paradigm; fulfilling different functions which in some languages require different inflected forms: *English nouns are in the common case whether used as subject or object.* **b.** constituting a gender comprising nouns that were formerly masculine or feminine: *Swedish nouns are either common or neuter.* **c.** noting a word that may refer to either a male or a female. **14.** *Math.* bearing a similar relation to two or more entities. —*n.* **15.** Often, **commons.** a tract of land owned or used jointly by the members of a community, usually a pasture or a park. **16.** *Law.* the right or liberty, in common with other persons, to take profit from the land or waters of another. **17. commons, a.** the commonalty; the nonruling class. **b.** the body of people not of noble birth or not ennobled, as represented in England by the House of Commons. **c.** (*cap.*) the representatives of this body. **d.** (*cap.*) the House of Commons. **e.** a large dining room, esp. at a university or college. **f.** *Brit.* food provided in such a dining room. **g.** food or provisions for any group. **18.** (*sometimes cap.*) *Eccles.* **a.** an office or form of service used on a festival of a particular kind. **b.** the ordinary of the Mass, esp. those parts sung by the choir. **19.** *Obs.* **a.** the community or public. **b.** the common people. **20. in common,** in joint possession or use; shared equally. [ME *comun* < OF < L *commūn(is)* = *com-* COM- + *mūnis* serviceable, obliging, akin to MEAN[2]] —**com′mon·ness,** *n.*

—**Syn. 5.** universal, prevalent, popular. See **general. 6.** customary, everyday. **10.** COMMON, VULGAR, ORDINARY refer, often with derogatory connotations of cheapness or inferiority, to what is usual or most often experienced. COMMON applies to what is accustomed, usually experienced, or inferior, to the opposite of what is exclusive or aristocratic: *She is a common person.* VULGAR properly means belonging to the people, or characteristic of common people; it connotes low taste, coarseness, or ill breeding: *the vulgar view of things; vulgar in manners and speech.* ORDINARY means what is to be expected in the usual order of things; or only average, or below average: *That is a high price for something of such ordinary quality.* —**Ant. 1.** individual, private, personal. **6.** unusual, strange.

com·mon·a·ble (kom′ə nə bəl), *adj.* **1.** held jointly; for general use; public: *commonable lands.* **2.** allowed to be pastured on common land: *commonable cattle.*

com·mon·age (kom′ə nij), *n.* **1.** the joint use of anything, esp. a pasture. **2.** the right to such use. **3.** the state of being held in common. **4.** something that is so held, as land. **5.** the commonalty.

com·mon·al·ty (kom′ə nᵊl tē), *n., pl.* **-ties. 1.** Also **com·mon·al·i·ty** (kom′ə nal′i tē), the ordinary or common people. **2.** an incorporated body or its members. [late ME < MF *comunalte* (see COMMUNAL, -TY); r. ME *communaute* < OF]

com′mon car′rier, an individual or company, as a railroad or steamship line, engaged in transporting passengers or cargo or both for payment. Also called **carrier.**

com′mon cold′, cold (def. 15).

com′mon coun′cil, the local legislative body of a municipal government.

com′mon denom′inator, 1. *Math.* a number that is a multiple of all the denominators of a set of fractions. **2.** a trait, characteristic, belief, or the like, common to or shared by all members of a group.

com′mon divi′sor, *Math.* a number that is a submultiple of all the numbers of a given set. Also called **com′mon fac′tor.**

com·mon·er (kom′ə nər), *n.* **1.** a member of the commonalty. **2.** *Brit.* **a.** a person without a title of nobility. **b.** a member of the House of Commons. **c.** (at Oxford and some other universities) a student who pays for his commons and other expenses and is not supported by any scholarship or foundation. **3.** a person who has a joint right in common land. [ME *cominer*]

Com′mon E′ra. See **Christian Era.**

com′mon frac′tion, *Arith.* a fraction represented as a numerator above and a denominator below a horizontal or diagonal line. Cf. **decimal fraction.**

com′mon law′, 1. the system of law originating in England, as distinct from the civil or Roman law and the canon or ecclesiastical law. **2.** the unwritten law, esp. of England, based on custom or court decision, as distinct from statute law. **3.** the general law administered through the system of courts, as distinct from equity, admiralty, etc. [ME *commune lawe*]

com·mon-law (kom′ən lô′), *adj.* of, pertaining to, or established by common law.

com′mon-law mar′riage, a marriage without a civil or ecclesiastical marriage ceremony, generally resulting from a couple's living together as man and wife for a specified time.

com′mon log′arithm, *Math.* a logarithm having 10 as the base. Cf. **natural logarithm.**

com·mon·ly (kom′ən lē), *adv.* **1.** in a common manner. **2.** usually; generally; ordinarily. [ME *communelich*]

com′mon man′, a man who is not distinguished by birth, station, education, or the like; the average man.

Com′mon Mar′ket, 1. Official name, **European Economic Community.** an economic association established in 1958, originally composed of Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany, created chiefly to abolish barriers to free trade among member nations and to adopt common import duties on goods from other countries. **2.** (*sometimes l.c.*) any economic association of nations created for a similar purpose.

com′mon meas′ure, 1. See **common time. 2.** Also called **hymnal stanza.** *Pros.* a ballad stanza of four iambic lines and strict rhymes, often used in hymns, rhyming *abcb* or *abab.*

com′mon mul′tiple, *Math.* a number that is a multiple of all the numbers of a given set.

com′mon noun′, *Gram.* a noun that denotes a class or any member of a class of entities and not an individual, as *man, city, horse.* Cf. **proper noun.**

com′mon peo′ple, those people who do not belong to the aristocracy or who lack social distinction; the masses.

com·mon-place (kom′ən plās′), *adj.* **1.** ordinary; undistinguished or uninteresting. **2.** platitudinous or dull. —*n.* **3.** a well-known, customary, or obvious remark; a trite or uninteresting saying. **4.** anything common, ordinary, or uninteresting. **5.** *Archaic.* a place or passage in a book or writing noted as important for reference or quotation. [trans. of L *locus commūnis*, itself trans. of Gk *koinòs tópos*] —**com′·mon-place′ness,** *n.*

—**Syn. 2.** COMMONPLACE, BANAL, HACKNEYED, STEREOTYPED, TRITE describe words, remarks, and styles of expression that are lifeless and uninteresting. COMMONPLACE characterizes thought that is dull, ordinary, and platitudinous: *commonplace and boring.* Something is BANAL that seems inane, insipid, and pointless: *a heavy-handed and banal affirmation of the obvious.* HACKNEYED characterizes that which seems stale and worn out through overuse: *a hackneyed comparison.* STEREOTYPED emphasizes the fact that situations felt to be similar invariably call for the same thought in exactly the same form and the same words: *so stereotyped as to seem automatic.* TRITE describes that which was originally striking and apt, but which has become so well known and been so commonly used that all interest has been worn out of it: *true but trite.* **3.** cliché, platitude.

com′monplace book′, a book in which noteworthy quotations, poems, comments, etc., are written.

com′mon pleas′, 1. any of various courts of civil jurisdiction in several U.S. states. **2.** the chief common-law court of civil jurisdiction in England, now merged in the King's Bench Division of the High Court.

com′mon pray′er, 1. prayer for reciting by a group of worshipers. **2.** (*caps.*) See **Book of Common Prayer.**

com′mon prop′erty, 1. property belonging to all members of a community. **2.** someone or something regarded as belonging to the public in general: *The personal lives of celebrities become common property.* **3.** information that is commonly known; common knowledge.

com′mon room′, *Chiefly Brit.* (in institutions, esp. schools and colleges) a room or lounge for informal use by all.

com′mon school′, *U.S.* a public school.

com′mon sense′, sound practical judgment that is independent of specialized knowledge, training, or the like; normal native intelligence. [trans. of L *sensus communis*, itself trans. of Gk *koinḕ aísthēsis*] —**com′mon-sen′si·cal, com′mon-sen′si·ble,** *adj.*

com′mon snipe′. See under **snipe** (def. 1).

com′mon stock′, stock that ordinarily has no preference in the matter of dividends or assets and represents the residual ownership of a corporate business.

com′mon time′, *Music.* a meter consisting usually of four quarter notes, or their equivalent, to the measure; 4/4 time. Also called **four-four time.**

com·mon-weal (kom′ən wēl′), *n.* **1.** the common welfare; the public good. **2.** *Archaic.* the body politic; a commonwealth. [ME *comen wele*]

com·mon-wealth (kom′ən welth′), *n.* **1.** (*cap.*) a group of sovereign states and their dependencies associated by their own choice and linked with common objectives and interests. **2. the Commonwealth.** See **British Commonwealth of Nations. 3.** (*cap.*) a federation of former colonies, esp. as a dominion of the British Commonwealth: *the Commonwealth of Australia.* **4.** (*cap.*) a self-governing territory associated with the U.S.: official designation of Puerto Rico. **5.** (*cap.*) *Eng. Hist.* the English government from the abolition of the monarchy in 1649 until the establishment of the Protectorate in 1653, sometimes extended to include the restoration of Charles II in 1660. **6.** (*cap.*) the official designation (rather than "State") of Kentucky, Massachusetts, Pennsylvania, and Virginia. **7.** any group of persons united by some common interest. **8.** the people of a nation or state; the body politic. **9.** a state in which the supreme power is held by the people. **10.** *Obs.* the public welfare. [late ME *commen wealthe*]

Com′monwealth Day′, May 24, the anniversary of Queen Victoria's birth, observed in some countries of the British Commonwealth of Nations. Formerly, **Empire Day.**

Com′monwealth of Na′tions. See **British Commonwealth of Nations.**

com′mon year′, an ordinary year of 365 days; a year having no intercalary period. Cf. **leap year.**

com·mo·tion (kə mō′shən), *n.* **1.** violent or tumultuous motion; agitation; noisy disturbance. **2.** political or social

EXHIBIT 9

Webster's Collegiate Thesaurus

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ISM 1, critique, notice, review, reviewal
syn REMARK 2, animadvert, commentate, ob-
elucidate, explain, explicate, expound; anno-
n syn REMARK 2, comment, note, obiter dic-
vb syn REMARK 2, animadvert, comment, ob-
1 syn CONTACT 2, communication, commu-
intercommunication, intercourse
characterized by mutual exchange (as of
those who feel that art should have no *commerce*
>
ion, dealings, intercourse, traffic, truck
unication, congress, contact, exchange, inter-
intercommunication; basis, common ground, take-
NESS 4, industry, trade, traffic
syn COMMUNIST, Bolshevik, ‖Bolshie, comrade,
n syn CURSE 1, anathema, imprecation, male-
diction
vb syn MIX 1, comingle, commix, compound,
immix, intermingle, intermix, merge, mingle
unify
vb syn PULVERIZE 1, bray, buck, contriturate,
powder, triturate
adj syn PITIFUL 1, pathetic, piteous, pitiable,
vb syn COMPASSIONATE, ache, feel (for), pity,
(with)
n syn PITY, compassion, rue, ruth, sympa-
vb 1 syn AUTHORIZE 1, accredit, empower,
license
designate, name, nominate; bid, charge, com-
instruct, order
LEGATE, depute, deputize
2 to assign (as to a person) especially for use or
<it is unwise to *commit* all power and author-
man) ⟨sainted beings who *commit* their spirits
commend, confide, consign, entrust, hand over, rele-
over
allot, assign, destine, ordain; move, remove,
deliver, give, offer, submit; delegate, depu-
give into the charge (*or* hands) of
responsible for or guilty of (an offense or wrong-
commit a crime>
perpetuate, pull
accomplish, achieve, do, effectuate, execute, perform,
contravene, transgress, trespass, violate; offend,
sin
n syn OBLIGATION 2, charge, committal, de-
must, need, ought, ‖right
n syn OBLIGATION 2, charge, commitment, de-
must, need, ought, ‖right
syn MIX 1, admix, commingle, compound, im-
mingle, intermix, meld, merge, mingle
n syn MIXTURE, admixture, composite, com-
immixture, interfusion, intermixture, mix,

commodious *adj* *syn* SPACIOUS, ample, capacious, roomy, wide
con cramped, narrow, strait
ant incommodious

commodities *n pl* *syn* MERCHANDISE, goods, line, vendible(s), wares
rel articles, items, things

common *adj* **1** generally shared in or participated in by members of a community <our *common* civic responsibilities>
syn communal, conjoint, conjunct, intermutual, joint, mutual, public, shared
rel general, generic, universal; like, reciprocal, similar; corporate
con personal, private, restricted
ant individual
2 *syn* GENERAL 2, generic, universal
rel popular, public
3 *syn* IMPURE 3, defiled, desecrated, polluted, profaned, unclean
4 taking place often <a *common* occurrence>
syn customary, everyday, familiar, frequent
rel repetitious, routine, usual
con infrequent, occasional, unfrequent; casual, chance, incidental
ant rare, uncommon
5 *syn* GENERAL, commonplace, matter-of-course, natural, normal, prevalent, regular, typic, typical, usual
6 conforming to a type without noteworthy excellences or faults <just a *common* everyday sort trying to get by in life>
syn commonplace, ordinary, prosaic, uneventful, unexceptional, unnoteworthy
rel down-to-earth, matter-of-fact, prosy, unexciting; dull, flat, trite, stale, uninteresting
con exceptional, noteworthy, remarkable; excellent, marvelous, prodigious, wonderful; aberrant, divergent, eccentric
ant extraordinary
7 *syn* DECENT 4, adequate, all right, good, satisfactory, sufficient, tolerable, unexceptionable, unexceptional, unimpeachable
8 *syn* CHEAP 2, mean, ‖ornery, paltry, poor, rubbishy, shoddy, sleazy, tatty, trashy
9 *syn* INFERIOR 2, déclassé, hack, low-grade, mean, poor, second-class, second-drawer, second-rate
‖**10** *syn* EASYGOING 3, breezy, casual, informal, low-pressure, relaxed, ‖sonsy, unconstrained, unfussy, unreserved

common *n* **1 commons** *pl but sing or pl in constr* *syn* COMMONALTY, commonage, commoners, common men, people, plebeians, plebs, populace, rank and file, third estate
2 an often improved and ornamentally planted open space for public use in a built-up area <in summer a band played on the village *common*>
syn green, plaza, square

---

syn synonym(s) — *rel* related word(s)
idiom idiomatic equivalent(s) — *con* contrasted word(s)
ant antonym(s) — * vulgar
‖ use limited; if in doubt, see a dictionary
The first word in a synonym list when printed in SMALL CAPITALS shows where there is more information about the group. For a more efficient use of this book see Explanatory Notes.

EXHIBIT 10

Third Edition

ELECTRIC CIRCUIT ANALYSIS

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Birmingham-Southern College

Johnny R. Johnson
University of North Alabama

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JOHN WILEY & SONS, INC.
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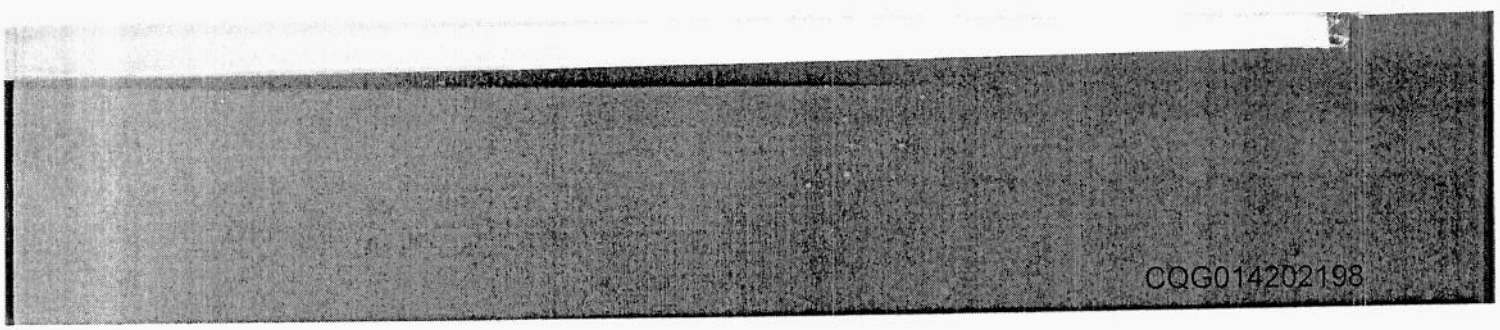
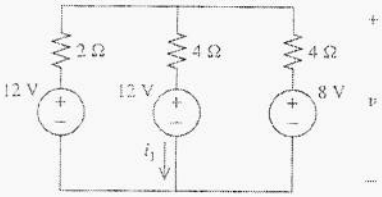


We also need the power through the 3-Ω resistor. Since we know its voltage v,

$$p = \frac{v^2}{R} = \frac{15^2}{3} = 75 \text{ W}$$

Note that we found v by superposition and then used the total voltage v *after* superposition of voltage components to compute the power. Had we computed the power through the resistor in the component problems separately and tried to superpose them, this would have given us a different and erroneous result, since the sum of component powers, $(v^{a2} + v^{b2})/R$, is not the same as the power due to the sum of components, $v^2/R = (v^a + v^b)^2/R$. Even in linear circuits, power does not superpose; only voltage and current do.

EXERCISES



EXERCISE 4.2.2

4.2.1. Solve Exercise 4.1.1 using superposition.

4.2.2. Find v and i_1 by superposition. Check by Thevenin–Norton transformations.

Answer 11 V; $-\frac{1}{4}$ A

4.2.3. Replace the 8 V by $4i_1$ in Exercise 4.2.2, converting an independent source to a dependent source. Find v and i_1 by superposition.

Answer 8 V; −1 A

4.3 NODAL ANALYSIS

In this section we develop a general method of circuit analysis in which voltages are the unknowns to be found. A convenient choice of voltages for many networks is the set of *node voltages*. Since a voltage is defined as existing between two nodes, it is convenient to select one node in the network to be a *reference node* and then associate a voltage at each of the other nodes. *The voltage of each of the nonreference nodes with respect to the reference node is defined to be a node voltage.* It is common practice to select reference directions for these voltages so that the plus ends are all at the nonreference nodes and the minus ends all at the reference node. For a circuit containing N nodes, there will be $N - 1$ nonreference nodes and thus $N - 1$ node voltages. Nodal analysis is a method in which we will break the circuit, that is, solve for a key set of circuit variables, by finding the node voltages themselves. Any other current or voltage will follow easily once the circuit is broken.

The reference node is often chosen to be the node to which the largest number of branches are connected. Many practical circuits are built on a metallic base or chassis, and usually a number of elements are connected to the chassis, which becomes a logical choice for the reference node. In many cases, such as in electric power systems, the chassis is shorted to the earth itself, becoming part of a single chassis–earth node. For

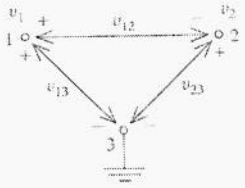


FIGURE 4.8 Reference and nonreference nodes.

this reason, the reference node is frequently referred to as *ground* or the *ground node*. The reference node is thus at ground potential or zero potential, and each other node may be considered to be at some potential above or below zero specified by the value of its node voltage.

The equations of nodal analysis are obtained by applying KCL at the nodes. Recall that each term in a KCL equation is an element current. For a resistor, this current is proportional to its voltage. This voltage, like any element voltage, is equal to a node voltage (if one end of the element is tied to the reference node) or the difference of two node voltages (if both ends are tied to nonreference nodes). For example, in Fig. 4.8 the reference node is node 3 with zero or ground potential. The symbol shown attached to node 3 is the standard symbol for ground, as noted in Chapter 3. The nonreference nodes 1 and 2 have node voltages v_1 and v_2. Thus the element voltage v_{12} with the polarity shown is

$$v_{12} = v_1 - v_2$$

The other element voltages shown are

$$v_{13} = v_1 - 0 = v_1$$

$$v_{23} = v_2 - 0 = v_2$$

These equations may be established by applying KVL around the loops (real or imagined). Evidently, if we know all the node voltages, we may find all the element voltages and thence all the element currents.

The application of KCL at a node, expressing each unknown current in terms of the node voltages, results in a *node equation*. Clearly, simplification in writing the resulting equations is possible when the reference node is chosen to be a node with a large number of elements connected to it. As we shall see, however, this is not the only criterion for selecting the reference node, although it is frequently the overriding one. Since we are going to apply KCL systematically at circuit nodes, the most straightforward case to consider is that of circuits whose only sources are independent current sources. We begin with examples of this type.

In the network shown in Fig. 4.9(a), there are three nodes, dashed and numbered as shown. [This may be easier to see in the redrawn version of Fig. 4.9(b).] Since there are four elements connected to node 3, we select it as the reference node, identifying it by the ground symbol shown.

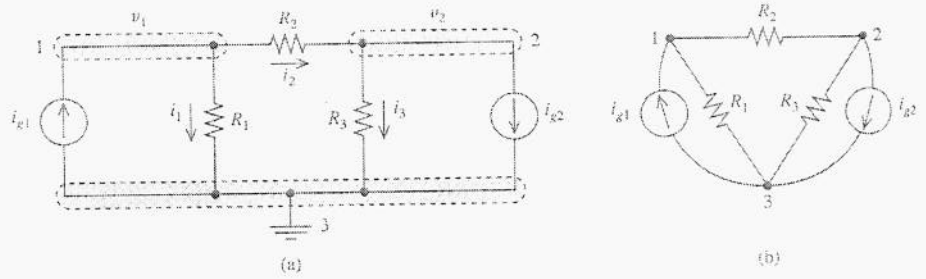


FIGURE 4.9 Circuit containing independent current sources.

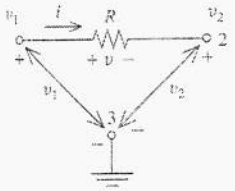


FIGURE 4.10 Single element.

Before writing the node equations, consider the element shown in Fig. 4.10, where v_1 and v_2 are node voltages. The element voltage v is given by

$$v = v_1 - v_2$$

and thus by Ohm's law we have

$$i = \frac{v}{R} = \frac{v_1 - v_2}{R}$$

or

$$i = G(v_1 - v_2)$$

where $G = 1/R$ is the conductance. That is, *the current from node 1 to node 2 through a resistor is the difference of the node voltage at node 1 and the node voltage at node 2 divided by the resistance R, or multiplied by the conductance G.* This relation will allow us to write the node equations rapidly by inspection directly in terms of the node voltages.

Now returning to the circuit of Fig. 4.9, the sum of the currents leaving node 1 must be zero, or

$$i_1 + i_2 - i_{g1} = 0$$

In terms of the node voltages, this equation becomes

$$G_1 v_1 + G_2(v_1 - v_2) - i_{g1} = 0$$

We could have obtained this equation directly using the procedure of the preceding paragraph. Applying KCL at node 2 in a similar manner, we obtain

$$-i_2 + i_3 + i_{g2} = 0$$

or

$$G_2(v_2 - v_1) + G_3 v_2 + i_{g2} = 0$$

Instead of summing currents leaving the node to zero, we could have used the form of KCL that equates the sum of currents leaving the node to the sum of currents entering the node. Had we done so, the terms i_{g1} and i_{g2} would have appeared on the right-hand side:

$$G_1 v_1 + G_2(v_1 - v_2) = i_{g1}$$

$$G_2(v_2 - v_1) + G_3 v_2 = -i_{g2}$$

Rearranging these two equations results in

$$(G_1 + G_2)v_1 - G_2 v_2 = i_{g1} \tag{4.8a}$$

$$-G_2 v_1 + (G_2 + G_3)v_2 = -i_{g2} \tag{4.8b}$$

These equations exhibit a symmetry that may be used to write the equations in the rearranged form (4.8) directly by inspection of the circuit diagram. In (4.8a) the coefficient of v_1 is the sum of conductances of the elements connected to node 1, while the coefficient of v_2 is the negative of the conductance of the element connecting node 1 to node 2. The same statement holds for (4.8b) if the numbers 1 and 2 are interchanged. Thus node 2 plays the role in (4.8b) of node 1 in (4.8a). That is, it is the node at which KCL is applied. In each equation the right-hand side is the current from the current sources that enters the corresponding node.

In general, in networks containing only conductances and current sources, KCL applied at the kth node, with node voltage v_k, may be written as follows. *On the left*

*side of the node k equation, the coefficient of the k*th*-node voltage is the sum of the conductances connected to node k, and the coefficients of the other node voltages are the negatives of the conductances between those nodes and node k. The right side of this equation consists of the net current flowing into node k due to current sources.*

This predictable pattern makes it easy to write down the node equations. Note that the signs, positive on the left-hand side for v_k terms and negative for other node voltage terms, and positive on the right-hand side for current sources flowing into node k, are a consequence of the form of KCL chosen. While other forms could be used quite as correctly, we advocate sticking to the form recommended, with the payoff that the terms will always fall in this pattern. It helps to make the pattern of signs fixed and predictable, so we can focus our attention on the larger issues when analyzing a circuit.

Nodal analysis consists in writing KCL node equations described above at all nonreference nodes in the circuit. This yields $N - 1$ linear equations in a similar number of unknowns (the node voltages). As discussed in Appendix C, these equations are linearly independent and thus are guaranteed to possess a unique solution. The node voltages may be found by a variety of means, including Gauss elimination, Cramer's rule, and matrix inversion.

Example 4.6

Consider the circuit of Fig. 4.11. The bottom node has been selected as the reference node since so many elements connect to it. The resistors are labeled according to their conductances.

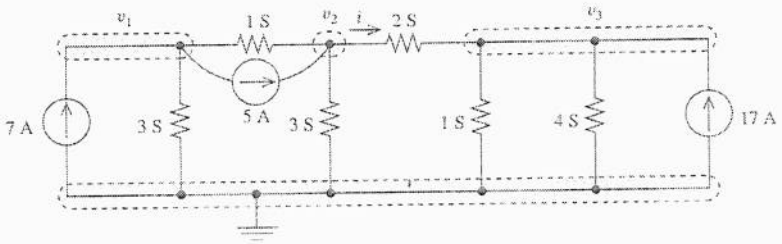


FIGURE 4.11 Circuit for Example 4.6.

Since there are three nonreference nodes, there will be three equations in three unknown node voltages. At node v_1, we note that the sum of conductances is $3 + 1 = 4$, the negative of the conductance connecting node v_2 to node v_1 is -1, and the net source current entering node 1 is $7 - 5 = 2$. Thus the first node equation is

$$4v_1 - v_2 = 2 \tag{4.9}$$

Similarly, at nodes v_2 and v_3, we have

$$-v_1 + 6v_2 - 2v_3 = 5 \tag{4.10a}$$

$$-2v_2 + 7v_3 = 17 \tag{4.10b}$$

We may solve (4.9) and (4.10) for the node voltages using any one of a variety of methods for solving simultaneous equations. Three such methods are matrix inversion, Cramer's rule, and

Gaussian elimination. For the reader who is not familiar with these methods, a discussion is given in Appendix A. Selecting Cramer's rule, first find the determinant of the coefficient matrix, given by

$$\Delta = \begin{vmatrix} 4 & -1 & 0 \\ -1 & 6 & -2 \\ 0 & -2 & 7 \end{vmatrix} = 145 \tag{4.11}$$

To determine v_1, we replace the first column of the coefficient matrix by the vector of constants on the right-hand side of (4.9)–(4.10), compute its determinant, and divide by the determinant of the coefficient matrix already found.

$$v_1 = \frac{\begin{vmatrix} 2 & -1 & 0 \\ 5 & 6 & -2 \\ 17 & -2 & 7 \end{vmatrix}}{\Delta} = 1 \text{ V}$$

v_2 is found by replacing the second and v_3 the third column of the coefficient matrix and calculating as above, yielding $v_2 = 2$ V and $v_3 = 3$ V.

Now that we have broken the circuit by finding the node voltages, we may easily find any other voltage or current. For example, if we want the current i in the 2-S element, it is given by

$$i = 2(v_2 - v_3) = 2(2 - 3) = -2 \text{ A}$$

Note that the coefficient matrix shown in (4.11) is symmetric [the (i, j) and (j, i) elements are equal]. This follows from the fact that the conductance between nodes i and j is that between nodes j and i. Symmetry further simplifies writing the node equations. While symmetry will hold as a general rule for all circuits not containing dependent sources, symmetry of the coefficient matrix cannot be counted on in that case, as we shall see in the next example.

Example 4.7

Consider the circuit of Fig. 4.12, which contains dependent current sources. We will begin by writing the node equations exactly as if the sources were independent. At node 1,

$$(1)(v_1) + (1)(v_1) + (2)(v_1 - v_2) = 5 - 5i$$

and at node 2,

$$\tfrac{1}{2}(v_2) + (2)(v_2 - v_1) = 5i + 2v$$

We next express the controlling variables for the dependent sources, i and v in these equations, in terms of the node voltages. By Ohm's law,

$$i = v_1$$

and by inspection

$$v = v_1 - v_2$$

Substituting the last two equations into the preceding two,

$$(1)(v_1) + (1)(v_1) + (2)(v_1 - v_2) = 5 - 5v_1$$

$$\tfrac{1}{2}(v_2) + (2)(v_2 - v_1) = 5v_1 + 2(v_1 - v_2)$$

These two equations in two unknowns can be solved by Cramer's rule, matrix inversion, or Gauss elimination, as desired. Selecting matrix inversion, we first rewrite as

$$\begin{bmatrix} 9 & -2 \\ -9 & \frac{9}{2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \end{bmatrix} \tag{4.12}$$

The determinant of the coefficient matrix is $(9)\left(\frac{9}{2}\right) - (-9)(-2) = 45/2$ and the inverse is

$$\frac{2}{45}\begin{bmatrix} \frac{9}{2} & 2 \\ 9 & 9 \end{bmatrix} = \begin{bmatrix} \frac{1}{5} & \frac{4}{45} \\ \frac{2}{5} & \frac{2}{5} \end{bmatrix}$$

Then

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{5} & \frac{4}{45} \\ \frac{2}{5} & \frac{2}{5} \end{bmatrix} \begin{bmatrix} 5 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

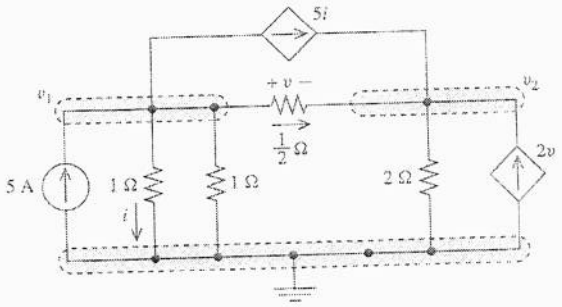


FIGURE 4.12 Circuit containing dependent sources.

From Example 4.7 we see that the presence of dependent sources destroys the symmetry in the coefficient matrix [see (4.12)] and that in such circuits the elements of this matrix may no longer simply be interpreted as sums of conductances, since the dependent sources also contribute. On the other hand, the presence of dependent sources has not significantly complicated nodal analysis, requiring only an additional substitution step, replacing controlling variables by node voltages.

EXERCISES

4.3.1. Take all resistors in Fig. 4.9 to be 1 Ω and both current source functions to be 1 A. Using nodal analysis, find the node voltages and the three labeled currents.

Answer $v_1 = 1$ V; $v_2 = -1$ V; $i_1 = 1$ A; $i_2 = 2$ A; $i_3 = -1$ A

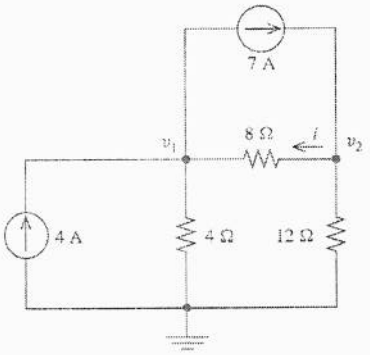
4.3.2. Using nodal analysis, find v_1, v_2, and i.

Answer 4 V; 36 V; 4 A

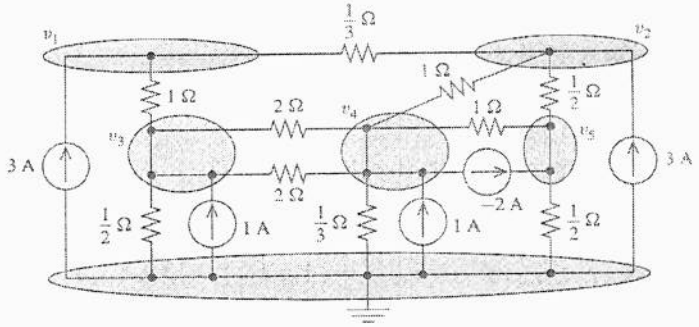
4.3.3. Write the nodal equations directly in vector-matrix form. Do not solve.

Answer

$$\begin{bmatrix} 4 & -3 & -1 & 0 & 0 \\ -3 & 6 & 0 & -1 & -2 \\ -1 & 0 & 4 & -1 & 0 \\ 0 & -1 & -1 & 6 & -1 \\ 0 & -2 & 0 & -1 & 5 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \end{bmatrix} = \begin{bmatrix} 3 \\ 3 \\ 1 \\ 3 \\ -2 \end{bmatrix}$$



EXERCISE 4.3.2



EXERCISE 4.3.3

4.4 CIRCUITS CONTAINING VOLTAGE SOURCES

At first glance it may seem that the presence of voltage sources in a circuit complicates nodal analysis. We can no longer write the KCL node equations, since there is no way to express the currents through these circuit elements in terms of their node voltages. As discussed in Chapter 2, the element law for a voltage source does not relate its current to its voltage, so we cannot use it to replace a current unknown by a voltage unknown in the node equation.

However, as we shall see, nodal analysis in the presence of voltage sources proves no more complicated, requiring only a small modification to the basic method for writing the equations of nodal analysis presented in Section 4.3. In fact, we will come to welcome voltage sources, since they reduce the number of simultaneous node equations that must be solved, yielding one less equation per voltage source.

Example 4.8

To illustrate the procedure, let us consider the circuit of Fig. 4.13. For convenience we have labeled the resistors by their conductances. Note that we have enclosed voltage sources in separate regions indicated by dashed lines. Recalling that the generalized form of KCL states that all currents entering a closed region must sum to zero

EXHIBIT 11

FOURTH EDITION

MICROELECTRONIC CIRCUITS

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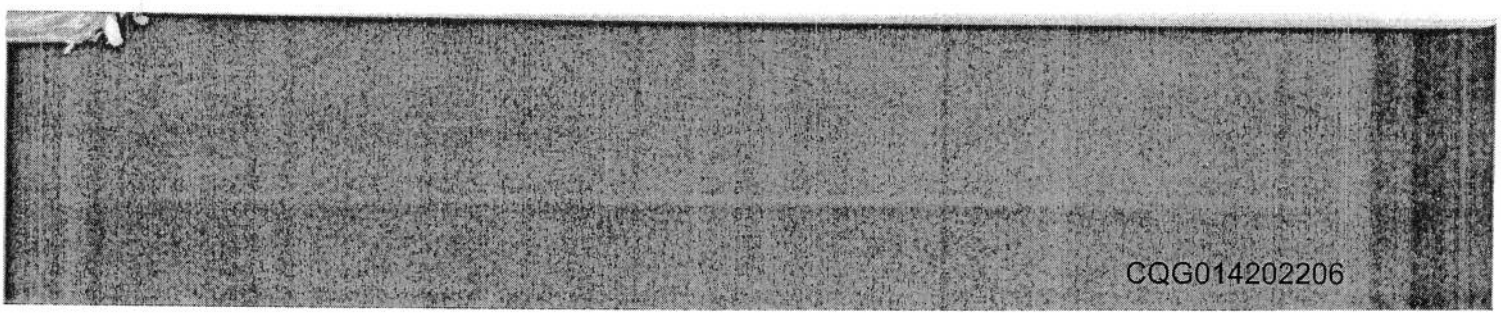

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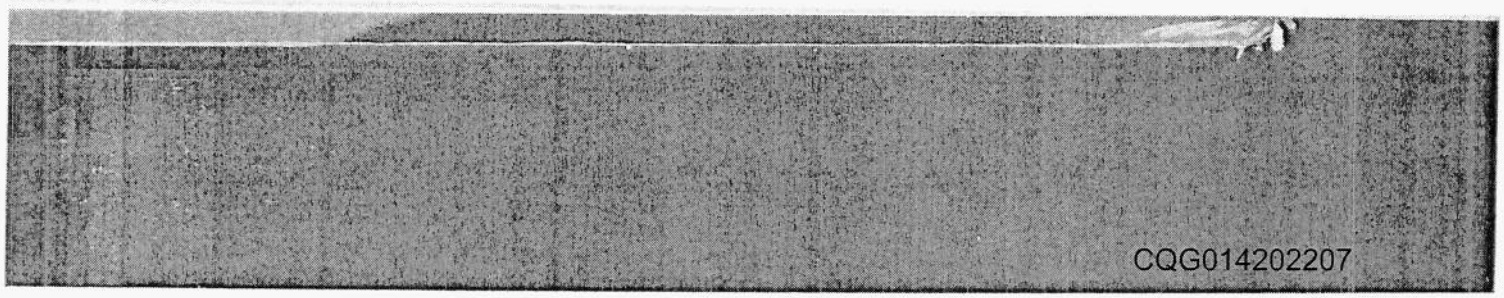
Cover Illustration: The chip shown is the ADXL-50 surface-micromachined accelerometer. For the first time, sensor and signal conditioning are combined on a single monolithic chip. In its earliest application, it was a key factor in the improved reliability and reduced cost of modern automotive airbag systems. Photo reprinted with permission of Analog Devices, Inc.



The basic building blocks of digital systems are logic circuits and memory circuits. We shall study both in this book, beginning in Section 1.7 with the most fundamental digital circuit, the digital logic inverter.

One final remark: Although the digital processing of signals is at present all-pervasive, there remain many signal processing functions that are best performed by analog circuits. Indeed, many electronic systems include both analog and digital parts. It follows that a good electronics engineer must be proficient in the design of both analog and digital circuits. Such is the aim of this book.

Exercise

1.4 Consider a 4-bit digital word $D = b_3b_2b_1b_0$ (see Eq. 1.3) used to represent an analog signal v_A that varies between 0 V and +15 V.

(a) Give D corresponding to $v_A = 0$ V, 1 V, 2 V, and 15 V.

(b) What change in v_A causes a change from 0 to 1 in: (i) b_0, (ii) b_1, (iii) b_2, and (iv) b_3?

(c) If $v_A = 5.2$ V, what do you expect D to be? What is the resulting error in representation?

Ans. (a) 0000, 0001, 0010, 1111; (b) +1 V, +2 V, +4 V, +8 V; (c) 0101, −4%

1.4 AMPLIFIERS

In this section, we shall introduce a fundamental signal-processing function that is employed in some form in almost every electronic system, namely, signal amplification.

Signal Amplification

From a conceptual point of view the simplest signal-processing task is that of **signal amplification.** The need for amplification arises because transducers provide signals that are said to be "weak," that is, in the microvolt (μV) or millivolt (mV) range and possessing little energy. Such signals are too small for reliable processing, and processing is much easier if the signal magnitude is made larger. The functional block that accomplishes this task is the **signal amplifier.**

It is appropriate at this point to discuss the need for **linearity** in amplifiers. When amplifying a signal, care must be exercised so that the information contained in the signal is not changed and no new information is introduced. Thus when feeding the signal shown in Fig. 1.2 to an amplifier, we want the output signal of the amplifier to be an exact replica of that at the input, except of course for having larger magnitude. In other words, the "wiggles" in the output waveform must be identical to those in the input waveform. Any change in waveform is considered to be **distortion** and is obviously undesirable.

An amplifier that preserves the details of the signal waveform is characterized by the relationship

$$v_o(t) = Av_i(t) \tag{1.4}$$

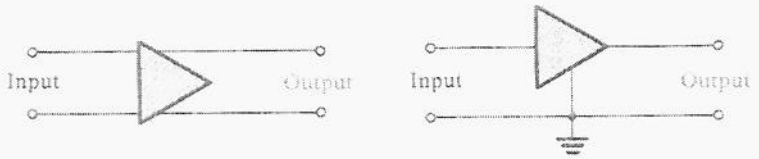
where v_i and v_o are the input and output signals, respectively, and A is a constant representing the magnitude of amplification, known as **amplifier gain.** Equation (1.4) is a linear relationship; hence the amplifier it describes is a **linear amplifier.** It should be easy to see that if the relationship between v_o and v_i contains higher powers of v_i, then the waveform of v_o will no longer be identical to that of v_i. The amplifier is then said to exhibit **nonlinear distortion.**

The amplifiers discussed so far are primarily intended to operate on very small input signals. Their purpose is to make the signal magnitude larger and therefore are thought of as **voltage amplifiers.** The **preamplifier** in the home stereo system is an example of a voltage amplifier. However, it usually does more than just amplify the signal; specifically, it performs some shaping of the frequency spectrum of the input signal. This topic, however, is beyond our need at this moment.

At this time we wish to mention another type of amplifier, namely, the power amplifier. Such an amplifier may provide only a modest amount of voltage gain but substantial current gain. Thus while absorbing little power from the input signal source to which it is connected, often a preamplifier, it delivers large amounts of power to its load. An example is found in the power amplifier of the home stereo system, whose purpose is to provide sufficient power to drive the loudspeaker. Here we should note that the loudspeaker is the output transducer of the stereo system: it converts the electric output signal of the system into an acoustic signal. A further appreciation of the need for linearity can be acquired by reflecting on the power amplifier. A linear power amplifier causes both soft and loud music passages to be reproduced without distortion.

Amplifier Circuit Symbol

The signal amplifier is obviously a two-port network. Its function is conveniently represented by the circuit symbol of Fig. 1.10(a). This symbol clearly distinguishes the input and output ports and indicates the direction of signal flow. Thus, in subsequent diagrams it will not be necessary to label the two ports "input" and "output." For generality we have shown the amplifier to have two input terminals that are distinct from the two output terminals. A more common situation is illustrated in Fig. 1.10(b), where a common terminal exists between the input and output ports of the amplifier. This common terminal is used as a reference point and is called the **circuit ground.**



(a) (b)

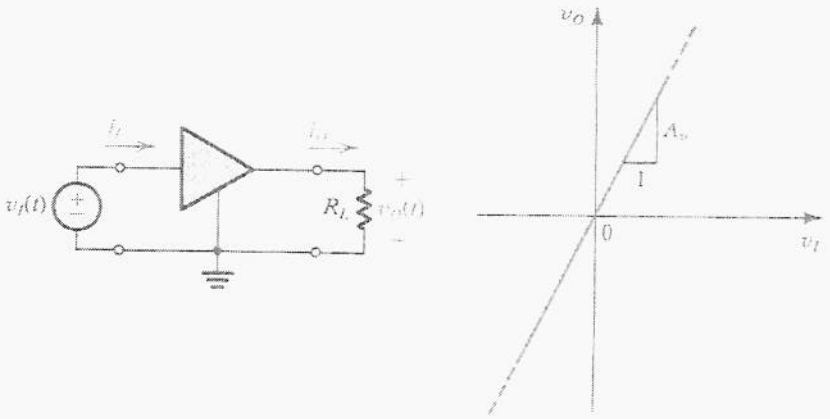
Fig. 1.10 (a) Circuit symbol for amplifier. (b) An amplifier with a common terminal (ground) between the input and output ports.

Voltage Gain

A linear amplifier accepts an input signal $v_I(t)$ and provides at the output, across a load resistance R_L (see Fig. 1.11(a)), an output signal $v_O(t)$ that is a magnified replica of $v_I(t)$. The **voltage gain** of the amplifier is defined by

$$\text{Voltage gain } (A_v) \equiv \frac{v_O}{v_I} \tag{1.5}$$

Fig. 1.11(b) shows the **transfer characteristic** of a linear amplifier. If we apply to the input of this amplifier a sinusoidal voltage of amplitude $\hat{V}$, we obtain at the output a sinusoid of amplitude $A_v\hat{V}$.



(a) (b)

Fig. 1.11 **(a)** A voltage amplifier fed with a signal $v_I(t)$ and connected to a load resistance R_L. **(b)** Transfer characteristic of a linear voltage amplifier with voltage gain A_v.

Power Gain and Current Gain

An amplifier increases the signal power, an important feature that distinguishes an amplifier from a transformer. In the case of a transformer, although the voltage delivered to the load could be greater than the voltage feeding the input side (the primary), the power delivered to the load (from the transformer secondary) is less than or at most equal to the power supplied by the signal source. On the other hand, an amplifier provides the load with power greater than that obtained from the signal source. That is, amplifiers have power gain. The **power gain** of the amplifier in Fig. 1.11(a) is defined as

$$\text{Power gain } (A_p) \equiv \frac{\text{load power } (P_L)}{\text{input power } (P_I)} \tag{1.6}$$

$$= \frac{v_O i_O}{v_I i_I} \tag{1.7}$$

where i_O is the current that the amplifier delivers to the load (R_L), $i_O = v_O/R_L$, and i_I is the current the amplifier draws from the signal source. The **current gain** of the amplifier is defined as

$$\text{Current gain } (A_i) = \frac{i_O}{i_I} \tag{1.8}$$

From Eqs. (1.5) to (1.8) we note that

$$A_p = A_v A_i \tag{1.9}$$

Expressing Gain in Decibels

The amplifier gains defined above are ratios of similarly dimensioned quantities. Thus they will be expressed either as dimensionless numbers or, for emphasis, as V/V for the voltage gain, A/A for the current gain, and W/W for the power gain. Alternatively, for a number of reasons, some of them historic, electronics engineers express amplifier gain with a logarithmic measure. Specifically the voltage gain A_v can be expressed as

$$\text{Voltage gain in decibels} = 20 \log|A_v| \quad \text{dB}$$

and the current gain A_i can be expressed as

$$\text{Current gain in decibels} = 20 \log|A_i| \quad \text{dB}$$

Since power is related to voltage (or current) squared, the power gain A_p can be expressed in decibels as follows:

$$\text{Power gain in decibels} = 10 \log A_p \quad \text{dB}$$

The absolute values of the voltage and current gains are used because in some cases A_v or A_i may be negative numbers. A negative gain A_v simply means that there is a 180° phase difference between input and output signals; it does not imply that the amplifier is **attenuating** the signal. On the other hand, an amplifier whose voltage gain is, say, −20 dB is in fact attenuating the input signal by a factor of 10 (that is, $A_v = 0.1$ V/V).

The Amplifier Power Supplies

Since the power delivered to the load is greater than the power drawn from the signal source, the question arises as to the source of this additional power. The answer is found by observing that amplifiers need dc power supplies for their operation. These dc sources supply the extra power delivered to the load as well as any power that might be dissipated in the internal circuit of the amplifier (such power is converted to heat). In Fig. 1.11(a) we have not explicitly shown these dc sources.

Figure 1.12(a) shows an amplifier that requires two dc sources: one positive of value V_1 and one negative of value V_2. The amplifier has two terminals, labeled V^+ and V^-, for connection to the dc supplies. For the amplifier to operate, the terminal labeled V^+ has to be connected to the positive side of a dc source whose voltage is V_1 and whose negative side is connected to the circuit ground. Also, the terminal labeled V^- has to be connected to the negative side of a dc source whose voltage is V_2 and whose positive side is connected

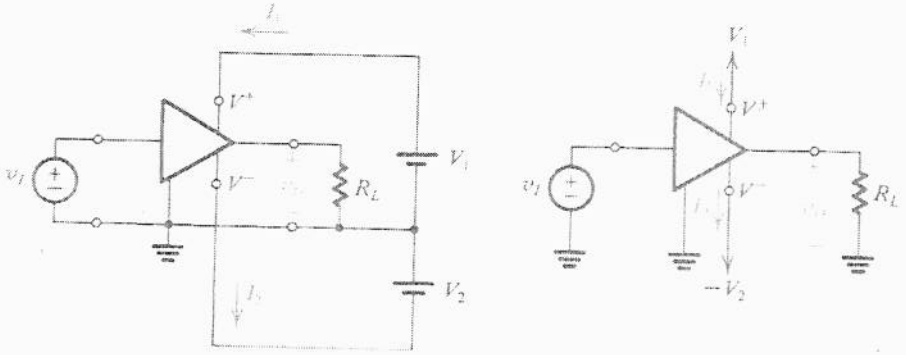


Fig. 1.12 An amplifier that requires two dc supplies (shown as batteries) for operation.

to the circuit ground. Now, if the current drawn from the positive supply is denoted I_1 and that from the negative supply is I_2 (see Fig. 1.12(a)), then the dc power delivered to the amplifier is

$$P_{dc} = V_1 I_1 + V_2 I_2$$

If the power dissipated in the amplifier circuit is denoted $P_{\text{dissipated}}$, the power-balance equation for the amplifier can be written as

$$P_{dc} + P_I = P_L + P_{\text{dissipated}}$$

where P_I is the power drawn from the signal source, and P_L is the power delivered to the load. Since the power drawn from the signal source is usually small, the amplifier **efficiency** is defined as

$$\eta = \frac{P_L}{P_{dc}} \times 100 \tag{1.10}$$

The power efficiency is an important performance parameter for amplifiers that handle large amounts of power. Such amplifiers, called power amplifiers, are used, for example, as output amplifiers of stereo systems.

In order to simplify circuit diagrams, we shall adopt the convention illustrated in Fig. 1.12(b). Here the V^+ terminal is shown connected to an arrowhead pointing upward and the V^- terminal to an arrowhead pointing downward. The corresponding voltage is indicated next to each arrowhead. Note that in many cases we will not explicitly show the connections of the amplifier to the dc power sources. Finally, we note that some amplifiers require only one power supply.

EXAMPLE 1.1

Consider an amplifier operating from ±10-V power supplies. It is fed with a sinusoidal voltage having 1 V peak and delivers a sinusoidal voltage output of 9 V peak to a 1-kΩ load. The amplifier draws a current of 9.5 mA from each of its two power supplies. The

input current of the amplifier is found to be sinusoidal with 0.1 mA peak. Find the voltage gain, the current gain, the power gain, the power drawn from the dc supplies, the power dissipated in the amplifier, and the amplifier efficiency.

SOLUTION

$$A_v = \frac{9}{1} = 9 \text{ V/V}$$

or

$$A_v = 20 \log 9 = 19.1 \text{ dB}$$

$$\hat{I}_o = \frac{9 \text{ V}}{1 \text{ k}\Omega} = 9 \text{ mA}$$

$$A_i = \frac{\hat{I}_o}{\hat{I}_i} = \frac{9}{0.1} = 90 \text{ A/A}$$

or

$$A_i = 20 \log 90 = 39.1 \text{ dB}$$

$$P_L = V_{o\text{rms}} I_{o\text{rms}} = \frac{9}{\sqrt{2}} \frac{9}{\sqrt{2}} = 40.5 \text{ mW}$$

$$P_I = V_{i\text{rms}} I_{i\text{rms}} = \frac{1}{\sqrt{2}} \frac{0.1}{\sqrt{2}} = 0.05 \text{ mW}$$

$$A_p = \frac{P_L}{P_I} = \frac{40.5}{0.05} = 810 \text{ W/W}$$

or

$$A_p = 10 \log 810 = 29.1 \text{ dB}$$

$$P_{\text{dc}} = 10 \times 9.5 + 10 \times 9.5 = 190 \text{ mW}$$

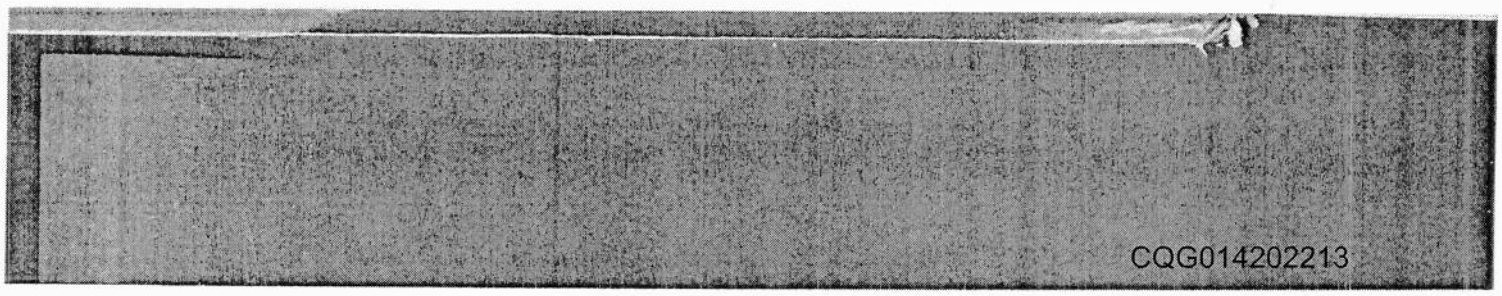
$$P_{\text{dissipated}} = P_{\text{dc}} + P_I - P_L$$
$$= 190 + 0.05 - 40.5 = 149.6 \text{ mW}$$

$$\eta = \frac{P_L}{P_{\text{dc}}} \times 100 = 21.3\%$$

From the above example we observe that the amplifier converts some of the dc power it draws from the power supplies to signal power that it delivers to the load.

Amplifier Saturation

Practically speaking, the amplifier transfer characteristic remains linear over only a limited range of input and output voltages. For an amplifier operated from two power supplies the output voltage cannot exceed a specified positive limit and cannot decrease below a specified



negative limit. The resulting transfer characteristic is shown in Fig. 1.13, with the positive and negative saturation levels denoted L_+ and L_-, respectively. Each of the two saturation levels is usually within 1 or 2 volts of the voltage of the corresponding power supply.

Obviously, in order to avoid distorting the output signal waveform, the input signal swing must be kept within the linear range of operation.

$$\frac{L_-}{A_v} \leq v_I \leq \frac{L_+}{A_v}$$

Figure 1.13 shows two input waveforms and the corresponding output waveforms. We note that the peaks of the larger waveform have been clipped off because of amplifier saturation.

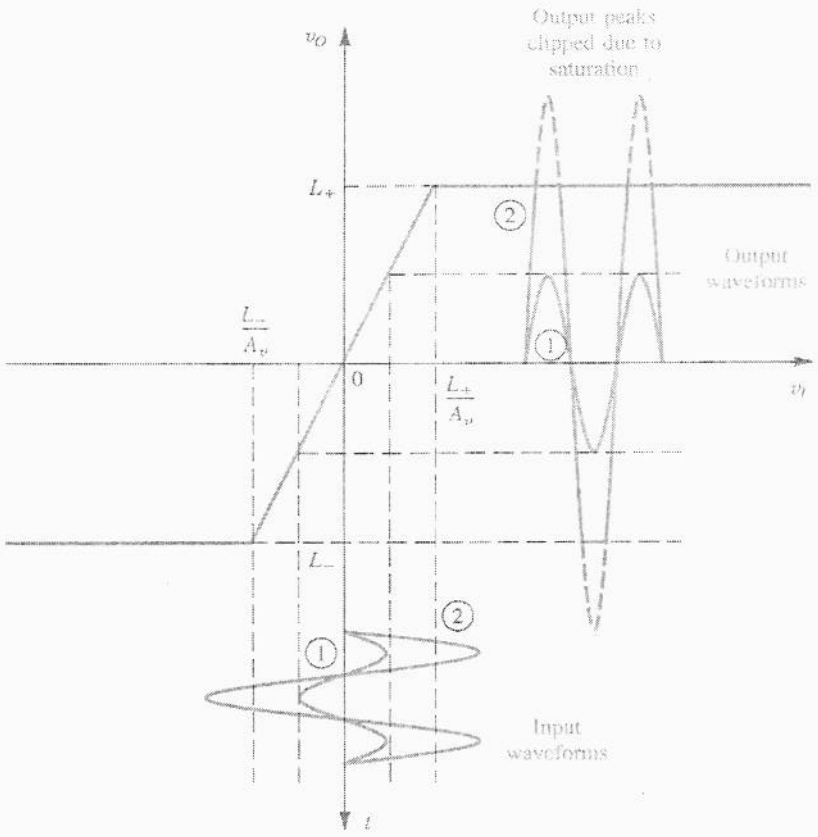
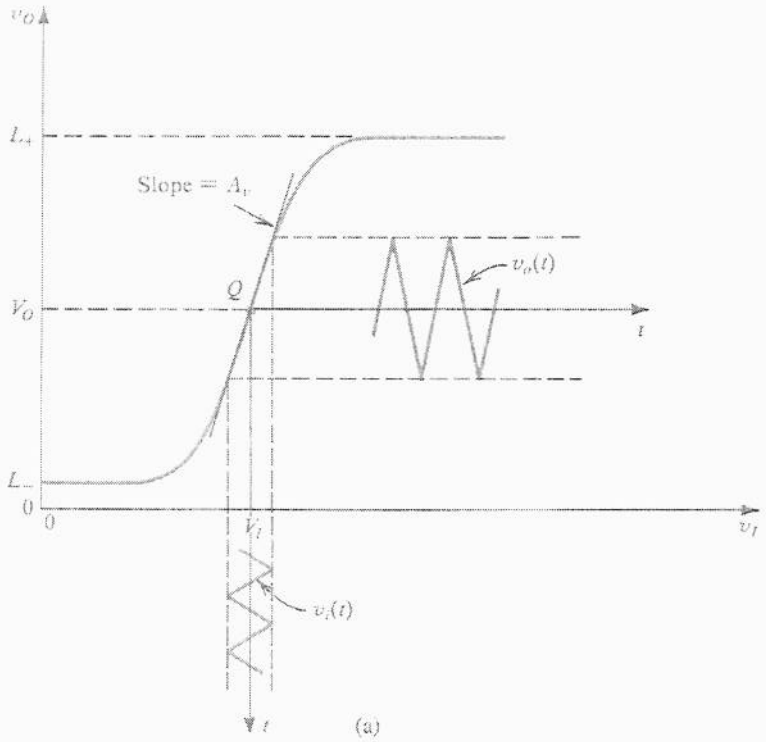


Fig. 1.13 An amplifier transfer characteristic that is linear except for output saturation.

Nonlinear Transfer Characteristics and Biasing

Except for the output saturation effect discussed above, the amplifier transfer characteristics have been assumed to be perfectly linear. In practical amplifiers the transfer characteristic

may exhibit nonlinearities of various magnitudes, depending on how elaborate the amplifier circuit is, and on how much effort has been expended in the design to ensure linear operation. Consider as an example the transfer characteristic depicted in Fig. 1.14. Such a characteristic is typical of simple amplifiers that are operated from a single (positive) power supply. The transfer characteristic is obviously nonlinear and, because of the single-supply operation, is



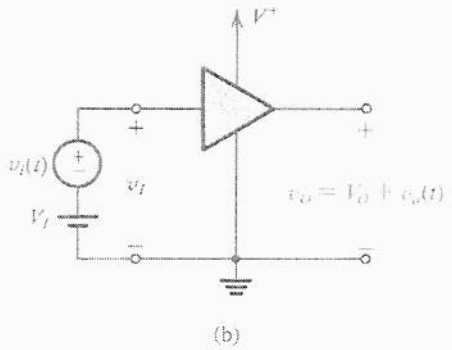


Fig. 1.14 (a) An amplifier transfer characteristic that shows considerable nonlinearity. (b) To obtain linear operation the amplifier is biased as shown, and the signal amplitude is kept small.

not centered around the origin. Fortunately, a simple technique exists for obtaining linear amplification from an amplifier with such a nonlinear transfer characteristic.

The technique consists of first **biasing** the circuit to operate at a point near the middle of the transfer characteristic. This is achieved by applying a dc voltage V_I, as indicated in Fig. 1.14, where the operating point is labeled Q and the corresponding dc voltage at the output is V_O. The point Q is known as the **quiescent point**, the **dc bias point**, or simply the **operating point**. The time-varying signal to be amplified, $v_i(t)$, is then superimposed on the dc bias voltage V_I as indicated in Fig. 1.14. Now, as the total instantaneous input $v_I(t)$,

$$v_I(t) = V_I + v_i(t)$$

varies around V_I, the instantaneous operating point moves up and down the transfer curve around the operating point Q. In this way, one can determine the waveform of the total instantaneous output voltage $v_O(t)$. It can be seen that by keeping the amplitude of $v_i(t)$ sufficiently small, the instantaneous operating point can be confined to an almost linear segment of the transfer curve centered about Q. This in turn results in the time-varying portion of the output being proportional to $v_i(t)$; that is,

$$v_O(t) = V_O + v_o(t)$$

with

$$v_o(t) = A_v v_i(t)$$

where A_v is the slope of the almost linear segment of the transfer curve; that is,

$$A_v = \left.\frac{dv_O}{dv_I}\right|_{\text{at } Q}$$

In this manner, linear amplification is achieved. Of course, there is a limitation: The input signal must be kept sufficiently small. Increasing the amplitude of the input signal can cause the operation to be no longer restricted to an almost linear segment of the transfer curve. This in turn results in a distorted output signal waveform. Such nonlinear distortion is undesirable: The output signal contains additional spurious information that is not part of the input. We shall use this biasing technique and the associated small-signal approximation frequently in the design of transistor amplifiers.

EXAMPLE 1.2

A transistor amplifier has the transfer characteristic

$$v_O = 10 - 10^{-11}e^{40v_I} \tag{1.11}$$

which applies for $v_I \geq 0$ V and $v_O \geq 0.3$ V. Find the limits L_- and L_+ and the corresponding values of v_I. Also, find the value of the dc bias voltage V_I that results in $V_O = 5$ V and the voltage gain at the corresponding operating point.

SOLUTION

The limit L_- is obviously 0.3 V. The corresponding value of v_I is obtained by substituting $v_O = 0.3$ V in Eq. (1.10); that is,

$$v_I = 0.690 \text{ V}$$

The limit L_+ is determined by $v_I = 0$ and is thus given by

$$L_+ = 10 - 10^{-11} \simeq 10 \text{ V}$$

To bias the device so that $V_O = 5$ V we require a dc input V_I whose value is obtained by substituting $v_O = 5$ V in Eq. (1.10) to find:

$$V_I = 0.673 \text{ V}$$

The gain at the operating point is obtained by evaluating the derivative dv_O/dv_I at $v_I = 0.673$ V. The result is

$$A_v = -200 \text{ V/V}$$

which indicates that this amplifier in an inverting one, that is, the output is 180° out of phase with the input. A sketch of the amplifier transfer characteristic (not to scale) is shown in Fig. 1.15, from which we observe the inverting nature of the amplifier.

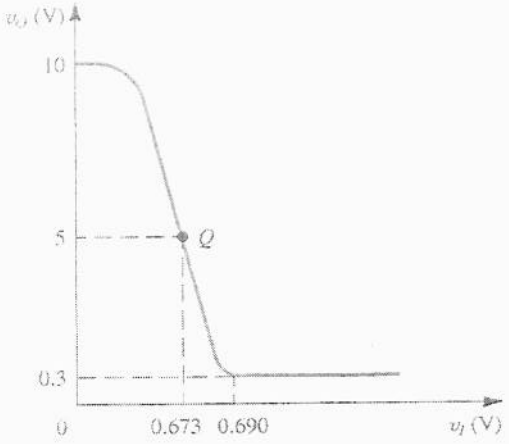


Fig. 1.15 A sketch of the transfer characteristic of the amplifier of Example 1.2. Note that this amplifier is inverting (that is, with a gain that is negative).

Once an amplifier is properly biased and the input signal is kept sufficiently small, the operation is assumed to be linear. We can then employ the techniques of linear circuit analysis to analyze the signal operation of the amplifier circuit. The following two sections provide a review and application of these analysis techniques.

Symbol Convention

At this point, we draw the reader's attention to the terminology used above and which we shall employ throughout the book. Total instantaneous quantities are denoted by a lowercase symbol with an uppercase subscript, for example, $i_A(t)$, $v_C(t)$. Direct-current (dc) quantities will be denoted by an uppercase symbol with an uppercase subscript, for example, I_A, V_C. Finally, incremental signal quantities will be denoted by a lowercase symbol with a lowercase subscript, for example $i_a(t)$, $v_c(t)$. This notation is illustrated in Fig. 1.16.

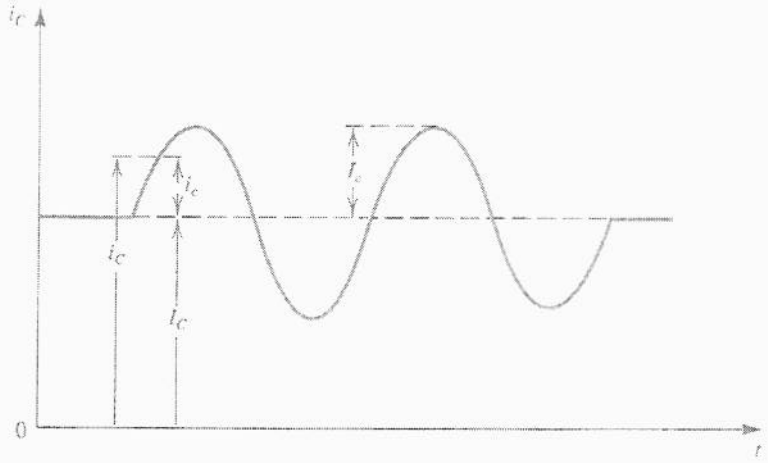


Fig. 1.16 Symbol convention employed throughout the book.

Exercises

1.5 An amplifier has a voltage gain of 100 V/V and a current gain of 1000 A/A. Express the voltage and current gains in decibels and find the power gain.

Ans. 40 dB; 60 dB; 50 dB

1.6 An amplifier operating from a single 15-V supply provides a 12-V peak-to-peak sine-wave signal to a 1-kΩ load, and draws negligible input current from the signal source. The dc current drawn from the 15-V supply is 8 mA. What is the power dissipated in the amplifier and what is the amplifier efficiency?

Ans. 102 mW; 15%

1.7 The objective of this exercise is to investigate the limitation of the small-signal approximation. Consider the amplifier of Example 1.2 with a positive input signal of 1 mV superimposed on the dc bias voltage V_I. Find the corresponding signal at the output for two situations: (a) Assume the amplifier is linear around the operating point; that is, use the value of gain evaluated in Example 1.2. (b) Use the transfer characteristic of the amplifier. Repeat for input signals of 5 mV and 10 mV.

Ans. −0.2 V, −0.204 V; −1 V, −1.107 V; −2 V, −2.459 V

1.5 CIRCUIT MODELS FOR AMPLIFIERS

A good part of this book is concerned with the design of amplifier circuits using transistors of various types. Such circuits will vary in complexity from those using a single transistor to those with 20 or more devices. In order to be able to apply the resulting amplifier circuit as a building block in a system, one must be able to characterize, or **model,** its terminal

amp has characteristics that closely approach the assumed ideal. This implies that it is quite easy to design circuits using the IC op amp. Also, op amp circuits work at levels that are quite close to their predicted theoretical performance. It is for this reason that we are studying op amps at this early stage. It is expected that by the end of this chapter the reader should be able to design nontrivial circuits successfully using op amps.

As already implied, an IC op amp is made up of a large number of transistors, resistors, and (usually) one capacitor connected in a rather complex circuit. Since we have not yet studied transistor circuits, the circuit inside the op amp will not be discussed in this chapter. Rather, we will treat the op amp as a circuit building block and study its terminal characteristics and its applications. This approach is quite satisfactory in many op-amp applications. Nevertheless, for the more difficult and demanding applications it is quite useful to know what is inside the op-amp package. This topic will be studied in Chapter 10. Finally, it should be mentioned that more advanced applications of op amps will appear in later chapters.

2.1 THE OP-AMP TERMINALS

From a signal point of view the op amp has three terminals: two input terminals and one output terminal. Figure 2.1 shows the symbol we shall use to represent the op amp. Terminals 1 and 2 are input terminals, and terminal 3 is the output terminal. As explained in Section 1.4, amplifiers require dc power to operate. Most IC op amps require two dc power supplies, as shown in Fig. 2.2. Two terminals, 4 and 5, are brought out of the op-amp package and connected to a positive voltage V^+ and a negative voltage V^-, respectively. In Fig. 2.2(b) we explicitly show the two dc power supplies as batteries with a common ground. It is interesting to note that the reference grounding point in op-amp circuits is just the common terminal of the two power supplies; that is, no terminal of the op amp package

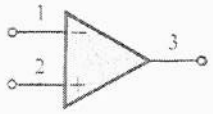


Fig. 2.1 Circuit symbol for the op amp.

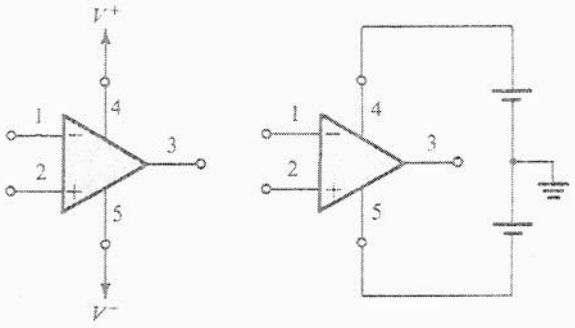


Fig. 2.2 The op amp shown connected to dc power supplies.

is physically connected to ground. In what follows we will not explicitly show the op-amp power supplies.

In addition to the three signal terminals and the two power-supply terminals, an op amp may have other terminals for specific purposes. These other terminals can include terminals for frequency compensation and terminals for offset nulling: both functions will be explained in later sections.

Exercise

2.1 What is the minimum number of terminals required by a single op amp? What is the minimum number of terminals required on an integrated-circuit package containing four op amps (called a quad op amp)?

Ans. 5; 14

2.2 THE IDEAL OP AMP

We now consider the circuit function of the op amp. The op amp is designed to sense the difference between the voltage signals applied at its two input terminals (that is, the quantity $v_2 - v_1$), multiply this by a number A, and cause the resulting voltage $A(v_2 - v_1)$ to appear at output terminal 3. Here it should be emphasized that when we talk about the voltage at a terminal we mean the voltage between that terminal and ground; thus v_1 means the voltage applied between terminal 1 and ground.

The ideal op amp is not supposed to draw any input current; that is, the signal current into terminal 1 and the signal current into terminal 2 are both zero. In other words, the input impedance of an ideal op amp is supposed to be infinite.

How about the output terminal 3? This terminal is supposed to act as the output terminal of an ideal voltage source. That is, the voltage between terminal 3 and ground will always be equal to $A(v_2 - v_1)$ and will be independent of the current that may be drawn from terminal 3 into a load impedance. In other words, the output impedance of an ideal op amp is supposed to be zero.

Putting together all of the above, we arrive at the equivalent circuit model shown in Fig. 2.3. Note that the output is in phase with (has the same sign as) v_2 and out of phase with (has the opposite sign of) v_1. For this reason, input terminal 1 is called the **inverting input terminal** and is distinguished by a "−" sign, while input terminal 2 is called the **noninverting input terminal** and is distinguished by a "+" sign.

As can be seen from the above description, the op amp responds only to the *difference* signal $v_2 - v_1$ and hence ignores any signal *common* to both inputs. That is, if $v_1 = v_2 = 1$ V, then the output will—ideally—be zero. We call this property **common-mode rejection,** and we conclude that an ideal op amp has infinite common-mode rejection. We will have more to say about this point later. For the time being note that the op amp is a **differential-input, single-ended-output** amplifier, with the latter term referring to the fact that the output appears between terminal 3 and ground. Furthermore, gain A is called the **differential gain,** for obvious reasons. Perhaps not so obvious is another name that we will

Exerci

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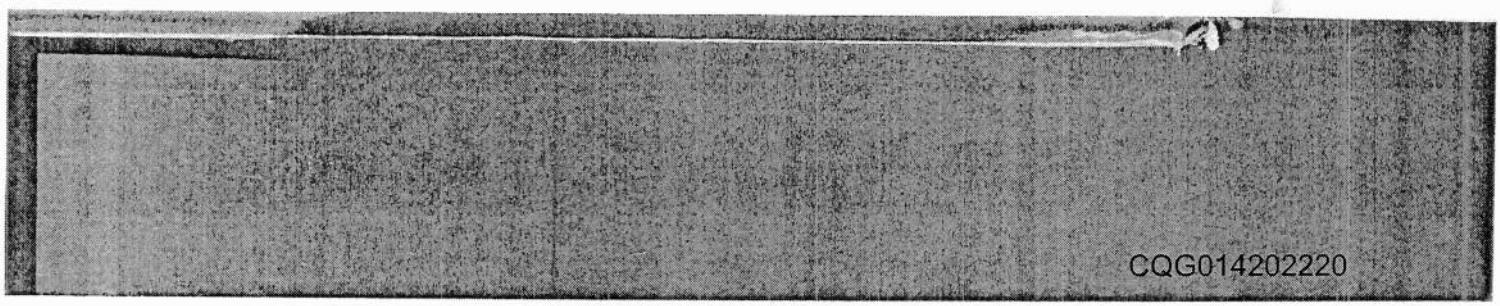
−3.6 V a

Ans. (a)



11.16 Consider a low-pass notch with $\omega_0 = 1$ rad/s, $Q = 10$, $\omega_n = 1.2$ rad/s, and a dc gain of unity. Find the frequency and magnitude of the transmission peak. Also find the high-frequency transmission.

Ans. 0.986 rad/s; 3.17; 0.69

11.5 THE SECOND-ORDER LCR RESONATOR

In this section we shall study the second-order LCR resonator shown in Fig. 11.17(a). The use of this resonator to derive circuit realizations for the various second-order filter functions will be demonstrated. Also, it will be shown in the next section that replacing the inductor L by a simulated inductance obtained using an op amp–RC circuit results in an op amp–RC resonator. The latter forms the basis of an important class of active-RC filters to be studied in the next section.

The Resonator Natural Modes

The natural modes of the parallel resonance circuit of Fig. 11.17(a) can be determined by applying *an excitation that does not change the natural structure of the circuit*. Two possible ways of exciting the circuit are shown in Figs. 11.17(b) and (c). In Fig. 11.17(b) the resonator is excited with a current source I connected in parallel. Since as far as the natural

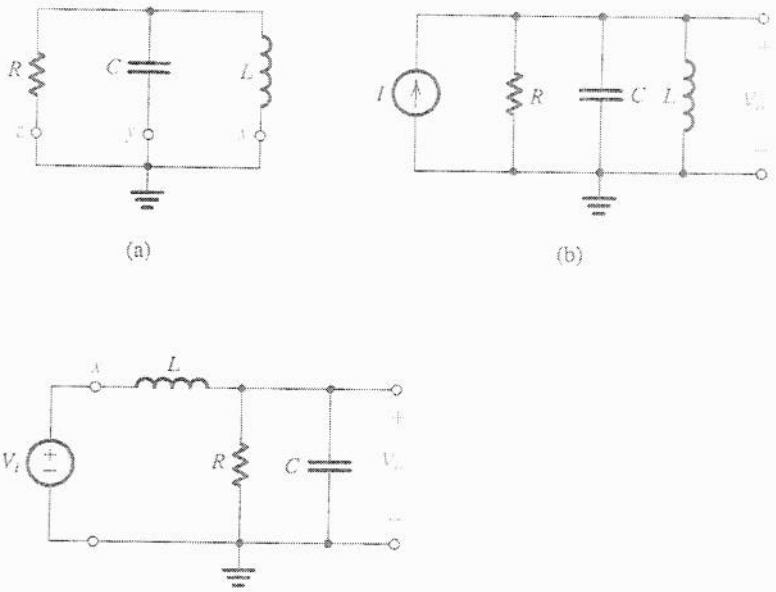


Fig. 11.17 (a) The second-order parallel LCR resonator. (b) and (c) Two ways for exciting the resonator of (a) without changing its *natural structure*. The resonator poles are the poles of V_o/I and V_o/V_i.

response of a circuit is concerned, an independent ideal current source is equivalent to an open circuit, the excitation of Fig. 11.17(b) does not alter the natural structure of the resonator. Thus the circuit in Fig. 11.17(b) can be used to determine the natural modes of the resonator by simply finding the poles of any response function. We can for instance take the voltage V_o across the resonator as the response and thus obtain the response function $V_o/I = Z$, where Z is the impedance of the parallel resonance circuit. It is obviously more convenient, however, to work in terms of the admittance Y; thus

$$\frac{V_o}{I} = \frac{1}{Y} = \frac{1}{(1/sL) + sC + (1/R)} = \frac{s/C}{s^2 + s(1/CR) + (1/LC)} \tag{11.31}$$

Equating the denominator to the standard form $s^2 + s(\omega_0/Q) + \omega_0^2$ leads to

$$\omega_0^2 = 1/LC \tag{11.32}$$

and

$$\omega_0/Q = 1/CR \tag{11.33}$$

Thus,

$$\omega_0 = 1/\sqrt{LC} \tag{11.34}$$

$$Q = \omega_0 CR \tag{11.35}$$

These expressions should be familiar to the reader from earlier studies of parallel resonance circuits in introductory courses on circuit theory.

An alternative way of exciting the parallel LCR resonator for the purpose of determining its natural modes is shown in Fig. 11.17(c). Here, node x of inductor L has been disconnected from ground and connected to an ideal voltage source V_i. Now, since as far as the natural response of a circuit is concerned, an ideal independent voltage source is equivalent to a short circuit, the excitation of Fig. 11.17(c) does not alter the natural structure of the resonator. Thus we can use the circuit in Fig. 11.17(c) to determine the natural modes of the resonator. These are the poles of any response function. For instance, we can select V_o as the response variable and find the transfer function V_o/V_i. The reader can easily verify that this will lead to the natural modes determined above.

In a design problem, we will be given ω_0 and Q and will be asked to determine L, C, and R. Equations (11.34) and (11.35) are two equations in the three unknowns. The one available degree of freedom can be utilized to set the impedance level of the circuit to a value that results in practical component values.

Realization of Transmission Zeros

Having selected the component values of the LCR resonator so as to realize a given pair of complex-conjugate natural modes, we now consider the use of the resonator to realize a desired filter type (e.g., LP, HP, etc.). Specifically, we wish to find out where to inject the input voltage signal V_i so that the transfer function V_o/V_i is the desired one. Toward that end, note that in the resonator circuit in Fig. 11.17(a) any of the nodes labeled x, y, or z can be disconnected from ground and connected to V_i without altering the circuit's natural

modes. When this is done the circuit takes the form of a voltage divider, as shown in Fig. 11.18(a). Thus the transfer function realized is

$$T(s) = \frac{V_o(s)}{V_i(s)} = \frac{Z_2(s)}{Z_1(s) + Z_2(s)} \tag{11.36}$$

We observe that *the transmission zeros are the values of s at which $Z_2(s)$ is zero, provided that $Z_1(s)$ is not simultaneously zero, and the values of s at which $Z_1(s)$ is infinite, provided that $Z_2(s)$ is not simultaneously infinite*. This statement makes physical sense: The output will be zero either when $Z_2(s)$ behaves as a short circuit or when $Z_1(s)$ behaves as an open circuit. If there is a value of s at which both Z_1 and Z_2 are zero, then V_o/V_i will be finite and no transmission zero is obtained. Similarly, if there is a value of s at which both Z_1 and Z_2 are infinite, then V_o/V_i will be finite and no transmission zero is realized.

Realization of the Low-Pass Function

Using the scheme outlined above we see that to realize a low-pass function, node x is disconnected from ground and connected to V_i, as shown in Fig. 11.18(b). The transmission zeros of this circuit will be at the value of s for which the series impedance becomes infinite (sL becomes infinite at $s = \infty$) and the value of s at which the shunt impedance becomes zero ($1/[sC + (1/R)]$ becomes zero at $s = \infty$). Thus this circuit has two transmission zeros at $s = \infty$, as an LP is supposed to. The transfer function can be written either by inspection or by using the voltage-divider rule. Following the latter approach, we obtain

$$T(s) = \frac{V_o}{V_i} = \frac{Z_2}{Z_1 + Z_2} = \frac{Y_1}{Y_1 + Y_2} = \frac{1/sL}{(1/sL) + sC + (1/R)} = \frac{1/LC}{s^2 + s(1/CR) + (1/LC)} \tag{11.37}$$

Realization of the High-Pass Function

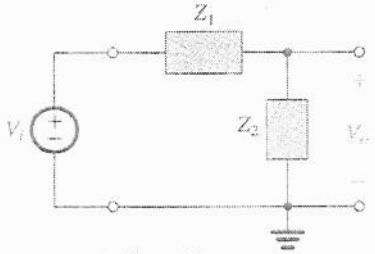
To realize the second-order high-pass function, node y is disconnected from ground and connected to V_i, as shown in Fig. 11.18(c). Here the series capacitor introduces a transmission zero at $s = 0$ (dc), and the shunt inductor introduces another transmission zero at $s = 0$ (dc). Thus, by inspection, the transfer function may be written as

$$T(s) = \frac{V_o}{V_i} = \frac{a_2 s^2}{s^2 + s(\omega_0/Q) + \omega_0^2} \tag{11.38}$$

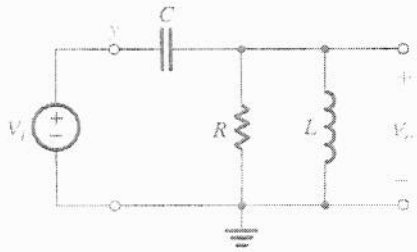
where ω_0 and Q are the natural mode parameters given by Eqs. (11.34) and (11.35) and a_2 is the high-frequency transmission. The value of a_2 can be determined from the circuit by observing that as s approaches ∞, the capacitor approaches a short circuit and V_o approaches V_i, resulting in $a_2 = 1$.

Realization of the Bandpass Function

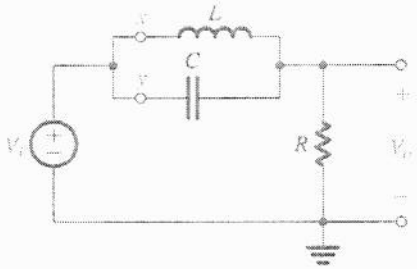
The bandpass function is realized by disconnecting node z from ground and connecting it to V_i, as shown in Fig. 11.18(d). Here the series impedance is resistive, and thus does not



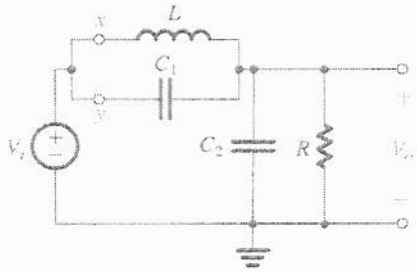
(a) General structure



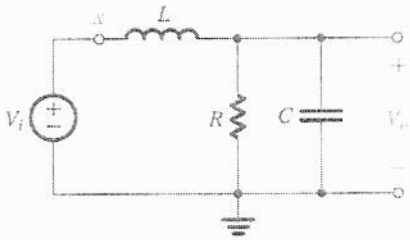
(c) HP



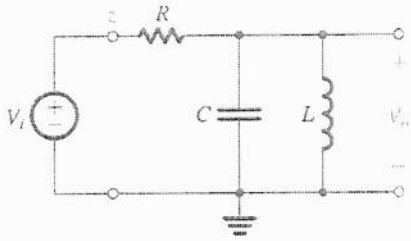
(e) Notch at ω_0



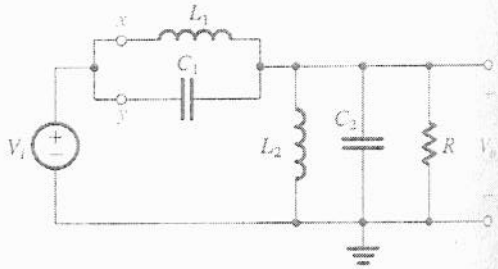
(g) LPN ($\omega_n > \omega_0$)



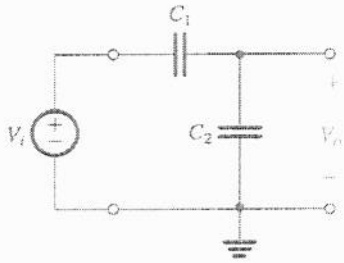
(b) LP



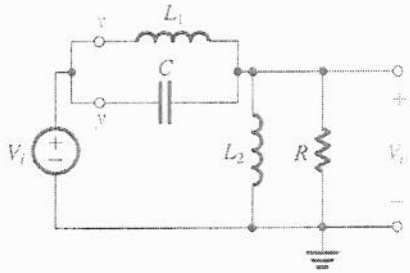
(d) BP



(f) General notch



(h) LPN as $s \to \infty$



(i) HPN ($\omega_n < \omega_0$)

Fig. 11.18 Realization of various second-order filter functions using the LCR resonator of Fig. 11.17(b): (a) general structure, (b) LP, (c) HP, (d) BP, (e) notch at ω_0, (f) general notch, (g) LPN ($\omega_n \geq \omega_0$), (h) LPN as $s \to \infty$, (i) HPN ($\omega_n < \omega_0$).

introduce any transmission zeros. These are obtained as follows: One zero at $s = 0$ is realized by the shunt inductor, and one zero at $s = \infty$ is realized by the shunt capacitor. At the center-frequency ω_0, the parallel LC tuned circuit exhibits an infinite impedance, and thus no current flows in the circuit. It follows that at $\omega = \omega_0$, $V_o = V_i$. In other words, the center-frequency gain of the bandpass filter is unity. Its transfer function can be obtained as follows:

$$T(s) = \frac{Y_R}{Y_R + Y_L + Y_C} = \frac{1/R}{(1/R) + (1/sL) + sC}$$
$$= \frac{s\,(1/CR)}{s^2 + s\,(1/CR) + (1/LC)} \tag{11.39}$$

Realization of the Notch Functions

To obtain a pair of transmission zeros on the $j\omega$-axis we use a parallel resonance circuit in the series arm, as shown in Fig. 11.18(e). Observe that this circuit is obtained by disconnecting both nodes x and y from ground and connecting them together to V_i. The impedance of the LC circuit becomes infinite at $\omega = \omega_0 = 1/\sqrt{LC}$, thus causing zero transmission at this frequency. The shunt impedance is resistive and thus does not introduce transmission zeros. It follows that the circuit in Fig. 11.18(e) will realize the notch transfer function

$$T(s) = a_2 \frac{s^2 + \omega_0^2}{s^2 + s\,(\omega_0/Q) + \omega_0^2} \tag{11.40}$$

The value of the high-frequency gain a_2 can be found from the circuit to be unity.

To obtain a notch filter realization in which the notch frequency ω_n is arbitrarily placed relative to ω_0, we adopt a variation on the above scheme. We still use a parallel LC circuit in the series branch, as shown in Fig. 11.18(f) where L_1 and C_1 are selected so that

$$L_1 C_1 = 1/\omega_n^2 \tag{11.41}$$

Thus the L_1C_1 tank circuit will introduce a pair of transmission zeros at $\pm j\omega_n$, provided that the L_2C_2 tank is not resonant at ω_n. Apart from this restriction, the values of L_2 and C_2 must be selected so as to ensure that the natural modes have not been altered; thus

$$C_1 + C_2 = C \tag{11.42}$$

$$L_1 /\!/ L_2 = L \tag{11.43}$$

In other words, when V_i is replaced by a short circuit, the circuit should reduce to the original LCR resonator. Another way of thinking about the circuit of Fig. 11.18(f) is that it is obtained from the original LCR resonator by lifting part of L and part of C off ground and connecting them to V_i.

It should be noted that in the circuit of Fig. 11.18(f), L_2 does *not* introduce a zero at $s = 0$ because at $s = 0$, the L_1C_1 circuit also has a zero. In fact, at $s = 0$ the circuit reduces to an inductive voltage divider with the dc transmission being $L_2/(L_1 + L_2)$. Similar comments can be made about C_2 and the fact that it does *not* introduce a zero at $s = \infty$.

The LPN and HPN filter realizations are special cases of the general notch circuit of Fig. 11.18(f). Specifically, for the LPN,

$$\omega_n > \omega_0.$$

thus

$$L_1C_1 < (L_1//L_2)(C_1 + C_2)$$

This condition can be satisfied with L_2 eliminated (i.e., $L_2 = \infty$ and $L_1 = L$), resulting in the LPN circuit in Fig. 11.18(g). The transfer function can be written by inspection as

$$T(s) = \frac{V_o}{V_i} = a_2 \frac{s^2 + \omega_n^2}{s^2 + s(\omega_0/Q) + \omega_0^2} \tag{11.44}$$

where $\omega_n^2 = 1/LC_1$, $\omega_0^2 = 1/L(C_1 + C_2)$, $\omega_0/Q = 1/CR$, and a_2 is the high-frequency gain. From the circuit we see that as $s \to \infty$, the circuit reduces to that in Fig. 11.18(h), for which

$$\frac{V_o}{V_i} = \frac{C_1}{C_1 + C_2}$$

Thus

$$a_2 = \frac{C_1}{C_1 + C_2} \tag{11.45}$$

To obtain an HPN realization we start with the circuit of Fig. 11.18(f) and use the fact that $\omega_n < \omega_0$ to obtain

$$L_1C_1 > (L_1//L_2)(C_1 + C_2)$$

which can be satisfied while selecting $C_2 = 0$ (i.e., $C_1 = C$). Thus we obtain the reduced circuit shown in Fig. 11.18(i). Observe that as $s \to \infty$, V_o approaches V_i and thus the high-frequency gain is unity. Thus, the transfer function can be expressed as

$$T(s) = \frac{V_o}{V_i} = \frac{s^2 + (1/L_1C)}{s^2 + s(1/CR) + [1/(L_1//L_2)\,C]} \tag{11.46}$$

Realization of the All-Pass Function

The all-pass transfer function

$$T(s) = \frac{s^2 - s(\omega_0/Q) + \omega_0^2}{s^2 + s(\omega_0/Q) + \omega_0^2} \tag{11.47}$$

can be written as

$$T(s) = 1 - \frac{s\,2(\omega_0/Q)}{s^2 + s(\omega_0/Q) + \omega_0^2} \tag{11.48}$$

The second term on the right-hand side is a bandpass function with a center-frequency gain of 2. We already have a bandpass circuit (Fig. 11.18d) but with a center-frequency gain of unity. We shall therefore attempt an all-pass realization with a flat gain of 0.5, that is,

$$T(s) = 0.5 - \frac{s(\omega_0/Q)}{s^2 + s(\omega_0/Q) + \omega_0^2}$$

This function can be realized using a voltage divider with a transmission ratio of 0.5 together with the bandpass circuit of Fig. 11.18(d). To effect the subtraction, the output of the all-

Exercis

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11.18 U
at a 60-H
3 dB over
10 kΩ.

Ans. C =
practical i

11.6 SEC

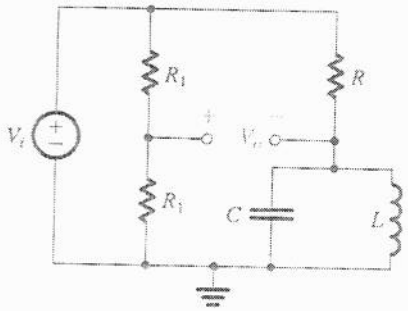

Fig. 11.19 Realization of the second-order all-pass transfer function using a voltage divider and an LCR resonator.

pass circuit is taken between the output terminal of the voltage divider and that of the bandpass filter, as shown in Fig. 11.19. Unfortunately this circuit has the disadvantage of lacking a common ground terminal between the input and the output. An op amp–RC realization of the all-pass function will be presented in the next section.

Exercises

11.17 Use the circuit of Fig. 11.18(b) to realize a second-order low-pass function of the maximally flat type with a 3-dB frequency of 100 kHz.

Ans. Selecting $R = 1\ \text{k}\Omega$, we obtain $C = 1125$ pF and $L = 2.25$ mH.

11.18 Use the circuit of Fig. 11.18(e) to design a notch filter to eliminate a bothersome power-supply hum at a 60-Hz frequency. The filter is to have a 3-dB bandwidth of 10 Hz (i.e., the attenuation is greater than 3 dB over a 10-Hz band around the 60-Hz center frequency; see Exercise 11.15 and Fig. 11.16d). Use $R = 10\ \text{k}\Omega$.

Ans. $C = 1.6\ \mu$F and $L = 4.42$ H (Note the large inductor required. This is the reason passive filters are not practical in low-frequency applications.)

11.6 SECOND-ORDER ACTIVE FILTERS BASED ON INDUCTOR REPLACEMENT

In this section, we study a family of op amp–RC circuits that realize the various second-order filter functions. The circuits are based on an op amp–RC resonator obtained by replacing the inductor L in the LCR resonator with an op amp–RC circuit that has an inductive input impedance.

The Antoniou Inductance-Simulation Circuit

Over the years, many op amp–RC circuits have been proposed for simulating the operation of an inductor. Of these, one circuit invented by A. Antoniou (see Antoniou, 1969) has proved to be the "best." By "best" we mean that the operation of the circuit is very tolerant to the nonideal properties of the op amps, in particular their finite gain and bandwidth. Figure 11.20(a) shows the Antoniou inductance simulation circuit. If the circuit is fed at its

EXHIBIT 12

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

TRADING TECHNOLOGIES INTERNATIONAL, INC.,	)	
Plaintiff,	)	
v.	)	No. 04 C 5312
eSPEED, INC., eSPEED INTERNATIONAL, LTD., ECCO LLC, and ECCOWARE, LTD.,	)	Chicago, Illinois
	)	September 10, 2007
Defendants.	)	10:00 o'clock a.m.

VOLUME 1-A
TRIAL TRANSCRIPT OF PROCEEDINGS
BEFORE THE HONORABLE JAMES B. MORAN, and a JURY

APPEARANCES:

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(The following proceedings were had in open court:)

THE COURT: Well, ladies and gentlemen, what we're going to be doing -- actually, for probably -- well, at this point, we think it's going to be three weeks; three days this week and then off Thursday and Friday because of Rosh Hashanah and then two more weeks on a patent case. The patents involved in this case relate to computer software used for electronic trading of financial instruments such as futures contracts and commodities.

The disputed actions in this are United States patents number 6,766,304, 6,722,132, and throughout the action, the parties may refer to the patents as the '304 patent or the '132 patent, because those are the last three numbers of each of the patents.

The '304 and '132 patents are both entitled click-based trading with intuitive grid display of market depth. The inventor's name in the '302 and '132 patents are Harris Brumfield, Gary Allen Kemp, II, and Jens-Uwe Schluette. The United States Patent and Trademark Office issued the '304 patent on June -- July 20, 2004, and the '132 patent on August 3, 2004.

Generally, the patents relate to a computer screen display used by traders when trading on electronic exchanges. The display includes a static

display of prices being traded, a dynamic display of quantity of offers to sell or ask, and offers to buy or bids and provides for a single-action order entry.

The plaintiff in this case is Trading Technologies International, Inc. During the trial, you may hear me or the parties refer to the plaintiffs as TT. TT is represented by the law firm of McDonnell, Boehnen, Hulbert & Berghoff, and the inventors have assigned their rights to the patent to TT, and TT is therefore the owner of the patents.

The defendants in this case are eSpeed, Inc., eSpeed International, Limited, Ecco, L.L.C., and Ecco Ware, Limited. And during the trial, you may hear me or the parties refer to the defendants collectively as eSpeed, or the defendants, but we will also from time to time refer to the eSpeed parties separately from the Ecco parties. Those defendants are represented by the law firm of Winston & Strawn.

I will first describe to you TT's contentions. TT owns the '304 and '132 patents and contends that the defendants directly infringed the '304 and '132 patents by making, selling, offering for sale, and/or using certain software patents; but TT further contends that eSpeed indirectly infringes the '304 and '132 patents by inducing others to directly infringe the

'304 and '132 patents.

The software at issue in this case is called Futures View and Price Ladder. Futures View is part of the software distributed by eSpeed prior to December 2004, while Price Ladder was part of a product sold by Ecco prior to December 2004. TT also contends that eSpeed's infringement was willful.

TT further contends that it is entitled to monetary damages in the form of a reasonable royalty for the period of time for when the patent issued, patents issued, in late July and early August of 2004 until the defendants stopped distributing or selling Futures View and Price Ladder in December 2004.

The defendants contend that their products do not infringe any of the patents, either directly or indirectly. They further contend that the patents are invalid. Finally, defendants contend that TT is not entitled to the damages it seeks.

TT has also filed lawsuits against other companies regarding the patents in suit. These other defendants are not officially parties to this suit, but you may hear their names from time to time. Those other defendants are CQG, CQGT, Rosenthal Collins Group, GL Consultants, Rosenthal Collins Group, GL Consultants, GL Trade SA, FuturePath Trading, L.L.C.

ESpeed is cooperating with these other defendants in what is known as a joint defense agreement. The Chicago Mercantile Exchange is also a party to the joint defense agreement. It's a common procedure to enter into joint defense agreements in circumstances such as this, and it's common for defendants to cooperate with each other about common patent defenses, and it's not inappropriate to do so.

Well, what we're going to be doing first this morning is selecting a jury. And as you can perhaps tell from the -- what I've already said, the jury that's going to be hearing this case is going to be hearing a fair amount about futures trading, and Chicago is -- has been done a lot in Chicago. It used to be done in open pit and people getting on the floor and screaming out orders and stuff, and nowadays, it's mostly done electronically with traders having little gizmos that have software in them and they use that to place orders and trade, and you're going to be learning a fair amount that, about the new technology and how it works and what people are doing and all the rest of it in an industry where as I think we all know, people have a tendency sometimes to make a lot of money and sometimes to lose a lot of money.

Anyway, so the first thing we're going to be

doing is picking a jury. And that's step one.

Then after that, the parties are going to be -- the lawyers are going to be telling you what they think the evidence is going to show or won't show, as the case may be, opening statements. And that's not evidence. It's just to tell you what's going to happen next or fit everything together so you have an idea as to why evidence is coming in when.

Then we have the real substance of the trial, which is testimony by witnesses and exhibits offered here from the witness chair.

Plaintiff goes first. Plaintiff has the burden of proof on part of it at least, and then defendant. And then there may be a rebuttal case, we don't know about that yet, but it can be. And then after that we hear from the lawyers. They have closing arguments and they tell you what they think the evidence showed or didn't show, and then the jury retires to deliberate and fulfills the function that juries are really there for which is to find facts, to determine what the jury thinks actually happened and what the facts actually are. And then in light of the jury instructions, which I will be giving you and which you are bound by, then you apply those jury instructions to the facts as you find them and reach a verdict. So

that's what we're going to be doing here.

Now, picking the jury is a very important part of the process because both sides are entitled to have a jury that is going to listen attentively, conscientiously, follow the evidence, suspend judgment, wait until all the evidence is in, and then collectively then determine on the basis of the evidence here in court and not on the basis of any extraneous information or any guesses decide what you think the facts actually are or were.

So what we're going to be doing first this morning is asking you a lot of questions. In doing so, we don't mean to impinge upon your privacy, but we -- the parties do need to know something about you so that they have some sort of an idea as to who you are and how you think about things, all for the purpose of ending up with a fair, representative, and impartial jury.

If in asking -- answering a question, you feel that there are -- you'd be sharing information you really don't want to share with everybody, I can just go off to the side with the lawyers and take -- and raise your hand, tell us you'd like to have a sidebar, and then we'll just go off to the side and you can answer the question and just share the information with me and the lawyers and the court reporter.

So anyway, the first thing we're going to do is have each of you get up in turn and provide us some information, and then I'm going to be asking some specific questions. And as you respond to those, I will be following up with those who say yes about whatever to get further information.

And it does not take a huge amount of time. I know that you probably read in the newspapers or heard about cases where they spend days picking juries. We don't do that. Hopefully we're going to be through picking a jury by the time we break for lunch.

So the first thing we need to do is have each one of you in turn starting with Cathy McBride, telling us your name, if you live in Chicago, what neighborhood, if you live elsewhere, where that might be, not by address but by municipality, your education, what you do for a living, what the other adult members of your household do for a living, and if you have any interests that take up a good deal of your time, hobbies, advocations, things like that, what those might be. And so why don't we start with Cathy McBride.

PROSPECTIVE JUROR McRIDE: My name is Cathy McBride. I live in Naperville.

THE COURT: I'm sorry. It would help if you would stand.

PROSPECTIVE JUROR McRIDE: My name is Cathy McBride. I live in Naperville, Illinois. My education is I graduated in social work, I work for HCR Manor Care, which is a nursing and rehab corporation, and social work consultant. I have my masters in social work. My husband is a registered financial adviser with Royal Alliance. He is a financial planner. I have two children who take up a lot of my time. One is 13, a boy, and I just sent my daughter to college.

THE COURT: Thank you.

Joseph Wronka.

PROSPECTIVE JUROR WRONKA: My name is Joe Wronka. I live in the Little Italy neighborhood here in Chicago. I have a major in management and sociology. I am engaged to be married next September and I work at Mercy Home for Boys and Girls.

THE COURT: I'm sorry.

PROSPECTIVE JUROR WRONKA: I work at Mercy Home For Boys and Girls as a planning officer in the development department, and I enjoy sports and being outside.

THE COURT: What does your fiance do for a living?

PROSPECTIVE JUROR WRONKA: She is a graduate student right now in social work.

THE COURT: Thank you.

Clare Donnenwirth.

PROSPECTIVE JUROR DONNENWIRTH: My name is Clare Donnenwirth. I live in Waukegan, Illinois. I have a bachelor's degree in medical technology. That means I work in a hospital laboratory. My husband of 29 years is a police officer for the city of Waukegan, and I have two children and that's about it.

THE COURT: Okay. Debra Hoffman.

PROSPECTIVE JUROR HOFFMAN: I am Debra Hoffman. I currently live in Winfield. I am a high school graduate. I currently work part-time as a personal trainer.

THE COURT: I'm sorry.

PROSPECTIVE JUROR HOFFMAN: Personal trainer and group fitness instructor. I have three children, 18, 16 and 13. And my husband works here in Chicago as vice president for Import Global Solutions.

THE COURT: Thank you.

Christina Hamilton.

PROSPECTIVE JUROR HAMILTON: My name is Christina Hamilton. I live in Rosco Village. I have a bachelor's degree.

THE COURT: A little louder, please.

PROSPECTIVE JUROR HAMILTON: I have a

bachelor's degree in biology. I work at Paper Source in sales, and I enjoy running and I live alone.

THE COURT: Any adult members in your household?

PROSPECTIVE JUROR HAMILTON: No, just me.

THE COURT: Thank you.

Sandra Laughlin.

PROSPECTIVE JUROR LAUGHLIN: Sandra Laughlin. I live in Geneva, and I am a high school graduate. My husband is a police officer with the Kane County forest preserve. I have two children, two adult children.

THE COURT: Thank you.

Sharon Nafea.

PROSPECTIVE JUROR NAFEA: Nafea. Yes, my name is Sharon Nafea. I went to high school. I currently live in Prospect Heights. I live with my retired handicapped mother. I am currently now unemployed, but I will be working for State Farm insurance part time and my mother when she was working 13 years ago worked for Warren Communications for New York in the Chicago district, and I have one adult son and he lives in Chicago and he works for the Board of Education.

THE COURT: Thank you.

David Feddor.

PROSPECTIVE JUROR FEDDOR: Yes. My name is David Feddor. I live in Sugar Grove, Illinois. I have my degree in accounting. I live with my wife. She is an assistant teacher's aide over in the Naperville school district. I have two children, one in Colorado, one in East Lansing, and I am retired a treasury agent, so recreational, I golf, I golf, and I golf.

THE COURT: When you said you're retired treasury agent --

PROSPECTIVE JUROR FEDDOR: Yes.

THE COURT: -- from the United States treasury department?

PROSPECTIVE JUROR FEDDOR: Yes, your Honor.

THE COURT: Okay. Ellen Scott Tillmon.

PROSPECTIVE JUROR TILLMON: My name is Ellen Scott Tillmon. I'm retired. Presently raising my three adopted granddaughters, 14, high school, 13, and 10 in grammar school. I am involved in a lot of volunteer work in our community. I also assist in the school as a parent coordinator, so most of my time is spent with my three girls.

THE COURT: Thank you, ma'am.

Marija Cetnik.

PROSPECTIVE JUROR CETNIK: It's Marija

Cetnik. I am a school psychologist. I have a masters in education. I live in Rogers Park. My husband is an editor and cartoonist and I love to travel.

THE COURT: Okay. Linda Buzzi.

PROSPECTIVE JUROR BUZZI: I actually have a question for you. I am a student and we start -- did you say this is three weeks?

THE COURT: I am sorry?

PROSPECTIVE JUROR BUZZI: Did you say this is going to be three weeks?

THE COURT: Yes.

PROSPECTIVE JUROR BUZZI: I go back to school next week.

THE COURT: Why don't you hold up then. Hold up for a bit.

PROSPECTIVE JUROR BUZZI: I am from Rogers Park, in Chicago, and I am a student, and I guess my mom works downtown.

THE COURT: I'm sorry. A little louder, please.

PROSPECTIVE JUROR BUZZI: From where? I am a student so I am up at school, and my mom is I guess the other adult member in my household, and she works downtown at a not-for-profit.

THE COURT: Okay. Brent Walters.

PROSPECTIVE JUROR WALTERS: Hello. I'm Brent Walters. I live in the up town neighborhood. I am an attorney. I work for the City of Chicago, the procurement of the aviation department of the city. I don't do much else than work for the city right now.

THE COURT: Any adult members?

PROSPECTIVE JUROR WALTERS: No, I live alone.

THE COURT: Bridget McEvers.

PROSPECTIVE JUROR McEVERS: I work for the Academy of General Dentistry. I am the coordinator of benefits. I have a bachelor's degree in marketing. I am engaged as well to be married next September. My fiance works for Price Waterhouse Coopers.

THE COURT: I'm sorry.

PROSPECTIVE JUROR McEVERS: Price Waterhouse Coopers as an auditor for their private company services. We are avid travelers as well as sports enthusiasts.

THE COURT: Thank you.

Marlon Dela Cruz.

PROSPECTIVE JUROR DELA CRUZ: My name is Marlon Dela Cruz. I am a registered nurse currently working at Northwest Community Hospital in the emergency room. I have a social degree in nursing. My wife is a

full-time nurse. She works as a CPA auditor as well, and I like to travel, go running.

THE COURT: Thank you.

Cynthia Robinson.

PROSPECTIVE JUROR ROBINSON: My name is Cynthia Robinson. I work for the Infant Caring (phonetic) Institute. We are contracted by DCFS, Department of Children and Family Services. We audit the Medicaid Rule Part 132 for substitute providers for wards of the state. My husband owns his own business. He is a rep for Dorn (phonetic) Hardware Industry. I have two adult children and I enjoy sports.

THE COURT: And you live in Frankfort?

PROSPECTIVE JUROR ROBINSON: I live in Frankfort, yes.

THE COURT: Thank you.

Evert Hill.

PROSPECTIVE JUROR HILL: My name is Evert Hill. I live in Homewood, Illinois. I am married, three kids. My wife is a nurse. I am a machinist with North Star, been there for the last 23 years.

THE COURT: Educational background?

PROSPECTIVE JUROR HILL: High school.

THE COURT: Okay. Thank you, sir.

Richard Goepper.

PROSPECTIVE JUROR GOEPPER: My name is Richard Goepper. I have an associate's degree in law enforcement and criminal justice. My wife Debbie is a surgical nurse from Joliet, Illinois. I have two children. My oldest daughter is a police dispatcher, my youngest daughter is a stay-at-home mother with two children, and I just recently retired from the Joliet Police Department.

THE COURT: Thank you, sir.

Glenn Gustke.

PROSPECTIVE JUROR GUSTKE: Glenn Gustke, Libertyville, Illinois. I have a degree in political science, minor in sociology. Divorced, two kids, 12-year-old son, 9-year-old daughter. I work for Krell (phonetic) Incorporated. It's a small manufacturer. They expect me to be on the road three out of four weeks of the month so that takes up just about all my time.

THE COURT: Okay. Janet Koehring.

PROSPECTIVE JUROR KOEHRING: Janet Koehring. I am a secretary at a community college. I live in Kaneville, Illinois, which is 20 miles west of Aurora. My husband is in concrete construction, and I have three children; a daughter in college, a daughter in high school, and a son in junior high.

THE COURT: I'm sorry. You probably gave it

and I missed it. Your educational background?

PROSPECTIVE JUROR KOEHRING: I have some college.

THE COURT: Thomas Adduci.

PROSPECTIVE JUROR ADDUCI: I am Thomas Adduci. I live in Oak Forest, Illinois. I am married with two daughters. I have two separate associate's degrees, one in liberal arts, the other one in electronics, computer technology, and a total equivalent of 132 semester hours. I work for MPC Containment Systems as a technical engineer and computer operator using auto cad software.

THE COURT: Okay. Thank you.

Matthew Zaucha.

PROSPECTIVE JUROR ZAUCHA: Matthew Zaucha. I live in Bolingbrook. I have a wife. I have three young kids, four-year-old boy, two-year-old girl and a newborn girl. I am a doctoral student at Northern in educational philosophy focusing on secular education, separation of church and state. I am also teacher for high school, and most of my time is taken up with the family and reading and doing research.

THE COURT: Thank you, sir.

Diane Guetschow.

PROSPECTIVE JUROR GUETSCHOW: I am Diane

Guetschow. I live in Carpentersville, Illinois. I am a hospital employee. I have gone to high school and a two-year certificate program for radiology, and my husband is a fire chief in Lake in the Hills, and we have two adult children.

THE COURT: Thank you.

Michael Pollacchi.

PROSPECTIVE JUROR POLLACCHI: My name is Michael Pollacchi. I work -- I live in Bartlett, Illinois. I work for Roberts and Schaeffer (phonetic) as a structural steel designer. My girlfriend lives with me and she works for 7-Eleven corporate as a store manager. And I spend a lot of time watching Cubs games.

THE COURT: Okay. Ralph Arispe.

PROSPECTIVE JUROR ARISPE: I am Ralph Arispe. I live in the Chicago area. I don't have a college degree. I did spend time in Knox College and at the University of Illinois, and I bartend right down here in Chicago. I am single.

THE COURT: Any adult members of your household?

PROSPECTIVE JUROR ARISPE: Sorry?

THE COURT: Any adult members of your household?

PROSPECTIVE JUROR ARISPE: No.

THE COURT: Thank you.

Julio Flores.

PROSPECTIVE JUROR FLORES: My name is Julio Flores. I have a degree in business management. My wife works for CS Corporate in Hoffman Estates. She is a senior admin. I am a senior technical representative for a company called Print Pack. We have four kids.

THE COURT: I'm sorry. What do you do?

PROSPECTIVE JUROR FLORES: I am a technical rep for a plastics company.

THE COURT: Okay.

PROSPECTIVE JUROR FLORES: I have been there 30 years. This is unheard of. We live in Elgin, Illinois, and we have four children, ranging from age 32 down to 14.

THE COURT: Okay. Thank you, sir.

Michael Cortese.

PROSPECTIVE JUROR CORTESE: Michael Cortese. I am from Naperville, Illinois. Bachelor degree in finance. I work in corporate banking for National Citibank and I market clients. I live with my fiance. She is in Internet marketing, and I like to play golf in my spare time.

THE COURT: Thank you.

Syed Shahid Muneer.

PROSPECTIVE JUROR MUNEER: Good morning. My name is Syed Shahid Muneer. I live in Lombard, Illinois. And I am with CTE Engineers for 10 years, supervising construction of highways and bridges in the Chicago area. I have a wife, four kids, and my hobbies are I like running and jogging.

THE COURT: Okay. Thank you.

Maryann Urban.

PROSPECTIVE JUROR URBAN: I live in Carpentersville also. I am a nurse by trade at ACR Manor Care in Elgin. I have no children, but my children are my two hound dogs and a cat. I am very active in two motorcycle fund-raiser clubs that I belong to, and I spend my whole heart in rescuing bassets.

THE COURT: Thank you. Are there any adult members of your household?

PROSPECTIVE JUROR URBAN: Pardon me?

THE COURT: Are there any adult members of your household besides yourself?

PROSPECTIVE JUROR URBAN: My husband -- I'm sorry. My husband is a software engineer, which is a computer programmer. He does software for investment firms like Merrill Lynch and anybody else who will buy his software.

THE COURT: Okay. Bret Jensen.

PROSPECTIVE JUROR JENSEN: Bret Jensen. I live in Gilberts, Illinois. I have a college degree. I am a mortgage broker. My wife works in the sales department at T-Mobile. I have a four-year-old daughter and twin boys that are two, and that's pretty much it.

THE COURT: Where is Gilberts?

PROSPECTIVE JUROR JENSEN: Gilberts is down by Carpentersville, Elgin, South Elgin.

THE COURT: Okay. Ashish Vora.

PROSPECTIVE JUROR VORA: My name is Ashish Vora. My permanent address is in Naperville, Illinois, although I currently live in Evanston. I am a full-time graduate student at Kellogg Graduate School of Management. I start classes on Monday. My educational background prior to that is I have a bachelor's degree.

THE COURT: I'm sorry. I missed the last thing.

PROSPECTIVE JUROR VORA: Educational background, I have a bachelor's degree in computer science. Let's see. Basically right now I'm spending my time at school and have three, four part-time jobs.

THE COURT: What's your area of studies as a graduate student?

PROSPECTIVE JUROR VORA: I am getting my MBA.

THE COURT: Sorry?

PROSPECTIVE JUROR VORA: I'm getting my MBA, masters in business administration.

THE COURT: Janet Sarek.

PROSPECTIVE JUROR SAREK: I am Janet Sarek. I live in Steger, Illinois. I have a high school education. I am an office manager for a billboard company. My husband is an electrician and we have two grown daughters.

THE COURT: Thank you.

David Von Holst.

PROSPECTIVE JUROR VON HOLST: My name is David Von Holst. I have a BA in history. My wife, she's got a teaching certificate so she teaches elementary school. My son who is 26 works for us.

THE COURT: Could you speak a little louder, Mr. Von Holst.

PROSPECTIVE JUROR VON HOLST: My older son is 26. He lives at home. He works with me at the plant, our sales. My daughter is finishing up her bachelor's degree in education, and I have an 8 year old.

THE COURT: What do you sell?

PROSPECTIVE JUROR VON HOLST: We sell structural steel, metals distributor.

THE COURT: David Lofton.

PROSPECTIVE JUROR LOFTON: I am David Lofton. I am from Riverside, Illinois. I am married. My wife is a physical therapist. I work for -- as a financial adviser for a brokerage firm, national brokerage firm, so I do trading on screens that you describe, and my partner does trade futures, too, as well. I just wanted to let you know.

THE COURT: Your educational background?

PROSPECTIVE JUROR LOFTON: College.

THE COURT: Thank you.

Timothy White.

PROSPECTIVE JUROR WHITE: My name is Timothy White. I have a bachelors in engineering. I work for a janitorial and billing maintenance company as a manager.

THE COURT: Any adult members of your household?

PROSPECTIVE JUROR WHITE: No.

THE COURT: Thank you.

Corey Smith.

PROSPECTIVE JUROR SMITH: Yes, Corey Smith. I live in Hoffman Estates. I have a certificate in computer technology. I work for Semantic Software as a consultant.

THE COURT: A little louder, Mr. Smith.

PROSPECTIVE JUROR SMITH: I work for Semantic Software as a consultant. I implement backup software nationally, and my wife is an occupational therapist. She works for the Lake Zurich school district. I have a son who is 20 who goes to Western Illinois.

THE COURT: Could you tell us a little bit more about what you do as a software specialist?

PROSPECTIVE JUROR WHITE: Yes, I am a solution specialist. Next week I am flying to Phoenix to install backup software for a corporation out there, train the customer, you know.

THE COURT: Okay. Thank you.

Katherine Sernett.

PROSPECTIVE JUROR SERNETT: My name is Katherine Sernett. I live in Hoffman Estates. I have a bachelors in management and marketing. I am a manager at Walgreens and my mom makes reservations for United Airlines and my dad is a retired plastic salesman and he works at a charity.

THE COURT: I'm sorry. You're a manager where?

PROSPECTIVE JUROR SERNETT: Walgreens.

THE COURT: Thank you.

Richard Leaneagh.

PROSPECTIVE JUROR LEANEAGH: My name is Richard Leaneagh. I am from Naperville. I live with my younger brother who works as a theater manager for Naperville North High School. I used to do construction but currently I am delivering pizza for a living. I have had some college. For a hobby, what I do is I just play video games on my computer.

THE COURT: Okay. And Tracy Garrison.

PROSPECTIVE JUROR GARRISON: My name is Tracy Garrison. I have a bachelor's degree in accounting. I work at Anixter, Inc., as a financial analyst. I live in Prospect Heights with my two dogs who are currently unemployed.

THE COURT: And what's their educational background?

PROSPECTIVE JUROR GARRISON: They both failed obedience school so there is no contributing.

THE COURT: Well, now to some specific questions.

First, I am going to be talking about the parties here and their lawyers and some of the companies that are one way are involved and interested in what's going on here.

How many of you are familiar with the company Trading Technologies or its attorneys McDonnell,

Boehnen, Hulbert & Berghoff. Anybody?

Yes. Is it Christina Hamilton?

PROSPECTIVE JUROR HAMILTON: Yes, my good friend works at Trading Technologies.

THE COURT: Okay. What's your good friend's name?

PROSPECTIVE JUROR HAMILTON: Melissa Staska (phonetic).

THE COURT: And what's that person do?

PROSPECTIVE JUROR HAMILTON: She is a consultant with Trading Technologies.

THE COURT: What?

PROSPECTIVE JUROR HAMILTON: She is a consultant with Trading Technologies.

THE COURT: In what kind of consulting?

PROSPECTIVE JUROR HAMILTON: I.T.

THE COURT: Anything about that relationship that would cause you to wonder about your ability to be totally fair to everybody here?

PROSPECTIVE JUROR HAMILTON: She showed me the software that you're speaking of before.

THE COURT: Well, you realize that what you're going to be ruling on is what's coming in through the evidence here.

PROSPECTIVE JUROR HAMILTON: Yes.

THE COURT: It's not what anybody else ever said. Do you have any -- do you have any questions about your ability to be fair here?

PROSPECTIVE JUROR HAMILTON: I mean, I might be a little bit biased because she works for that company.

THE COURT: If you're a little bit biased, then you shouldn't serve.

And somebody back there. Yes. You are?

PROSPECTIVE JUROR McEVERS: Bridget McEvers. I formerly worked for MBHB.

THE COURT: For who?

PROSPECTIVE JUROR McEVERS: Is this MBHB?

THE COURT: Yes.

MR. ROSEN: That's our firm.

THE COURT: In what capacity?

PROSPECTIVE JUROR McEVERS: I was a clerical assistant as a contract worker for a few months.

THE COURT: And you know the law firms represent people, and sometimes they win and sometimes they lose?

PROSPECTIVE JUROR McEVERS: Yes.

THE COURT: Is there anything about your having worked there at some point in the past cause you to be concerned about your ability to be fair here?

PROSPECTIVE JUROR McEVERS: No.

THE COURT: Anybody else?

Next one. Who is representing eSpeed, Winston & Strawn, so I guess I ask the same question: Are any of you familiar with eSpeed, and when I say eSpeed, I'm talking about eSpeed and its related companies, which are Ecco and Ecco Ware and eSpeed International. And are any of you familiar with any of those companies or with Winston & Strawn?

Yes, back there. Your name is?

PROSPECTIVE JUROR CORTESE: Michael Cortese. I work for National Citibank, and we use Winston & Strawn for some of our legal documents. I know a few people that work there.

THE COURT: Okay. Anything about those relationships that would cause you to wonder about your ability to be fair here?

PROSPECTIVE JUROR CORTESE: I don't think so.

THE COURT: Anybody else?

Then, anybody familiar with one of these companies? GL Consultants, GL Trade, FuturePath Trading L.L.C., or their attorneys Alston & Bird, Salans, or a different firm, Bullaro & Carton? Any of those names strike a bell at all?